NORGES HANDELSHØYSKOLE

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Commodity price integration in Norway 1832 - 1871

A quantitative study

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NORGES HANDELSHØYSKOLE

Preface

In many ways, the compilation of this thesis has been the perfect conclusion to my studies at NHH. It combines my two foremost fields of interest; econometrics and economic history. Even if the work has been frustrating at times, it has always been educative and rewarding.

I am very grateful for the help and support I have received from my supervisor Professor Ola Honningdal Grytten. I would also like to thank Professor Frode Steen for his advice on applied econometrics and literature suggestions. Last, but not least, thank you to my many helpers and proofreaders. You know who you are!

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Anne Marie Anonsen Johansen

Abstract

This thesis explores price integration in Norwegian commodity markets in the 19th century, using quantitative methods.

Convergence regressions confirm that the price growth rate is lower in towns with high initial prices, implying that the price level was equalised. This supports the assumption that the price differentials were diminished, and that the commodity markets became more integrated.

Cointegration tests performed on a selection of the commodities reveal that there was a fixed relationship between the prices in different locations. Cointegration is mostly found for the so-called traded goods in the dataset, supporting the assumption that there was a stronger relationship between the prices of goods that were more frequently traded then others.

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APPENDICES

1. Introduction

The 19th century has been characterized as the first wave of globalisation, and compared to the global integration we see today. In many ways the integration in the second half of the 19th century surpassed the one observed in the 20th century. The massive reduction in trade barriers and transportation costs led to an unprecedented free flow of goods, capital and labour.

The European countries dominated the world economy, and the integration was spread to other parts of the world through their many colonies. This can be described as globalisation through imperialism. The globalisation of the 20th and 21st century is characterised by regionalisation. There is a high degree of integration within regions (i.e. the EU, South-East Asia), but the barriers between regions can be substantial. Despite this and other differences, studying the 19th century integration may be useful to gain insights and understand the present situation.

Norway was strongly influenced by international impulses. Policies and innovations were adopted from abroad and adapted to Norwegian conditions. As a country that relied heavily on exports and custom revenue, the increase in international trade was crucial for the Norwegian economic development.

Liberalisation and the reductions in transportation costs also had consequences for domestic trade. As infrastructure was enhanced, the risk, cost and travel time of goods transportation was reduced. The vast communication improvements further reduced domestic trade costs. In the spirit of liberalism, restrictions on trade were also lifted, and the number of retailers increased dramatically. Cheaper transport and a stiffening of the competition among retailers might lead to an equalisation of the price level in different towns.

This thesis will address the following research question:
Was there integration in Norwegian commodity markets in the 19th century?
Integration is here measured as a convergence of prices, that the price differentials between towns are reduced. More similar prices indicate that the markets in different locations are more integrated. It can also be interesting to see if the degree of integration varies for different commodities.

Two different quantitative techniques are used on a dataset of price observations in Norwegian towns. First, convergence regressions are employed to analyse whether or not the price levels have become more equal. The second part of the empirical analysis is tests for cointegration on a selected number of towns and commodities. These tests ascertain if there was a relatively fixed relationship between prices.

More then half of the convergence regressions show significant integration in prices. Of the entire set, all but two of the regression coefficients have the expected sign. The prices became more equal. The cointegration tests show that there was a relatively fixed relationship between the prices of some of the commodities.

As far as I know no extensive studies of Norwegian price integration in the 19th century have been carried out before. There have, however been several works on related subjects.

Ola H. Grytten (2003) examines price development in the Scandinavian countries in the 19th century, and constructs a Consumer Price Index (CPI) for Norway 1819 – 1871 based on price data from the Wedervang Archive.

David S. Jacks (2006) explores integration in the wheat-market world-wide in the 19th century and uses this as a measure for integration in the commodity markets generally. Norwegian price data was used in this study. The main object of the article is to assess the determinants of the integration, such as railroad construction, the International Gold Standard and wars.

Kevin H. O'Rourke and Jeffrey Williamson (1996) use growth regressions to explore reasons for the rapid Scandinavian GDP growth and convergence with the other western countries in the late 19th century. They find both unconditional and conditional convergence.

Charles Engel and John H. Rogers (1995) examine regional patterns in the Law of One price, and find that the failure of the law is closely linked to nominal exchange rates and sticky nominal prices. Their 1996 paper is a closer study of the "border effect" and the role of sticky nominal prices. In this paper, they find that the variation of the price is much higher for two cities located in different countries than for cities in the same country, even if the distance between the cities is equal. Some of this difference can be linked to sticky nominal prices, but there is still an unexplained residual.

In the present thesis, section two gives an overview on the methodical framework and models used. Section three describes the historical background; important developments of the period (such as business cycles), and more specifically the improvements in infrastructure and subsequent reduction in transaction costs. Section four is devoted to the dataset, its origins and properties. Section five elaborates on the methods and procedures used in the analysis, and section six contains the results of the empirical analysis and discussion of these results. Section seven is the conclusion.

2. Analytical framework

In order to analyse commodity market integration in 19th century Norway, this thesis employs two different quantitative methods; convergence regressions and cointegration tests. A basic assumption behind both of these methods is the markets' natural adjustment of price differentials through arbitrage.

2.1 Arbitrage and the Law of One Price

The "law of one price" implies that prices of identical goods sold in different locations should be the same in the absence of transaction costs.

In theory, competitive markets will equalize the price of an identical good in two countries (when the prices are expressed in the same currency) by arbitrage, which in its simplest form is the "practice of buying at a low price in one location and selling at a higher price in another" (Pindyck and Rubinfeld 2005). Arbitrage is considered a necessary activity in an efficient market. It helps to reduce price disparities between different markets and increases a market's liquidity (ability to buy and sell).

Most transactions leads to costs of some kind, be that tangible costs such as transportation costs, or intangible costs such as communication difficulties due to the lack of a common language. When trade costs are present, the price difference should in theory be equal to the costs. However, most markets are imperfect, and even completely identical product may have different prices in separate markets even when trade costs are taken into consideration.

If price differentials are larger than the transaction costs, arbitrage is profitable. Formally: Arbitrage is profitable if

(1) $$C_{ij} < (p_j - p_i)$$

where C_{ij} are transaction costs of selling a good produced in location *i* in location *j*.

When a commodity is traded it's generally assumed that price differences will be arbitraged away if they become large enough to exceed the costs of the exchange. When observing an opportunity for profit through arbitrage agents will buy in the low price market, thus increasing the demand in this location. If supply is constant this will increase the price.

Similarly, the increase in supply in the high price market due to imports from the other location will lower the price if demand is stable. Over time the price differential will decrease as the prices converge. In the case where no exchange costs exist, prices will equalise. If there are transaction costs present, the long run prices will fluctuate in a band defined by the transaction costs.

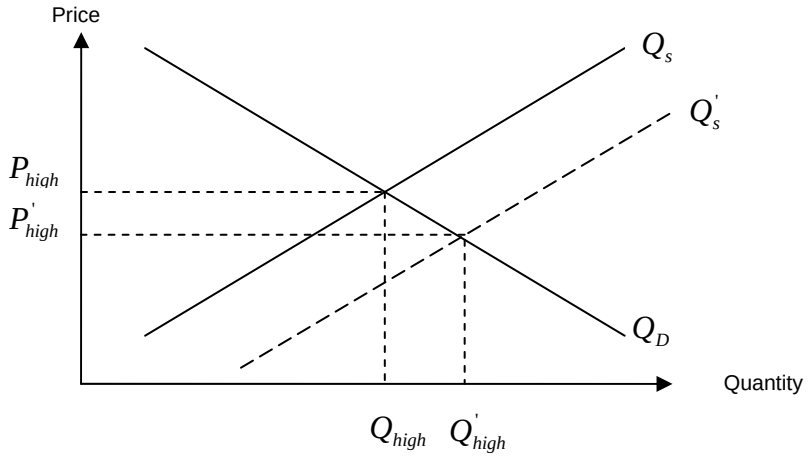

Figure 1: Consequences of arbitrage in the high price market

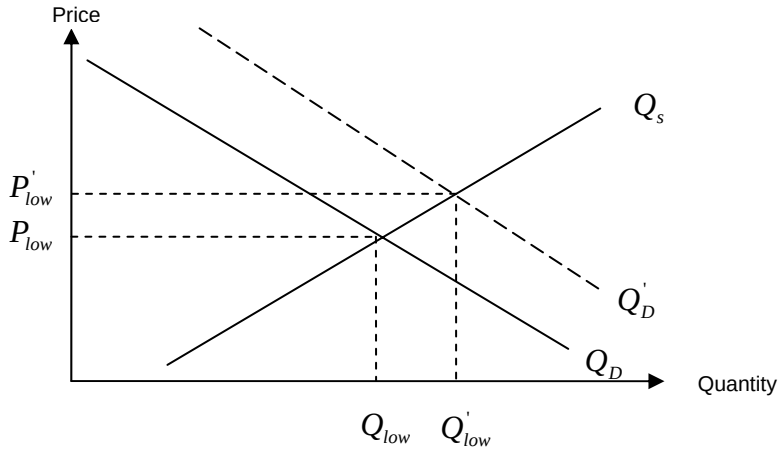

Figure 2: Consequences of arbitrage in the low price market

In reality prices can differ by significant amounts even if the goods are completely identical. This has been called the “failure of the Law of One Price” and has been a puzzle for economists for decades. A classical study was published by Peter Isard in 1977 (“How far can we push the law of one price?”). The subject has received renewed interest in the late

1990s and 2000s by among others Engel and Rogers (Engel and Rogers 1995, 1996). They find that the law of one price holds more nearly within regions than with interregional trade. They also find that the variation of price is much lower within than between countries even when controlling for distance between locations.

2.2 Convergence regressions

One way to test for convergence is described by Kevin H. O'Rourke and Jeffrey G. Williamson in "Education, Globalization and Catch-Up: Scandinavia in the Swedish Mirror" (1996). In this paper, they explore the extent of and reasons for the rapid growth of Scandinavia during the late 19th century. In their analysis they compare the Scandinavian countries to other OECD-countries by running unconditional and conditional convergence regressions. Time-series used include real wages, GDP per worker and GDP per capita.

First to last year growth ($\ln x_T - \ln x_0$) is used as the dependent variable, while the initial value ($\ln x_0$) is the independent variable. In the conditional convergence regressions other explanatory variables are included as well. If the estimated coefficient is significantly negative, this implies convergence. Growth is lower in countries that have a higher initial level, making the variable levels relatively more equal.

Similar methods to test for convergence are used by among others Barro and Sala-i-Martin (1991, 1992).

The method is mostly used to analyse catching-up in GDP and other measures of wealth and standard of living, but it's also applicable when analysing other time-series, such as prices.

An exact description of the procedure used in this thesis is given in section five.

2.3 Cointegration

Ordinary least squares (OLS) and other standard regression techniques, require that the variables be covariance stationary. A time-series is stationary when its statistic properties, such as variance and mean, don't change over time (StataCorp 2004). This is unfortunately not the case for many of the time-series studied in economics and econometrics. Many series

have underlying trends, and can not be made stationary by simply removing the trend or drift because the conditions of constant mean and variance are not satisfied (Dolado et al. 2001).

2.3.1 Time-series and stationarity

A stationary time-series is said to be I(0). Many economic time series are not stationary on level form, but their first differences are. Such series are known as I(1) processes, integrated processes of first order. More generally, an I(d) process is a series that is stationary when differentiated d times. A classic example of a I(1) process is the random walk. The random walk is a time-series where

(2) $x_t = x_{t-1} + \varepsilon_t$ ε_t is i.i.d (independent and identically distributed)

i.e. the present values of the variable depends on the value of the variable the previous period. The model is autoregressive with one lag, AR(1).

The variance of x_t is time dependent, so this series is not stationary. The first difference however is stationary, since $\Delta x_t = x_t - x_{t-1} = \varepsilon_t$. As ε_t is i.i.d., and has mean zero and a finite variance (σ^2), x_t is first-difference stationary (Stata Corp 2004).

Using non-stationary variables in regressions is problematic. There is a significant possibility of obtaining significant results when there is no real relationship, due to the underlying trends. Such regressions are said to be spurious. Even if there is a real relationship, problems will arise due to the fact that the relationship between the variables is not constant over time. In these cases the estimates and the t-statistics are not reliable, as the Gauss-Markov conditions are not fulfilled (Hill et al 2001).

Testing for stationarity

A popular method used to test for stationarity is the Dickey-Fuller test for unit root in variables. The Dickey-Fuller test is based on an AR(1) model

(3) $x_t = \rho x_{t-1} + \varepsilon_t$

If $\rho = 1$ the time-series is a non-stationary random walk process, as the effect of shocks does not decrease over time.

(3) can be transformed

$$x_t = \rho x_{t-1} + \varepsilon_t$$

$$x_t - x_{t-1} = \rho x_{t-1} - x_{t-1} + \varepsilon_t$$

$$\Delta x_t = (\rho - 1)x_{t-1} + \varepsilon_t \qquad \gamma \equiv \rho - 1$$

(4) $$\Delta x_t = \gamma x_{t-1} + \varepsilon_t$$

Δx_t is the first-difference of x_t

$H_0 : \rho = 1 \Rightarrow \gamma = 0$ The series is non-stationary

$H_A : \rho < 1 \Rightarrow \gamma < 0$ The series is stationary

The test statistics of the Dickey-Fuller test d not follow a normal t – distribution, but must be compared to specifically calculated critical values. These critical values have been estimated by economists Dickey and Fuller, and this is why the test has been named after them. If the null hypothesis is rejected in favour of the alternative hypothesis that implies that shocks die out over time, thus the first-difference of the series is stationary, and is I(1) (Hill et al. 2001).

2.3.2 The theory of cointegration

Cointegration is a relatively new, but vast area of research. The theory is based on the works of Clive W. J. Granger and Robert F. Engle III.

The concept of cointegration was originally introduced by Clive Granger in his 1981 article "Some properties of time series data and their use in econometric model specification". The theory of cointegration variables was summed up and extended in an influential article published by Engle and Granger in 1987 ("Co-integration and error-correction: Representation, estimation and testing"). In this article, they jointly developed techniques for cointegration testing and estimation of parameters of linear systems with cointegration. These articles have become classics in econometric literature and opened the gate for a new field of research. The theory of cointegrating variables has been extended by among others Søren Johansen, who has written several influential articles. In 2003, Clive Engle and Robert

Granger were awarded the Nobel Prize in Economic Sciences[1] for their work on time-series[2].

Consider a regression model

(5) $y_t = \beta x_t + \varepsilon_t$ ε_t is i.i.d., "white noise"

If y_t and x_t both are I(1), there might exists a β that makes $\varepsilon_t = y_t - \beta x_t$ level stationary, I(0). If such a β exists, y_t and x_t are said to be cointegrated, with a vector (1,- β). This implies that the two variables share similar stochastic trends, and never diverge too far from each other. An illustration of two cointegrating series is given in figure 3 below. The variables have a long term relationship, and the error term ε_t represent short term deviations from the equilibrium (Hill et al. 2001). These results are also applicable for multivariate models.

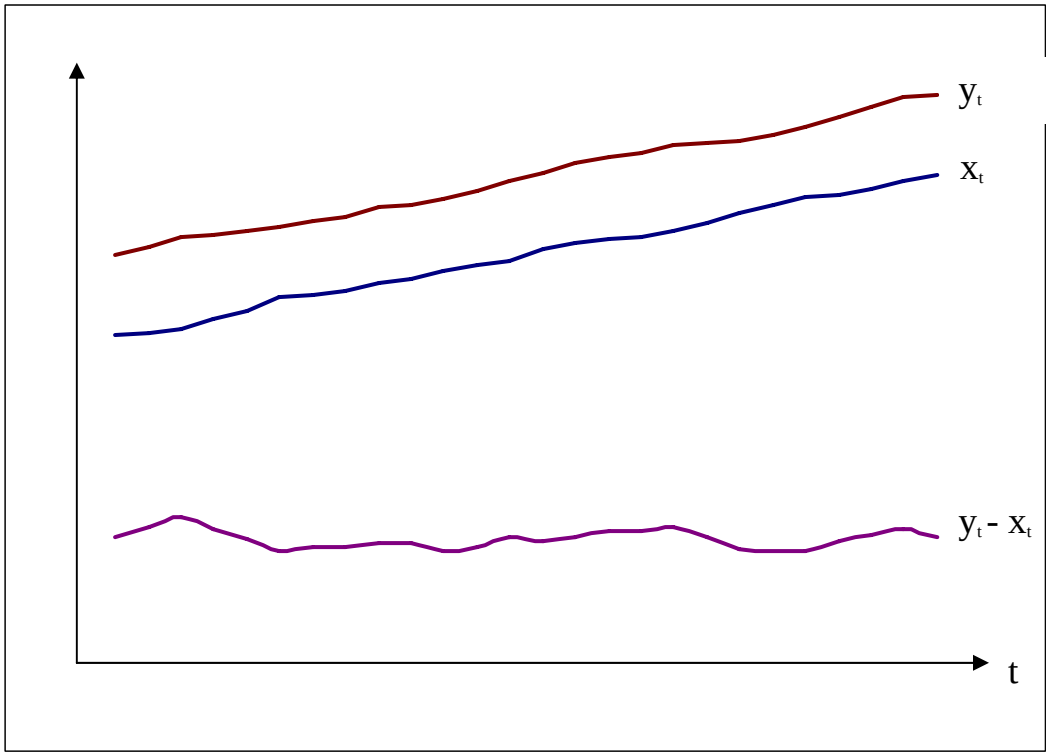

Figure 3: Cointegrating time-series

[1] The Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel, often called the Nobel Prize in Economics

[2] http://nobelprize.org/nobel_prizes/economics/laureates/2003/adv.html

The basic estimation problems that arise when using I(1)-series in regressions are solved by using the first-difference of the I(1) variable, but this specification can only describe the short-run effects. By removing the trend the interesting long-run dynamics are lost. Also, if the variables cointegrate, a regression based on the first differences will be misspecified, and the results are meaningless.

If time-series converge, the relationship between them should become more stable over time as the price differences are diminished.

2.3.3 Two-step Engle-Granger

In their 1987 article, Clive Granger and Robert Engle suggest a two-step procedure to estimate an error correction model for cointegrating systems. This method includes a test for cointegration based on residuals (Woolridge 2003).

Consider two non-stationary time-series x_1 and x_2.

Step 1: The long-run equation is estimated, and the residual is predicted

Estimate the regression

(6) $x_{1,t} = \beta x_{2,t} + \varepsilon_t$

Predict the residuals $\hat{\varepsilon}_t$

(7) $\hat{\varepsilon}_t = x_{1,t} - \hat{\beta} x_{2,t}$

Step 2: The error terms are tested for unit root, and the ECM is estimated

A Dickey-Fuller test is commonly used to test $\hat{\varepsilon}_t$ for unit root

As in *(4)* $\Delta\varepsilon_t = \gamma\varepsilon_{t-1} + u_t$ $\gamma \equiv \rho - 1$

$H_0 : \rho = 1 \Rightarrow \gamma = 0$ The series is non-stationary

$H_A : \rho < 1 \Rightarrow \gamma < 0$ The series is stationary

The critical values are slightly different than the ones normally used in a Dickey-Fuller test, because the test is based on estimates of the error term. The specific critical values are calculated by R. Davidson and J.G. MacKinnon.

	Significance level		
	1 %	5 %	10 %
Critical value	-3.90	-3.34	-3.04

Table 1: Asymptotic critical values for cointegration test: No time trend. Davidson and MacKinnon (1993) in Woolridge (2003), table 18.4

If the null hypothesis is rejected, this implies that the error term is stationary, I(0). The variables cointegrate. The residuals are used to estimate the ECM.

2.3.4 Vector error-correction models (VECMs)

"[The VECM formulation] …could be seen as capturing the transitional dynamics of the system to the long-run equilibrium suggested by economic theory" (Dolado et al. 2001).

A VECM is an error correction model that describes the joint behaviour of y_t and $x_{i,t}$ over time and combines dynamic specification with long-run properties. If cointegration is present, VECM will generate better forecasts than the first-differentiated representation.

Cointegration methods - including testing, estimation of VECMs and forecasting - in Stata are based on maximum likelihood methods developed by Johansen (StataCorp 2004). The maximum likelihood method is based on the so-called reduced rank regression method. It takes into account the short-run dynamics of the system when estimating the cointegrating vectors.

3. Historical background

Being a small, open economy, Norway was strongly affected by international impulses. The Norwegian economic development had a high correlation with the international business cycles, and ideologies and policy making were also greatly influenced by those of other western countries. Internationally, the period was characterised by the rise and fall of liberalism as well as a dramatic reduction in transaction costs.

3.1 International development

As mentioned in section one, the 19th century has been viewed by many as the first wave of globalisation. After centuries of mercantilism liberalism took hold at the end of the first half of the 19th century and tariffs and other trade barriers were diminished.

Transportation costs were reduced as infrastructure was enhanced. Sail ship technology was greatly improved, shortening the travel time and reducing risk. In the second half of the century the steam vessel gradually replaced the sailing ships. Steamers required fewer sailors per ton, and were more regular in the service than sailing ships, being more dependable in departures and arrivals as they did not rely on weather conditions. This further reduced the cost of sea-transport. The 19th century also saw the break-through of railroad development.

Several canals were built, such as the Erie Canal in USA (1825), the Fredrikshald/Halden Canal in Norway (1849) and the Suez Canal in Egypt (1869). The canals not only allowed transport by sea to formerly unavailable locations, but also reduced travel time between ports immensely (Cameron and Neal 2003). New roads were built, and existing ones were improved. The International Gold Standard was adopted widely from the 1860/70s to stimulate international trade by providing a stable fixed exchange course system.

All these factors contributed to reduced transaction costs. If arbitrage is possible, the lowering of transaction costs should lead to a tightening of the band in which prices vary, and make them converge.

3.2 Norwegian Business cycles

In the aftermath of the Napoleonic Wars at the beginning of the 19th century, Norway experienced a relatively long post-war depression. The monetary system was chaotic and needed reforms. The new currency introduced in 1816, the speciedaler, quickly depreciated due to lack of confidence. A long period of restrictive monetary policy followed to bring the value back to par and make the currency convertible. Investments were curtailed as the appreciating currency made it unprofitable to use credit to finance investments. An appreciation of the currency meant that the real value of loans increased, making it unprofitable to launch fresh lines of credit, and harder to service old debt. The international post-war depression lowered the demand for Norwegian export products. This also had a significant negative effect on the economic activity. Pessimism spread, and the Norwegian economy stagnated.

Although the currency was not made convertible at the par silver value before 1842 there was a change in attitude and rapid increase in investments from the late 1830s as the real value of the speciedaler was getting close to the face value. A more stable currency and the end of the international recession gave positive impulses to Norwegian exports. International trade liberalisation led to a significant rise in international trade, which was important for the Norwegian economy. There were recessions in the late 1840s and the late 1850s, both due to international circumstances (revolutions and civil unrest in the 40s, and the Crimean War as well as trouble in the international finance industry in the 50s), but in general the period from the late 1830s to the 1870s was a period of growth.

3.3 Liberalism

One of the most influential theoretical works on liberalism and free trade was ”An Inquiry into the Nature and Causes of the Wealth of Nations” (Commonly abbreviated to “Wealth of nations”), published in 1776 by the Scottish moral philosopher Adam Smith. In “Wealth of Nations” Smith uses the metaphor of an “invisible hand” to describe how competitive markets reach equilibrium. Individuals pursuing their own good also tend to promote the welfare of the whole community in the competitive markets of capitalism. His work was an attack on the - at the time - dominating system of mercantilism and the feudal state, with high tariffs and privileges both on trade and establishment of business. The state had a very

active role in planning and regulating. Smith's ideas were greatly influential to contemporary and later economists and authors. However, there was a strong resistance against the principle of free trade, as customs revenues were of major significance for government income.

Economic liberalisation in Norway had its breakthrough in the late 1830s. Although there was a firm belief in the "invisible hand", one recognised that in some areas the marked failed, specifically in the supply of public goods such as defence and the justice system. The government was given specific tasks to "secure the citizens' personal and economic rights" (Hanisch et al. 1999, p 35), but were not to interfere in the private sector (laissez-faire). The market itself was considered a public good, and it was the government's task to keep it open and available for everyone. Privileges were to be abolished to assure free entry.

From the 1870s there was a reversion towards protectionism as the international commodities markets were flooded by cheap goods produced in "the New World" (e.g. USA, Australia). Labour costs were considerably higher in the European countries, making prices much higher and their goods less competitive. To protect domestic producers, tariffs were raised. Norway had gone relatively far in the direction of international free trade, and the reversion towards protectionism was also slower and weaker compared to other European countries. The domestic liberalisation was never reversed.

3.4 Infrastructure and trade costs

Norway has a long coastline and a challenging topography, with steep mountainsides, large forests and deep fjords. The climate is rough, but habitable, and varies considerably between the different parts of the country. The population density was and still is relatively low. Building and maintaining infrastructure and communications was expensive, while the income was low or non-existing. Infrastructure is non-excludable and non-rival, making it a public good. Although some types of communication are excludable (such as the telephone), private companies would only make a profit, and thus operate, in the most densely populated areas. Connecting the whole country was a political matter, and infrastructure was considered a government responsibility.

In 1845 a new central ministry was set up, the Domestic Ministry (Indredepartementet) under the leadership of Fredrik Stang. There was a surge for government involvement in

education, healthcare and infrastructure, all public goods (Hodne and Grytten 2000). These expenses were considered investments to enhance the Norwegian economic performance. Education and healthcare would increase the quality of labour, while improved transportation and communication was important to reduce distribution costs and encourage investment in private businesses.

Public investments were made possible by customs revenue from international trade, the main source of income for the government. As Norway was (and is) a small, open economy, the business cycles and public income were greatly influenced by the international economic climate, making the magnitude of the investments variable and pro-cyclic.

					Infrastructure and communication													
	Education		**Healthcare**		*Roads*		*Railways*		*Ports and lighthouses*		*Steamship operation*		*Telegraph and telephone*		*Infrastructure total*		**Total**	
Year	NOK	%	NOK	%	NOK	%	NOK	%	NOK	%	NOK	%	NOK	%	NOK	%	NOK	%
1825	203	37	126	23					213	39					213	39	543	100
1835	231	45	83	16	6	1			73	14	126	24			205	39	519	100
1845	336	31	156	15	182	17			106	10	290	27			578	54	1070	100
1850	450	28	266	17	79	5			136	9	650	41			865	55	1581	100
1860	852	14	567	9	897	15	2520	40	371	6	829	14	94	2	4711	77	6103	100
1865	1004	22	668	15	132	3	1312	29	344	8	692	15	340	8	2820	63	4492	100
1870	961	23	716	17	280	7	430	10	392	8	661	17	775	18	2538	60	4215	100
1875	1427	9	1023	7	746	5	9192	60	936	6	538	3	1527	10	12939	84	15392	100
1880	2970	22	1595	12	391	3	6234	46	987	7	442	3	973	7	9027	66	13592	100
1885	4326	43	1548	16	1136	11	280	3	1178	12	388	4	1109	11	4091	41	9965	100
1890	4718	34	1968	14	1968	14	2100	15	1066	8	736	5	1328	10	7198	52	13884	100
1895	6872	34	2534	12	2086	10	4103	20	1945	10	904	4	1927	10	10965	54	20371	100
1900	9455	25	3161	8	2342	6	11990	32	2096	6	1175	3	7118	19	24721	66	37337	100
1905	10663	35	3301	11	2206	7	7906	26	1687	6	1220	4	3134	10	16153	53	30087	100
1910	15108	41	3808	10	2702	7	5176	14	2304	6	1663	5	5647	16	17492	48	36408	100

Table 2: Investment expenditures of the state, measured in 1000 NOK, current prices. Percentages are of total expenditure. Source: Hodne (1985), table 23

Infrastructure was given a high priority on government investment budgets, as shown in table 2. Investments expenditures show a volatile pattern, especially the expenditures on railroad investments. Trends and developments in the specific areas of infrastructure and communication are discussed below.

3.4.1 Shipping

Relatively low wages and abundance of material for ship-building gave Norway a comparative advantage in international goods transport, and shipping services was one of Norway's top 3 export industries in the 19th century, along with fish and timber. Sea

transport was also the preferred method of goods transport internally due to the long coastline and many waterways. The fjords were very important for transportation of both passengers and goods.

During the 19th century several enhancements in sail technology were adopted. The size of ships was increased. Fast clippers replaced older and slower ships, further improving the efficiency of the Norwegian fleet (Hodne and Grytten 2000). However, the development of the steamship was the most significant naval improvement of the 19th century. The steam vessel was introduced in the Norwegian merchant marine early in the 19th century, but wooden sail ships dominated the Norwegian fleet until late in the 19th century.

The invention of the modern steam vessel is usually credited to Robert Fulton, whose ship the *Clairmont* had its maiden voyage on the Hudson river in 1807. The first steamers were mainly used on lakes and other inland waterways. Ocean steamers came later, and the first trans-Atlantic service began in 1838. The true age of the ocean steamer did not arrive until later in the century, when important inventions such as the screw propeller (1840s), the compound engine (1850s) and steel hulls (1860s) greatly enhanced the efficiency of the vessels (Cameron and Neal 2003). Unlike sailing ships, steamers did not rely on weather conditions, and were thus more dependable for regular service. As they required fewer sailors per ton wage costs were lower, and as the price of coal decreased during the century, the competitiveness of the steam vessel opposed to the sail ship increased.

In 1878 Belgium was the first country to have a larger steam vessel fleet than sail fleet. United Kingdom followed in 1883, and Germany a few years later. In Norway the transition from sail to steam technology in the merchant navy was relatively late compared to other large shipping nations. The steamer tonnage did not surpass the sailing ship tonnage before 1907. This led to a period of stagnation and transformation problems in the late 19th century, and the Norwegian shipping industry lost significant market shares (Hodne and Grytten 2000). Even though the transformation from sail to steam was relatively late, it was fast and successful once initiated.

Government steamship operations

Regular service of passengers and mail was important for both interior and international communication. As early as in 1826 and 1827 two paddle steam engines were imported from the United Kingdom to improve the reliability of services. By 1855 eleven paddle

steamships were operated by the government in regular service along the coastline and abroad, and loans were granted for at least four ships that operated on lakes and in rivers and canals. The government was deeply involved in steam ship services until 1857, when the large costs of this activity lead to reforms (Hodne and Grytten 2000). This is clearly shown in table 4, where 1850 is a peak year for investments in steamship operations at 41 percent of total investment expenditures. The parliament decided that direct state operation should be limited to the regions where profitable services were impossible (market failure). In regions where profitable services were possible, subsidised private and county operated companies were to take over.

Ports and lighthouses

The introduction of the steamship meant higher requirements to port facilities. The government got involved by building jetties, as well as building and improving existing ports. Lighthouses along the coast were also needed to reduce shipwrecks.

3.4.2 Roads

Norway was a scarcely populated country with many natural obstructions, such as mountain ranges, forests and glaciers. The topography made road construction expensive and difficult. The fjords and other waterways were important transportation channels, but added to the difficulty of road construction. The government's investment plans for infrastructure led to an increased activity in road construction and improvement during the 19th century.

Roads were classified as either main roads; roads that connected Norway and Sweden, and roads that connected the Norwegian cities, or local roads which were in more rural areas. Laws passed in 1824 and 1851 regulated the responsibility for building, improving and maintaining roads, distributing the costs between the central and local government. The main roads were the responsibility of the central government, while the respective counties were responsible for the local roads. A state fund was established in to help finance local projects, and officials were hired to supervise the work with the local roads (Hodne and Grytten 2000). Road construction increased significantly and road length doubled in the period 1850-1910, from 16 500 to 31 700 (Hodne and Grytten 2000), but transport of goods by sea dominated by far well into the 20th century.

3.4.3 Mail services

Road improvements as well as more regular and less expensive sea transport were important for the efficiency of mail services. Delivery was made faster and cheaper. From 1848 there were only two different rates, and in 1854 the stamp-system was adopted and the postal rates were made nationally uniform. This reform meant a reduction of postage. The volume of mail increased massively, from 1 million postal items in 1848 to 3,3 million in 1860 and 26,7 million in 1880 (Hodne 1985).

3.4.4 Railroads

"The steam locomotive and its adjuncts, iron (or steel) railways, more than any other technological innovation of the nineteenth century, epitomized the process of economic development" (Cameron and Neal 2003)

Railroads offered cheap, fast and reliable transportation over land (Cameron and Neal 2003). The first railroad to carry both goods and passengers on a regular schedule was the Stockton and Darlington Railroad Company in England. It began operations on September 27, 1825.[3] This is considered the start of modern railway history, and the success of the Stockton and Darlington Railroad Company inspired investors and planners in USA, Great Britain and other Western European countries. The first Norwegian railroad was built with expertise, investments and initiative from British specialists. Tracks were laid between Eidsvoll and Christiania (Oslo). The line was 68 km and was opened for traffic in September 1854.[4]

Railway construction was very capital intensive, and the project was financed in cooperation by the government and private Norwegian and British investors. In 1857 the parliament granted money for the building of three more railways. The costs were to be mainly carried by the government through the national budget. Investments were low in the 1860s due to lack of funding. In the 1870s the public economy was improved and the country was swept

[3] http://homepage.ntlworld.com/johnmoore/1825/index.htm

[4] http://www.jernbaneverket.no/jernbanenettet/Historie/

by a “railroad fever”. Several new railroad projects were started, and existing lines were extended. From 1851 to 1883 15 railroads were built in Norway.[5]

3.4.5 Telegraph and telephone

The Morse telegraph was invented in 1835 by Samuel B. F. Morse. The first commercial line, between Washington DC and Baltimore (USA), was officially opened in 1844. It was a revolutionary invention, enabling people to communicate almost instantly over large distances for the first time. The Norwegian telegraph network was built at a rapid pace from 1855, when Fredrikshald (Halden) was connected to the Swedish lines. By 1860 the entire coast up to Trondheim was covered, and Vadsø in the far north was connected in 1870. Lines were also built connecting Norway to Denmark (1868), Scotland (1869) and USA (1866), facilitating both interior and international communication (Hodne and Grytten 2000).

The telephone was patented in 1876 by Alexander Graham Bell. The first telephone was brought to Norway by Joakim Anderssen from Ålesund the same year (Hodne and Grytten 2002), and as early as in 1880 there were several private Norwegian telephone companies. Telephone use was mainly restricted to the cities the first years, as the operating companies were private and limited the building of lines to densely populated areas where they could make a profit. From 1881 the parliament passed an act ensuring state monopoly on telegraph and telephone services, requiring private companies to apply for a license (Hodne 1985).

3.4.6 Summary

Both international and domestic transaction costs were greatly reduced in the 19th century by developments in infrastructure. Goods- and passenger traffic by sea was made cheaper and more reliable by improvements in sail ship technology and the introduction of the steam vessel. Building of roads and railroads significantly improved inland passenger- and goods transportation. Mail services were made more efficient by the improvements in both sea and inland transport, and the invention and adoptation of the telephone and the telegraph further improved communication. The reduction in trade costs should lead to a tightening of the band in which prices must be in equilibrium, thus lowering the observed price differences and lead to integration in commodity markets.

[5] http://www.jernbaneverket.no/jernbanenettet/Historie/

4. Data

The dataset used in this thesis is collected from Professor Ingvar B. Wedervang's Archive of Historical Wages and Prices, kept at the NHH (The Norwegian School of Economics and Business Administration) in Bergen, Norway. The dataset contains price observations on 15 commodities in up to 40 cities in the years 1832 – 1871.

4.1 The Wedervang Archive

The Wedervang Archive is a large collection of Norwegian wage- and price statistics. It is currently located at the library of the NHH, and is one of the worlds largest of its kind. The observations span from 1641 to 1940, but the main parts of the data are from the period 1830 - 1910.

The collection was initiated during the 1930s by Professor Dr. Ingvar B. Wedervang, then a scholar at the Economics department of the University of Oslo (UiO). Professor Ragnar Frisch, who later won the Nobel Prize in Economic Sciences (1969), was also deeply involved in the project. As the interwar period in Norway was characterized by rapid changes from boom to recession and saw three serious recessions[6], there was a renewed interest in business cycle theory in the 1930s. The purpose was to identify and describe underlying regularities and "laws" of economic growth, and develop tools for policy-making based on the findings. Detailed empirical knowledge of prices and wages was considered a good basis for business cycle theory (Ramstad 1985).

The data was collected from a broad variety of sources, including official records and private business archives. Wedervang was appointed the first rector of the newly established NHH and moved to Bergen in 1937, but frequently travelled to Oslo to supervise the work. He was convinced that the material would be most powerful when presented as an entity, and did not want to publish central findings before the whole project was finished. Large parts of the collection were ready for printing by 1940, but the plans were put on hold after the German occupation and later pre-empted by reconstruction after the war. The archive was kept in

[6] The international post-war depression early 1920s, a currency-related crisis in the mid 1920s and the Great Depression in the early 1930s

boxes at the NHH until 1973 when the folders were unpacked and systemized to make the material available for research. Since then a number of papers and dissertations based on material from the archive have been published (Ramstad 1985).

The material is organised in approximately 500 folders. The dataset used in this thesis is copied from folder W139, while some background information is collected from folder W272.

4.2 Folder W139

Folder W139 – "Market prices in Norwegian towns" contains price data reported by civil servants – notably magistrates - of 40 Norwegian towns and cities between 1832 and 1871. The prices are reported as "spot" consumer prices in the various market places observed on the middle day of the first month of each quarter; January, April, July and October. An annual average is also computed. The prices are reported in Speciedaler and Skilling, the Norwegian currency at the time. One speciedaler contained 120 skilling. In the current Norwegian currency Norske kroner (NOK), one speciedaler would be four kroner.[7] The series are grouped by commodity.

The data were collected following the orders in a circular from the so-called 4th Ministry, later renamed the Ministry of Finance, dated 20 January 1816 to the Norwegian county officials. In this circular, the ministry requested price statistics on eight goods (mostly grains) in rural districts and 16 goods (the eight reported from rural districts and eight more) in the towns and cities. The Magistrates of the towns were ordered to report the prices (on the middle day of the first month of each quarter) to the county. The county thereafter forwarded the statistics to the Ministry. Price information was regarded as highly important for the government to supervise the social and economic development.[8]

[7] http://www.maritimt.net/arkforsk/norskem.htm

[8] Circular from 4th Department dated January 20th 1816 to all executive county public servants, kept at the Wedervang Archive, W 272.

4.2.1 Privileged market towns

The towns that were required to report commodity prices were the so-called “kjøpstader” or privileged market towns, towns that had certain privileges with regards to trade. This special status was first created in Norway in the 12th century to encourage businesses to be concentrated around specific towns. Almost all trade was to go through these market towns following a law of 1662 that gave the towns a monopoly on trade. In return, the towns were required to keep enough goods in stock to supply the surrounding rural areas. Exports and imports were also required to go through a town with trade privileges. Only citizens certified by the government could engage in trade. In 1818 the parliament even passed a law specifying personal and business-related qualities a candidate had to possess to be certified (Hodne and Grytten 2000).

There were some exceptions from the monopoly. From 1814 certain citizens were licensed to establish general stores in the countryside. The number of these rural merchants was low the first years, but increased steadily towards the middle of the century. There were also some small stores in the more remote ports, often connected to inns. Some areas had seasonal markets, usually occurring once or twice a year. Also, trade was not limited to stores only. In the countryside, most of the trade was barter, trading one good for another. From the 1860s the use of money gradually replaced barter as the dominant method of settlement. This change was brought on by a sharp increase in the number of travelling merchants and rural shops, who only accepted payment in cash, as well as the growth in rural tourism. The establishment of the Norwegian savings bank sector also played a significant part in the development of the money economy. By the turn of the century cash settlement had almost completely replaced exchange of goods (Hodne og Grytten 2000).

The trade privileges of the market towns were gradually revoked from the 1840s and onwards as liberalisation took hold. In 1842 a law was passed that allowed free establishment of rural merchants that were allowed to sell certain basic products. The right to establish this type of general store was originally limited to areas more than 30 km from a city. The number of products allowed increased steadily and the required distance was reduced in following years. Even though the privileges were removed from the cities, the name “kjøpstad” remained.

Norway is divided in 5 main regions; East, South, West, Middle and North, and further into 19 counties. The present division is quite similar to that of the 19th century, but the many of the counties have changed name, see Appendix A.

Table 3 below shows the towns included in the dataset, the year they reached status as market town, and also which region of Norway they belong to.

Town name	Current name if changed	Town status, year	Region
Fredrikshald	Halden	1665	East
Fredrikstad		1567	East
Sarpsborg		1839	East
Moss		1720	East
Drøbak		1842	East
Christiania	Oslo	1000	East
Kongsvinger		1854	East
Hamar		1848	East
Lillehammer		1842	East
Gjøvik		1861	East
Hønefoss		1852	East
Kongsberg		1624	East
Drammen		1811	East
Holmestrand		1752	East
Tønsberg		871	East
Horten		1858	East
Sandefjord		1845	East
Larvik		1671	East
Skien		1000	East
Porsgrund	Porsgrunn	1842	East
Brevik		1845	East
Kragerø		1666	East
Risør		1630	South
Arendal		1723	South
Grimstad		1816	South
Christiansand	Kristiansand	1641	South
Flekkefjord		1842	South
Stavanger		1125	West
Haugesund		1854	West
Bergen		1070	West
Molde		1742	West
Ålesund		1848	West
Christiansund	Kristiansund	1742	West
Trondhjem	Trondheim	997	Middle
Levanger		1836	Middle
Bodø		1816	North
Tromsø		1794	North
Hammerfest		1789	North
Vardø		1789	North
Vadsø		1833	North

Table 3: Market towns in the dataset

In the folder, the market towns are listed by geographical location. With a few exceptions the order follows the location on the coastline from the southernmost point of the border with Sweden to the Russian border in the north. Only five of the cities are in the interior of the country; Lillehammer, Hamar, Hønefoss, Kongsvinger and Kongsberg. The remaining 35 are situated along the coastline.

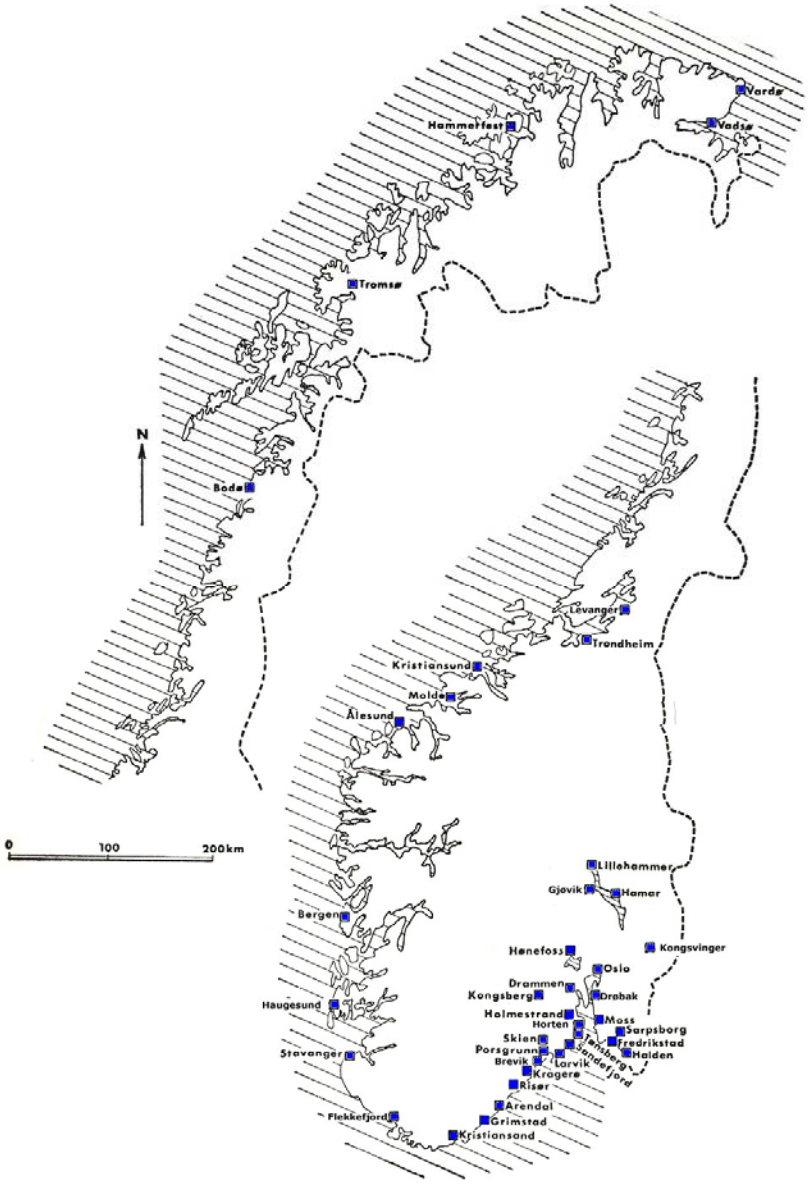

Figure 4: Map of Norway with the 40 cities included in the dataset marked. A larger version of the map is available in Appendix A

In 1800, approximately 90 percent of the population lived in rural areas. Structural changes during the 19th century (productivity gains in agriculture, early industrialization) led to

massive migration and urbanisation. Some towns grew around railway stations and industrial sites as these were developed. Small villages grew to larger towns, and by 1900 36 percent of the population lived in urban areas (Hodne and Grytten 2000). Many of the 40 mentioned cities were not classified as a market town and were therefore not required to report prices in 1832, but grew and reached this status during the period. For these cities, data do not exist before a certain year. Some of the series also have lacunas. There are years in which prices were not reported by a town, for unknown reasons. The time series are less consistent in general for some commodities the others, most notably wool, linen and hemp.

4.2.2 Commodities

Prices were reported for 15 commodities, shown in table 4 below.

Commodity	Measure
Barley	Barrel
Peas	Barrel
Hemp	Ship's pound
Oat	Barrel
Wheat	Barrel
Iron	Ship's pound
Spirits[9]	Pot
Linen	Ship's pound
Potatoes	Barrel
Rye	Barrel
Salt	Barrel
Herring	Barrel
Tar	Barrel
Stockfish	Barrel
Wool	Ship's pound

Table 4: Commodities reported

For most of the commodities the price given is based on one barrel (tønne). For dry goods, a grain barrel was used. The volume of this barrel corresponded to about 139 litres. The barrels used for liquid goods contained about 117 litres. The prices of hemp, linen, wool and iron and stockfish reported for one unit of the old Norwegian ship's pound (skippund). One ship's pound is equal to about 160 kilos. The price of spirits is given for a pot (potte), which was slightly less than 1 litre (0.966).[10]

[9] The prices are given for spirits made of grain. Spirits were also made out of potatoes.

[10] http://www.maritimt.net/arkforsk/norskem.htm

In some cases prices are reported for other quantities. A few of these prices have been converted to the same measurements as the others in the series by Wedervang and his staff. Others have not been converted. There are also a few cases the prices reported are even for similar, but not identical goods, e.g. oatmeal in stead of oat. I have chosen to omit the last two mentioned prices in the dataset as they are not directly comparable to the rest of the prices. The ones converted by Wedervang and his associates are included.

Local goods

Local products are goods that are possible to produce everywhere and/or that are expensive to transport. Traded products are goods that either have natural monopolies or must be imported and/or products that are cheap to transport. It is likely that typical local goods were less traded than others, and therefore the mechanisms of price integration would be weaker.

Local goods
Peas
Oat
Spirits
Potatoes
Tar
Wool

Table 5: Local goods of the 15 reported commodities

The potato was brought from the Andes to Spain by explorers in the 16th century, and spread from there to the rest of Europe. There was widespread production of potatoes in Norway from the early 19th century. As the potato was more nourishing, gave larger crops and was more resistant to frost then the Norwegian grain, many farmers partially or entirely substituted their production of grain with potatoes (Hodne and Grytten 2000). One of the most attractive features of the potato as a crop is that it can grow almost everywhere. As it is quite heavy it's also expensive to transport.

Oat is the only type of grain that can be grown anywhere in Norway, despite the rough climate and often barren soil. Peas were also grown all over the country. Spirits and tar were produced locally as well. Sheep were kept on most farms, even in the far north, making wool available for clothing and other purposes.

Traded goods

The so-called traded goods include imported goods, as well as some goods that were either partially imported or had a local monopoly within Norway due to natural conditions. The last type of commodity is tagged as limited goods.

Limited goods
Iron
Salt
Barley
Herring
Stockfish

Table 6: Limited goods of the 15 reported commodities

The production of iron requires iron ore and the costs of establishment are large, making this a natural monopoly. The main deposit of iron ore in Norway was in the hills close to Arendal in the southern part of the country. This field probably supplied approximately 80 % of the total amount of iron ore smelted by Norwegian iron works in the years 1580 - 1880. The iron works were mainly located in the southern and eastern part of Norway, and production was based on charcoal smelting technology. As charcoal grew relatively expensive in Norway during the 19th century, the domestically produced iron was gradually replaced by imported iron, especially from United Kingdom. When the Bessemer process was patented in 1855, older production techniques were made obsolete, further reducing the competitiveness of Norwegian iron works[11].

Salt was produced mostly along the coast, but was also imported. In some periods salt was even exported, making this a hard commodity to classify. Barley can be grown almost everywhere except the northernmost parts of the country; Nord-Troms and Finnmark.

The production of stockfish and herring was naturally limited to areas with natural occurrences of fish populations. Stockfish was mostly produced in the northern part of Norway where the catch of cod was plentiful, while herring was caught and preserved on the western and north-western coast.

Imported goods
Hemp
Wheat
Linen
Rye

Table 7: Imported goods of the 15 commodities

Some goods were not produced at all in Norway, and had to be imported. Weather and soil conditions made it impossible to grow rye and wheat with the technology at hand. Hemp and linen was also imported.

[11] http://www.museumsnett.no/jernverksmuseet/index.html

It is pretty safe to assume that the typical local products were less traded than the two other groups of goods. This should imply that price integration was slower for these products. Also, products with high transaction costs must have larger price differentials for arbitrage to be profitable. This implies a wider band in for the fluctuations in prices from the equilibrium. Imported goods and goods with natural monopolies should be more traded than others, making the price convergence mechanisms stronger for these types of products.

5. Analysis methods

The dataset consists of observations of prices of 15 commodities in up to 40 Norwegian towns and cities in the period 1832 – 1871. The data can be divided into two subsets: 1832 – 1850 and 1851 – 1871, giving three different samples;

Sample number	Period	Observations (N)
1)	1832-1871	40
2)	1832-1850	19
3)	1851-1871	21

Table 8: Samples used in the analysis

5.1 Convergence regressions

For each of the three samples, growth rates are computed for every city and commodity-pair by running a regression with price as a dependent variable and time as the independent variable.

$$\ln price_{city,commodity} = \alpha + \beta_{city,commodity} \cdot t + u_{city,commodity} \quad (8)$$

By using the natural logarithm of prices, the regression coefficient $\beta_{city,commodity}$ in (8) denotes the growth rate in percent per year.

A geometric average of the three first observations in the sample is also computed for each city-commodity pair. This average is used as initial value to avoid possible problems in case the first observation is an extreme value/outlier.

$$initialvalue = \frac{\sum_{t=1}^{t=3} \ln price_{city,t}}{3} \quad (9)$$

The most inconsistent time series are dropped: series with more than three missing observation for the two subsets (2 and 3), and series with more than five missing observations for the 1832 - 1871 sample (1). For each commodity and sample, regressions are run with growth rate as the dependent variable and the average of the first three observations as the independent variable.

Regression model:

(10) $$Growthrate_{city} = \alpha + \beta_{integration} \cdot initialvalue_{city} + \varepsilon_{city}$$

As initial value is an average of logarithmical values, the regression model is log-log. If the average initial price increases by 1%, the growth rate of prices changes by $\beta_{integration}$ percent. If there has been integration one should expect a negative sign of the regression coefficient $\beta_{integration}$ in (10). This would indicate that in the cities with high initial values, prices have grown less than in cities with low initial values. Hence, the prices have converged, and the price level has become relatively more equal. To test whether or not this is the case, a two-sided t-test is used.

T-testing

The t-test is widely used to test hypothesis about a single parameter in regressions. β_j measures the partial effect of the variable x_j on the dependant variable controlling for all other (if any) independent variables. The so-called null hypothesis (H_0) is that $\beta_j = a_j$, the coefficient β_j is equal to a hypothesised value a_j. This hypothesis is tested against an alternative, either one-sided ($\beta_j > a_j$ or $\beta_j < a_j$) or two-sided ($\beta_j \neq a_j$). A two-sided test with $a_j = 0$ is commonly used to test whether or not a specific variable has an effect on the dependant variable.

Hypotheses are formed about the properties of the entire population. Usually only a sample is available for analysis. The estimated coefficient in regressions is the sample coefficient ($\hat{\beta}_j$), while the true coefficient (β_j) is unknown. However, if the estimator is consistent, the distribution of $\hat{\beta}_j$ becomes more and more tightly distributed around β_j as the sample size grows. If the estimator is consistent and the Gauss-Markov-conditions are fulfilled, the sample can be used to test population properties (Woolridge, 2003).

When a regression model has been estimated, a t-statistic can be computed for each of the estimated regression coefficients;

(11) $$t_{\hat{\beta}_j} \equiv \frac{\hat{\beta}_j - a_j}{SE(\hat{\beta}_j)}$$

This statistic measures how many estimated standard deviations the estimated coefficient $\hat{\beta}_j$ is from the hypothesised value a_j. The t-statistic is *t-distributed* with *n – k – 1* degrees of freedom. $t_{\hat{\beta}_j}$ is compared to a critical t-value *c*, which depends on the significance level selected. The significance level is the probability of rejecting the null hypothesis when it's actually true. A significance level of five percent is the most popular choice. The critical value *c* is estimated based on the significance level and degrees of freedom. If $\left|t_{\hat{\beta}_j}\right| > c$ the null hypothesis is rejected (Woolridge 2003).

In the analysis part of this thesis the following will be the null hypothesis

(12) $H_0 : \beta_{\text{int}egration} = 0$

That is, the initial value has no effect on the growth rate.

(13) $H_A : \beta_{\text{int}egration} \neq 0$

Initial value has an effect on the growth rate.

If $\left|t_{\hat{\beta}_j}\right|$ is higher than the critical value *c*, the null hypothesis that the initial price level has no effect on the growth rate is rejected in favour of the alternative hypothesis.

5.2 Cointegration

As mentioned in section 4.2.2, some of the commodities were most likely traded more than others, and thus should have a stronger convergence mechanism. Traded goods include imported goods and goods that were only produced in certain parts of the country. To test the assumption that the integration mechanism is stronger for traded goods than for local, four commodities have been selected for cointegration testing. Two of these commodities are typical local products, and the two others are traded goods.

Commodity	Type
Oat	Local
Spirits	Local
Rye	Imported
Stockfish	Limited

Table 9: Commodities tested for cointegration

Oat is the only type of grain that can be grown all over Norway, and spirits were also distilled locally. Rye was imported, because Norwegian weather and soil conditions were too rough to grow it domestically. The production of stockfish was naturally limited to the Northern region, where the population of cod was large. The cod was dried locally and then transported to Bergen for export and domestic distribution.

The two methods of cointegration testing are based on the same theories, as Johansen's works is an extension of Engle and Granger's. For practical purposes, the main difference is that the Johansen routine in Stata tests the whole system, the Engle-Granger two-step method only tests for a single cointegrating relationship. To test a system with more than two series, pairs must be created and tested one by one. Although a bit more extensive, the Engle Granger method might be more informative in the present case. The Johansen routine in Stata only returns the number of cointegrating relationships, while the Engle-Granger method gives more specific information. It is very likely that towns that are geographically close have a stronger correlation in prices than cities that are far apart, because transportation costs is an important part of trade costs. Therefore, it might be interesting to see the variations between regions.

5.2.1 Two-step Engle-Granger

This method is based on creating pairs of towns, and test the two time-series in question for cointegration. With a total of 40 towns there are 780 potential city-pairs, making testing with all the towns a massive task. To lighten the load five towns, each representing a region, have been selected for each commodity tested. The towns selected have consistent time-series for the sample period. If no towns have suitable time-series for the commodity in question, the region is dropped. With up to five towns, as much as ten possible pairs are created, shown in table 10.

	North	Middle	West	South	East
East	E-N	E-M	E-W	E-S	-------
South	S-N	S-M	S-W	-------	-------
West	W-N	S-W	-------	-------	-------
Middle	M-N	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 10: Possible city-pairs

For each city-pair, a regression is run, following this regression model:

(14) $\ln \Pr ice_{City1,t} = \beta \ln \Pr ice_{City2,t} + \varepsilon_t$

The error term $\hat{\varepsilon}_t$ is then predicted, and a Dickey-Fuller test is run on the predicted residual. $H_0 : \rho = 1 \Rightarrow \gamma = 0$ The error term is non-stationary

$H_A : \rho < 1 \Rightarrow \gamma < 0$ The error term is stationary

The test-statistic is compared to the critical values calculated by Davidson and MacKinnon.

5.2.2 Johansen/VECM

As mentioned in Section 2.3.4, Stata's cointegration methods, both estimation and testing, are based on VECMs and Johansen's framework. The built-in cointegration test in Stata compares the log likelihood of two different models. The first model is an unconstrained model that includes the cointegrating equations, while the other does not include these equations. If the log likelihood for the unconstrained model is significantly larger than for the constrained model, the null hypothesis of no cointegration is rejected. The testing procedure starts with the test of zero cointegrating variables. It then increases the number of equations and accepts the first null hypothesis that is not rejected (StataCorp 2004).

The test has a few limitations. All the series have to be complete. Also, when this test is run on many time-series, multicolinearity is a common problem. Therefore, a limited number of cities are tested. To ensure consistency, the same cities and goods are used for both types of cointegration tests.

5.3 Convergence versus cointegration

The methods may be viewed as complements, not substitutes. With decreasing transaction costs, prices may converge on their way from one long-term cointegrating relationship to another. In this case, no cointegration should be found as the difference between the two series, represented by the error term, has a negative trend. Also, if prices cointegrate, they have already reached their long term relationship and should not converge significantly. It is possible to get positive results on both tests if the prices converged, but not enough to break the long-term relationship.

6. Results

This section contains the results of the procedures described in section five. All econometric analysis is performed in Stata version 9.

6.1 Time-series characteristics

Often, much information can be obtained by simply studying the time series visually. Common trends and convergence tendencies can be observed with the naked eye, even if a more thorough analysis is needed to decide whether or not they are statistically significant.

15 reported commodities in 40 towns make 600 unique time-series. Many of these are incomplete, making them unsuitable for graphical comparison. Also, too many time series in one graph can simply be confusing and make common trends harder to spot. Therefore, a limited number of cities are used. For consistency, the same cities and commodities tested for cointegration are also used for the graphic presentation. The five chosen towns each represent one of the country's regions. When possible, the largest town in the region is selected; Christiania (East), Christiansand (South), Bergen (West), Trondheim (Middle) and Tromsø (North). In the cases where one or more of these towns do not have a complete series for the commodity, the town in question is substituted by one nearby, as described in table 11.

			Region				
Sample	**Good**	**Figure**	*East*	*South*	*West*	*Middle*	*North*
1832 - 1871	Oat	5	Christiania	Christiansand	Bergen	Trondheim	Tromsø
	Spirits	6	Christiania	Arendal	Bergen	Trondheim	Bodø
	Rye	7	Christiania	Christiansand	Bergen	Trondheim	Bodø
	Stockfish	8	Fredrikstad	Arendal	Bergen	Trondheim	Bodø
1832 - 1850	Oat	9	Christiania	Christiansand	Bergen	Trondheim	Bodø
	Spirits	10	Christiania	Christiansand	Bergen	Trondheim	Bodø
	Rye	11	Christiania	Christiansand	Bergen	Trondheim	Bodø
	Stockfish	12	Christiania	Arendal	Bergen	Trondheim	Bodø
1851 - 1871	Oat	13	Christiania	Christiansand	Bergen	Levanger	Tromsø
	Spirits	14	Christiania	Christiansand	Bergen	Levanger	Tromsø
	Rye	15	Christiania	Christiansand	Bergen	Trondheim	Tromsø
	Stockfish	16	Fredrikstad	Flekkefjord	Bergen	Levanger	Tromsø

Table 11: Towns selected for cointegration tests and graphic analysis

A more extensive graphical presentation is found in Appendix B. The appendix contains graphs of the prices of all the 15 commodities in up to 5 cities (one from each region if

eligible time-series are available) for each of the three samples. The conclusions drawn when studying these graphs are consistent with the findings in this section.

1832-1871

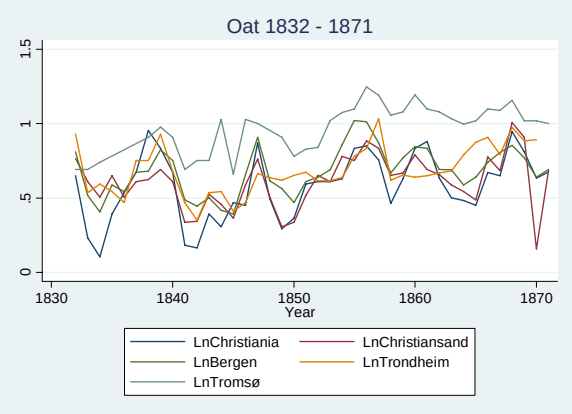

Figure 5: The price of oat 1832 – 1871

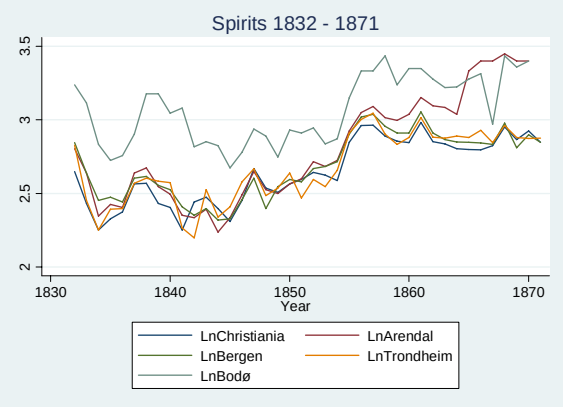

Figure 6: The price of spirits 1832 - 1871

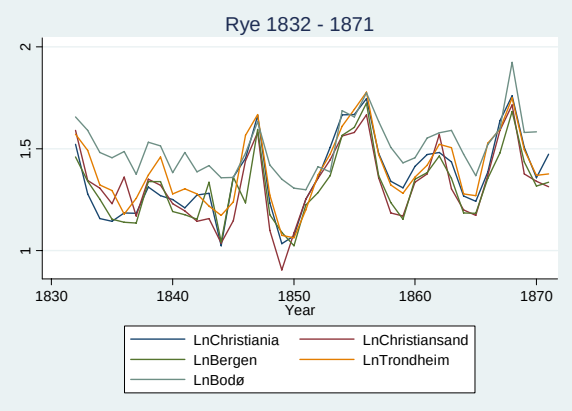

Figure 7: The price of rye 1832 – 1871

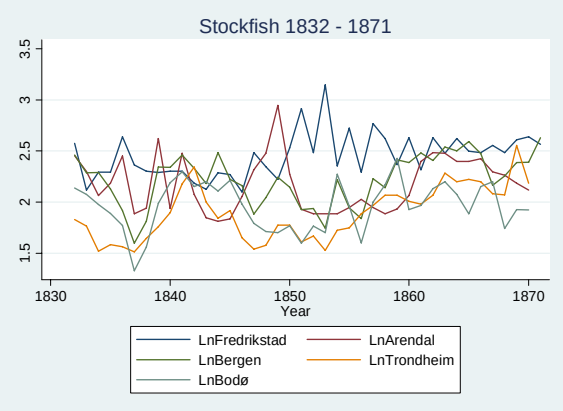

Figure 8: The price of stockfish 1832 - 1871

At first glance, the price series for oat, spirits and rye seem to share similar trends. Spikes and lows occur at the same time. It is harder to draw a conclusion for the series for stockfish. The covariation is especially remarkable for rye from the second half of the 1840s. Note also that the scale of this graph is lower than the scale of the other three commodities. The price differentials seem to be lower towards the end of the period for rye and stockfish.

The two grain sorts; rye and oat, have price spikes in the late 1840s and the late 1850s, followed by a low a few years later. This could be due to weather conditions, such as draught or a wet year. The price of spirits has the same tendency, but the fluctuations are smaller. As the spirits were made of grain it is natural that these series have similar variations.

1832-1850

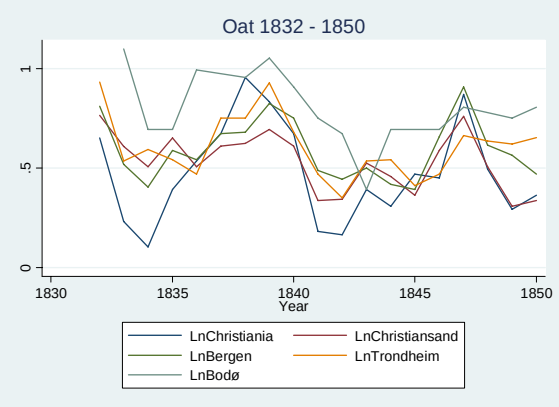

Figure 9: The price of oat 1832 – 1850

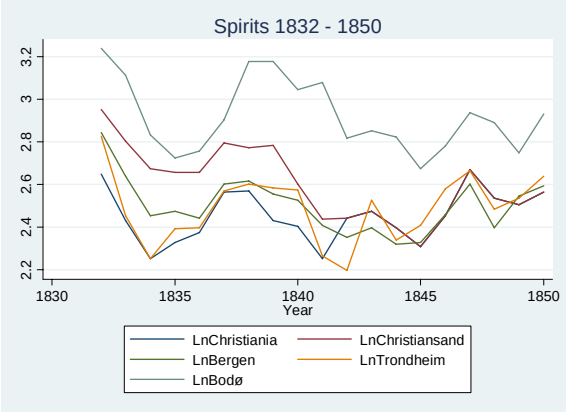

Figure 10: The price of spirits 1832 - 1850

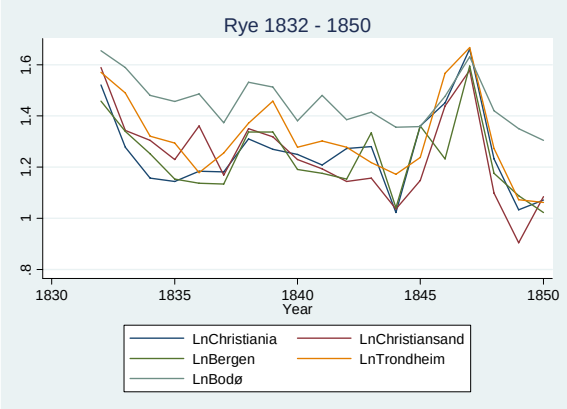

Figure 11: The price of rye 1832 – 1850

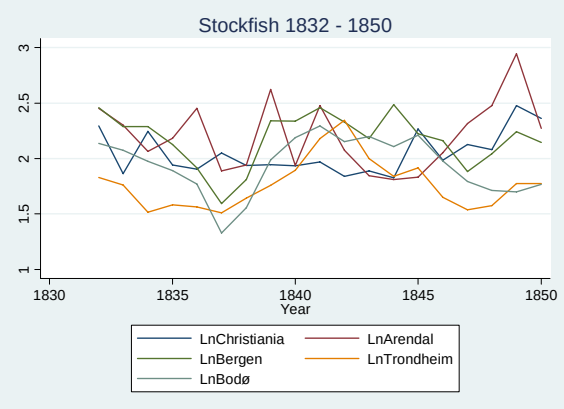

Figure 12: The price of stockfish 1832 - 1850

All of the series have a falling trend the first years. This is most likely due to the efforts to bring the currency to par silver value after the reforms in the first part of the century. Price deflation increased the purchasing power and the currency appreciated. The prices are quite volatile. The price spike in the late 1840s and the subsequent fall in the prices of oat, rye and spirits is even more striking in these graphs than in the ones illustrating the entire period.

The prices of rye and spirits apparently follow each other closely, with spikes and lows at the same time. The price of spirits is not surprisingly consequently higher in Bodø, the northernmost town. The price of rye is also mostly higher in Bodø than in the other cities. The variations in the price of stockfish seem more independent of each other. The price of oat is harder to classify, but the series of Christiania, Christiansand, Bergen and Trondheim appear to covariate quite closely. The price of oat in Bodø, on the other hand, seems to have similar trends as the other series at times, but lags behind at others.

1851 – 1871

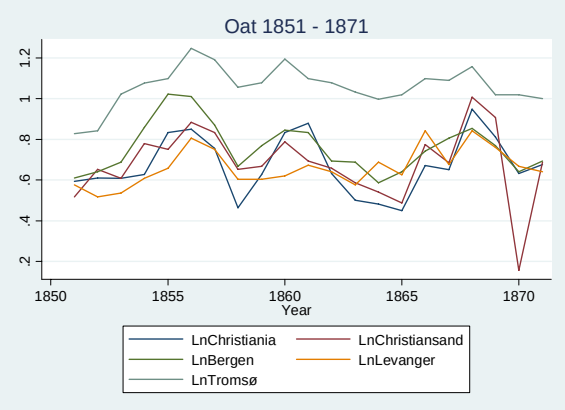

Figure 13: The price of oat 1851 – 1871

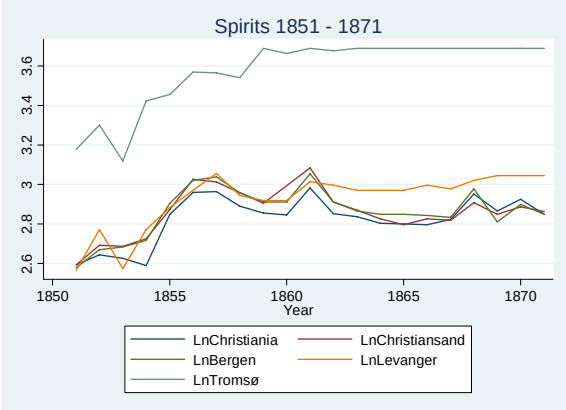

Figure 14: The price of spirits 1851 - 1871

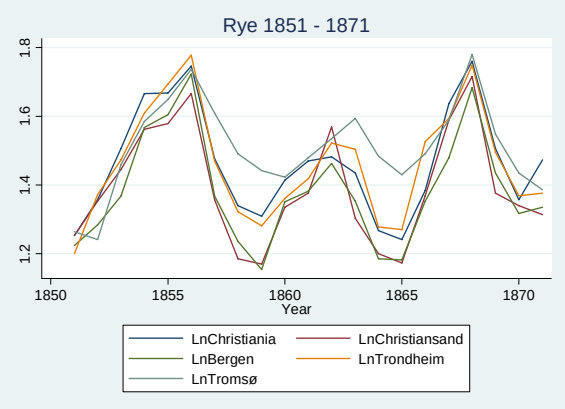

Figure 15: The price of rye 1851 – 1871

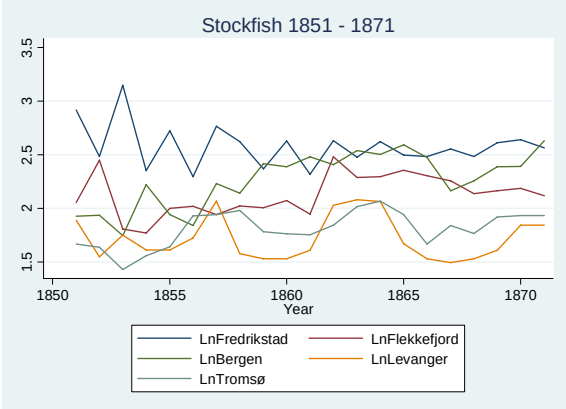

Figure 16: The price of stockfish 1851 - 1871

As in the earlier period, the prices of oat, spirits and rye have spikes and lows approximately at the same time. There are price spikes around 1857, in 1861/62 and again in 1867/68. The price of rye may appear to be much more volatile than the other prices, but the scale of the graph is much smaller. The prices of oat and spirits both increase and then stabilises. The prices of both these commodities are considerably higher in Tromsø than in the town further south.

Again, the price covariation is most remarkable for rye. The prices seem to diverge slightly between 1855 and 1865. Even if the time-series are slightly further apart in this period, they still move in the same rhythm. The prices of oat and spirits also appear to share similar trends, although the price level is much higher in Tromsø than in the other towns for both commodities. It is hard to draw a conclusion about the price of stockfish, but the price differential looks smaller towards the end of the period than in the beginning.

6.2 Convergence Regressions

The convergence regressions test whether or not the price level is significantly more equal at the end of a specific period than at the beginning.

6.2.1 Growth rates

As described in section 5.1, the convergence regressions are based on the following model:

$$(10) \qquad Growthrate_{city} = \alpha + \beta_{\text{int}\,egration} \cdot initialvalue_{city} + \varepsilon_{city}$$

where $Growthrate_{city}$ is an estimated linear time trend for the time period in question. An important potential problem with this method is that not all of the series display such a trend, i.e. the estimated growth rate is not significantly different from 0. This is most problematic for the series covering the entire period (1832 – 1871). While many of the series show a trend in the shorter time periods (sample 2 and 3), the long term trend is more ambiguous. There is a turning point in many of the series around 1850, as the prices go from falling to increasing or stagnating. This is naturally an issue when trying to estimate linear trends. Despite these potential problems, the growth rate is used in the convergence regressions, as it is the best alternative. First-to last year growth certainly would not represent the trends better, and several tries with non-linear trend have failed. However, the fact that the significance of the growth rates in many cases is low should be kept in mind, especially when analysing the entire period.

Figures 17 - 19 show three examples of growth rate regression fits, one from each sample.

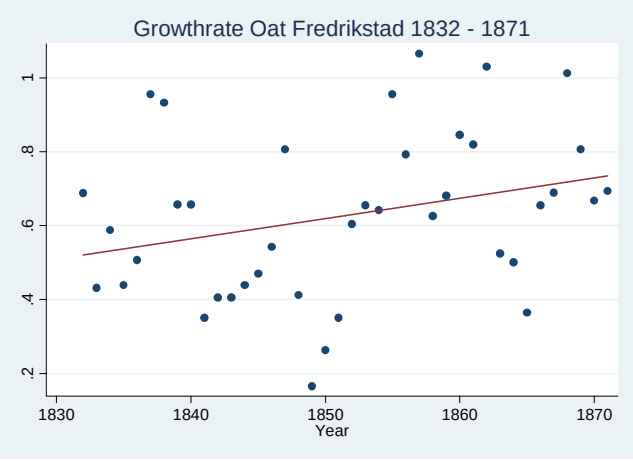

Figure 17: Regression fit for the growth rate of oat in Fredrikstad 1832 – 1871

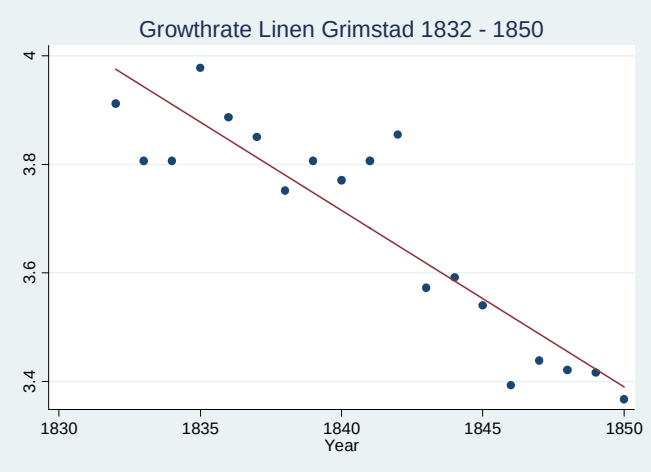

Figure 18: Regression fit for the growth rate of linen in Grimstad 1832 - 1850

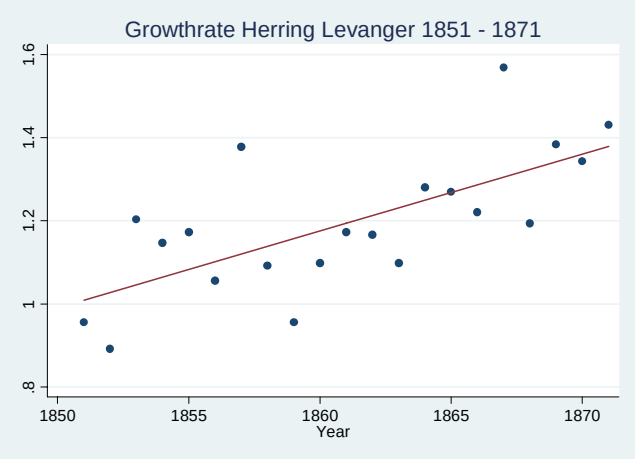

Figure 19: Regression fit for the growth rate of herring in Levanger 1851 - 1871

The growth rate coefficient is significant and the fits are quite good for the prices of linen in Grimstad 1832-1850 and herring in Levanger 1851-1871. However, when the whole period is considered the growth rate is not significant and the fit is bad for the price of oat in Fredrikstad 1832-1871. The significance of the growth rates varies considerably from commodity to commodity, but in general these results are quite representative for the entire dataset.

6.2.2 Regression results

The results of the convergence regressions are summarised in table 12. The reported value is the regression coefficient $\beta_{\text{int}egration}$. The number in parenthesis below is the t-statistic of each coefficient. The t-statistics have been compared to a table of critical values, and significant coefficients are labelled.

	Growth rate 1832-1871	Growth rate 1832-1850	Growth rate 1851-1871
Barley	-0.0138***	-0.0294***	-0.0216**
	(-5.38)	(-3.22)	(-2.32)
Peas	-0.0115***	-0.0169**	0.0027
	(-3.37)	(-2.48)	-0.22
Hemp	-0.0089	-0.0401***	-0.0799*
	(-1.35)	(-4.71)	(-2.06)
Oat	-0.0016	-0.0196**	-0.0247***
	(-0.36)	(-2.28)	(-3.14)
Wheat	-0.0168***	-0.0368***	-0.0109
	(-3.73)	(-3.99)	(-0.69)
Iron	-0.0131***	-0.0343***	-0.0072
	(-5.04)	(-3.72)	(-0.64)
Spirits	-0.0092**	-0.0087	-0.0072
	(-2.17)	(-1.03)	(-1.2)
Linen	0.0024	-0.0082	-0.0394
	(-0.13)	(-0.48)	(-1.72)
Potatoes	-0.0160***	-0.0176	-0.0186***
	(-4.37)	(-1.68)	(-3.97)
Rye	-0.0134***	-0.0135	-0.0075
	(-3.29)	(-1.04)	(-0.68)
Salt	-0.0078***	-0.0389***	-0.0169**
	(-2.87)	(-4.16)	(-2.17)
Herring	-0.0249***	-0.0236*	-0.0193**
	(-6.6)	(-1.84)	(-2.41)
Tar	-0.0135***	-0.0368***	-0.0254
	(-3.73)	(-4.09)	(-1.72)
Stockfish	-0.0074	-0.0236**	-0.0229**
	(-1.07)	(-2.32)	(-2.64)
Wool			-0.0277*
			(-1.88)

Table 12: Results of the convergence regressions.

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

The estimated regression coefficient for **barley** and **salt** is negative and significant for all the three samples. The growth rate is significantly lower in towns with high initial prices, implying convergence. **Herring** has significantly negative regression coefficients at a five percent level for samples 1832 – 1871 and 1851 – 1871 and at a ten percent level for the third sample.

The results for **wheat, iron** and **tar** are very similar. The coefficients are all negative, but only significant for two of the three samples, 1832 – 1871 and 1832 – 1850. Likewise, the regression coefficient for **peas** is negative and significant for the samples 1832 – 1871 and 1832 – 1850. However, it is positive and not significant for the period 1851-1871. The price of **hemp** significantly converged 1832-1850. The regression coefficients for **oat** and **stockfish** are negative and significant for the two sub periods (1832 – 1850 and 1851 – 1871). The coefficients for the entire period are also negative, but not significant.

Convergence is also found for **spirits** and **rye** 1832 – 1871. The two sub periods also have negative coefficients, but they are not significant. As the only of the 15 commodities, the price of **linen** does not convergence significantly in any of the samples. The coefficient for 1832 **–** 1871 is positive, and the two other coefficients are negative. $\beta_{\text{int}egration}$ is negative and significant at a five percent significance level for **potatoes** for the two samples 1832-1871 and 1851-71. The coefficient for the 1851 - 1871 sample is also negative, but not significant. Last, but not least, **wool** has a negative $\beta_{\text{int}egration}$, significant at a ten percent level for the period 1851 – 1871[12].

With only two exceptions, all of the estimated coefficients are negative, implying convergence in prices. The two positive coefficients are not significant; in fact they have the lowest t-statistics of the entire set.

The magnitude of the coefficients that are significantly different from zero at a five percent significance level vary from -0,0078 (Salt, 1832 – 1871) to -0,0401 (Hemp, 1832 – 1850). The regression coefficient $\beta_{\text{int}egration}$ shows the change in the growth rate of prices when the initial value increases by one percent. In other words, if one town had a one percent higher initial price of salt than another, the growth rate of the price would be 0,0078 percent lower for the period 1832 – 1871. Likewise, the growth rate of hemp prices 1832 – 1850 would be 0,0401 percent lower in a town with a one percent higher initial price. The meaning of the other coefficients is similar.

[12] 1851 - 1871 is the only period there was enough consistent time series to run convergence regressions for wool. There are too many missing observations in the early period. Most remarkably, there are no price observations for wool in any cities between 1842 and 1847.

The fact that all the coefficients except two are negative supports the assumption of commodity price integration. 25 of the 43 estimated coefficients are significantly different from zero, and all of these are negative. A relatively lower growth rate in towns with higher initial price level implies that the prices have become relatively more equal, they have converged.

6.2.3 Graphical presentation of the convergence regressions

To illustrate the results from table 12, two regression fits from each of the three samples are graphed in this section. Of these two graphs, one is for a commodity with a significant coefficient for $\beta_{\text{int}egration}$, and the other is for a commodity that does not show significant signs of convergence. Regression fits for all the 43 convergence regressions are available in Appendix C.

1832 - 1871

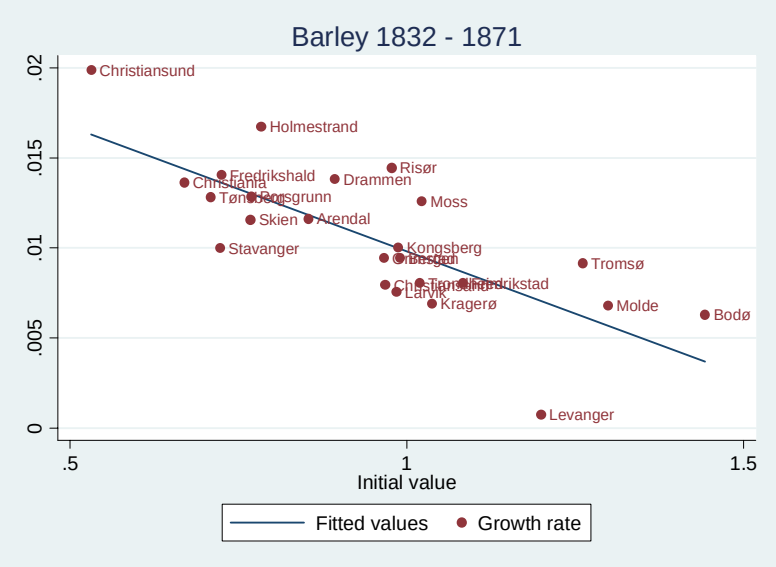

Figure 20: Convergence regression fit barley 1832 - 1871

The estimated coefficient for barley 1832 – 1871 is negative (-0,0138) and significant, even at a one percent significance level. The fit is quite good. There are two clusters, but the observations are pretty equally distributed on both sides of the regression line. The only outlier is Levanger.

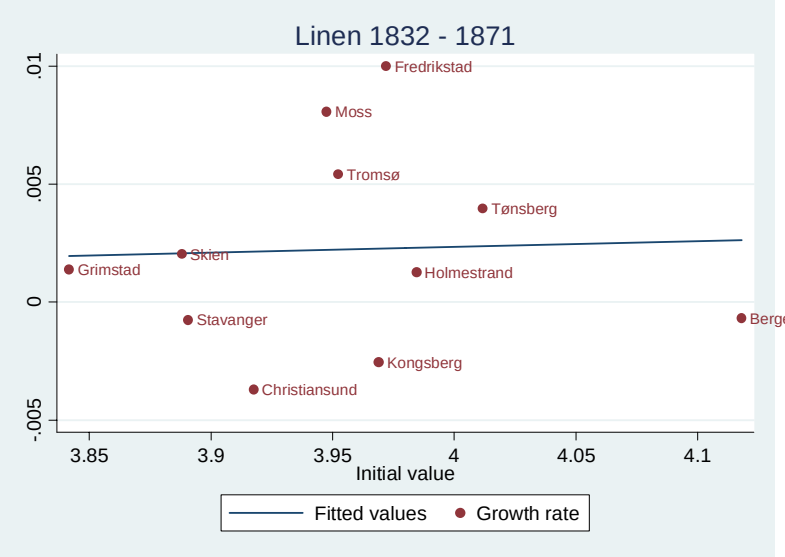

Figure 21: Convergence regression fit linen 1832 – 1871

The regression fit for the convergence regression for the price of linen 1832 – 1871 shows no trend at all, and very scattered observations. This is consistent with a very low, not significant positive coefficient (0,0024). The number of towns included is also much lower than for barley, as there were many inconsistent time-series.

1832 - 1850

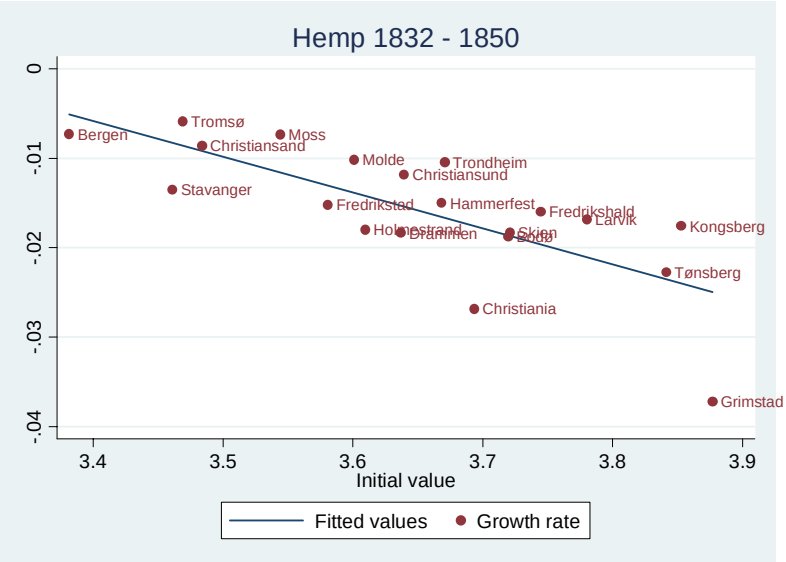

Figure 22: Convergence regression fit hemp 1832 – 1850

$\beta_{\text{int}egration}$ for hemp 1832 – 1850 is negative (-0,0401) and significant at a 1% significance level. The regression fit is very good, and Grimstad is the only extreme observation.

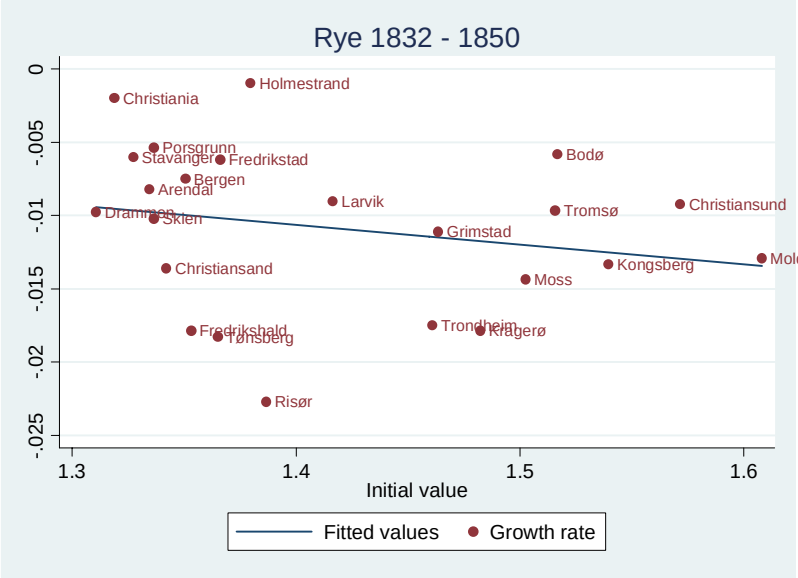

Figure 23: Convergence regression fit rye 1832 - 1850

There was no significant convergence in the price of rye 1832 – 1850. The coefficient is negative (-0,0135), but the observations are very scattered, especially those with low initial value.

1851 - 1871

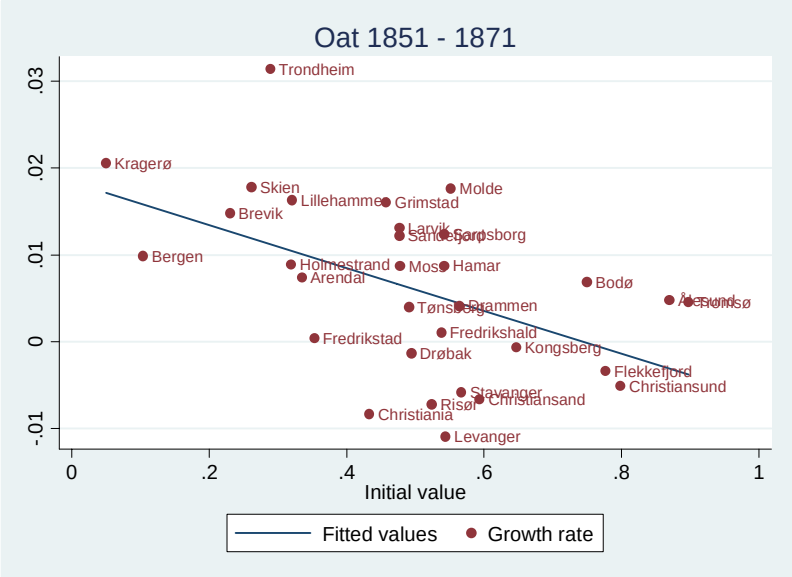

Figure 24: Convergence regression fit oat 1851 – 1871

The regression coefficient for oat 1851 – 1871 is negative (-0,0247) and significant, implying price integration. Although there is a cluster of towns with initial value between 0,4 and 0,6, they are pretty equally distributed on both sides of the regression line. The most notable outlier is Trondheim.

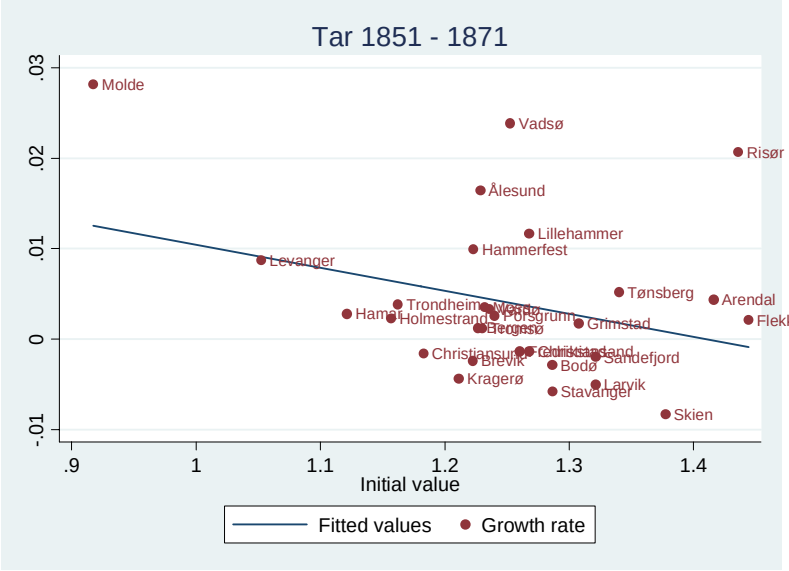

Figure 25: Convergence regression fit tar 1851 – 1871

The regression fit of tar 1851 – 1871 show a large cluster below the regression line, and quite a few outliers above the line (e.g. Vadsø, Molde, Risør), making this a bad fit. The majority of the observations are below the regression line. The estimated coefficient is negative (-0,0254), but not significant.

6.3 Cointegration testing

As described in section 5.2 and table 11, one town from each of Norway's five regions was selected for cointegration tests. The same set of cities is used in both types of tests.

6.3.1 Results of two-step Engle-Granger tests

The tables in this section report the test statistics obtained by running a Dickey-Fuller test on the residuals of equation (14) for each of the ten city-pairs. This test-statistics has been compared to the critical values computed by Davidson and MacKinnon (Table 1). Significant relationships are marked. If the null hypothesis is rejected the error term is stationary, which implies cointegration.

1832-1871

Oat 1832 -1871

	North	Middle	West	South	East
East	-5.740***	-3.664**	-4.046***	-4.026***	-------
South	-5.833***	-3.417**	-6.126***	-------	-------
West	-5.147***	-3.053*	-------	-------	-------
Middle	-4.192***	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 13: Cointegration tests, oat 1832-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

The null hypothesis is rejected at a five percent significance level for nine of the city pairs, implying that the prices of oat cointegrate in the period. Seven of these relationships are even statistically significant at a one percent level. The last relation, the city pair Middle–West, is significant at a ten percent level. This is indication of strong cointegration.

Spirits 1832 -1871

	North	Middle	West	South	East
East	-3.156*	-5.248***	-3.106*	-2.540	-------
South	-2.794	-2.551	-1.602	-------	-------
West	-3.301*	-3.464*	-------	-------	-------
Middle	-3.674**	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 14: Cointegration tests, spirits 1832-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

The city pairs Middle-East and North-Middle cointegrate, as the null hypothesis is rejected at a five percent significance level. In the case of Middle-East, the null hypothesis is rejected at a one percent significance level. Four other city pairs are significant at a ten percent level. None of the pairs that include Arendal from the southern region cointegrate. This is most likely due to the substantial increase prices in Arendal from around 1860, as seen in figure 6. The time series of the other towns do not exhibit a similar trend.

Rye 1832 -1871

	North	Middle	West	South	East
East	-4.020***	-5.16***	-5.335***	-3.764**	-------
South	-4.603***	-6.223***	-7.700***	-------	-------
West	-7.418***	-12.151***	-------	-------	-------
Middle	-4.553***	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 15: Cointegration tests, rye 1832-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

Nine of the city pairs have significantly cointegrating prices at a one percent significance level, and the last relationship (South-East) is significant at a five percent level, thus the null hypothesis of non-stationary error term is rejected at a five percent significance level for all ten possible city pairs. The prices of rye definitely cointegrate. This confirms the impression from the graphical analysis, where rye was the most striking case.

Stockfish 1832 -1871

	North	Middle	West	South	East
East	-1.819	-1.926	-1.803	-1.851	-------
South	-4.225***	-4.243***	-4.176***	-------	-------
West	-3.729**	-4.545***	-------	-------	-------
Middle	-2.427	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 16: Cointegration tests, stockfish 1832-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

The null hypothesis of no cointegration is rejected for five of the city pairs at a five percent significance level (four of these relations are significant even at a one percent level), one at ten percent. None of the city pairs involving Fredrikstad in the eastern part of the country show significant cointegration. This is probably due to the anomalous movements of the price of stockfish in Fredrikstad in the period around 1850-1860. While there is a falling trend in the price series of the other towns, the price in Fredrikstad increases, and is relatively high up to around 1860, as shown in figure 8.

1832-1850

Oat 1832 -1850

	North	Middle	West	South	East
East	-2.691	-2.882	-3.070*	-2.132	-------
South	-2.153	-2.101	-1.692	-------	-------
West	-1.692	-2.756	-------	-------	-------
Middle	-2.742	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 17: Cointegration tests, oat 1832-1850

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

When the time period is limited to 1832 – 1850, none of the price relationships for oat cointegrate at a 5% significance level. The city pair West-East has a significantly cointegrating relationship at a ten percent level. The very low number of cointegrating relationships is quite surprising, since the result was the opposite when the entire period was considered.

Spirits 1832-1850

	North	Middle	West	South	East
East	-2.659	-3.432**	-2.174	-2.16	-------
South	-1.880	-1.342	-1.789	-------	-------
West	-3.134*	-2.256	-------	-------	-------
Middle	-3.169*	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 18: Cointegration tests, spirits 1832-1850

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

Only one of the city pairs have significantly cointegrating prices; East-Middle. Two more pairs; West-North and Middle-North, have a significant relationship when the level is ten percent. As the price levels appear to be more similar at the end of the period then in the beginning, it is not unexpected that only a few of the city pairs cointegrate, as the error term has a negative trend.

Rye 1832-1850

	North	Middle	West	South	East
East	-2.972	-4.984***	-3.332*	-2.607	-------
South	-3.971***	-4.583***	-4.731***	-------	-------
West	-7.318***	-11.543***	-------	-------	-------
Middle	-3.365**	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 19: Cointegration tests, rye 1832-1850

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

Seven of the city pairs cointegrate at a five percent significance level. Six of these pairs have significant relationships even at a one percent level. One additional pair is significant at a ten percent level (East-West). The high number of cointegrating relationships is consistent with the impression from the graphic analysis.

Stockfish 1832-1850

	North	Middle	West	South	East
East	-2.849	-2.629	-2.290	-3.720**	-------
South	-3.937***	-3.733**	-3.393**	-------	-------
West	-4.162***	-3.210*	-------	-------	-------
Middle	-2.245	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 20: Cointegration tests, stockfish 1832-1850

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

For stockfish, five of the city pairs cointegrate at a five percent level. Two of these five relationships are significant at a one percent level. One is significant at a ten percent

significance level, but not at a higher. This is approximately the same result as when the whole period was considered.

1851-1871

Oat 1851-1871

	North	Middle	West	South	East
East	-2.905	-2.373	-2.811	3.237*	-------
South	-5.137***	-4.164***	-5.560***	-------	-------
West	-2.282	-2.216	-------	-------	-------
Middle	-3.059*	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 21: Cointegration tests, oat 1851-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

The prices of oat cointegrate at a five percent significance level for the following three city pairs: South-North, South-Middle and South-West. Additionally two pairs cointegrate at a ten percent level (East-South and North-Middle).

Spirits 1851-1871

	North	Middle	West	South	East
East	-3.192*	-3.348**	-2.053	-2.477	-------
South	-2.718	-2.555	-4.776***	-------	-------
West	-2.713	-2.878	-------	-------	-------
Middle	-2.926	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 22: Cointegration tests, spirits 1851-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

The city pair West-South has a significantly cointegrating relationship at a one percent significance level. The null hypothesis is rejected at a five percent level for the city pair Middle-East and at a ten percent level when the two cities in question are from the northern and the eastern region.

Rye 1851-1871

	North	Middle	West	South	East
East	-1.949	-3.464**	-4.745***	-4.257***	-------
South	-2.552	-4.425***	4.062***	-------	-------
West	-2.437	-4.232***	-------	-------	-------
Middle	-2.624	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 23: Cointegration tests, rye 1851-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

Six of the city pairs significantly cointegrate at a five percent significance level, five of these at a one percent level. All of the remaining four relationships include Tromsø. These combinations do not cointegrate. Figure 15 reveals that the time series for prices in Tromsø follow the others closely in the beginning and the end of the period. Between 1857 and 1867, there are two price falls and one spike in the price series. Although the prices in Tromsø follow the general tendencies, both price falls are considerably lighter in the northernmost city, so the overall price level is higher. Also, the price spike in this ten year period is a year later in time in Tromsø than in the other four cities. Therefore, the null hypothesis is not rejected when testing the city pairs that include Tromsø.

Stockfish 1851-1871

	North	Middle	West	South	East
East	-4.644***	-4.614***	-4.522***	-4.813***	-------
South	-3.151*	-3.128*	-3.480**	-------	-------
West	-2.838	-2.038	-------	-------	-------
Middle	-3.532**	-------	-------	-------	-------
North	-------	-------	-------	-------	-------

Table 24: Cointegration tests, stockfish 1851-1871

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

Four of the city pairs cointegrate at a one percent significance level, and two more pairs at a five percent level. There are two more relationships that are significant at a ten percent level only. All the city pairs involving Fredrikstad in the eastern region show cointegration.

6.3.2 Results of Johansen cointegration tests

Stata returns only the number of cointegrating equations in a system; it does not specify which ones of the relationships cointegrate. The test requires series without gaps. In three cases, no eligible series were available for a region, and the region was therefore removed from the test. The significance level used is five percent.

1832-1871

Commodity	Maximum rank	Towns
Oat	2	4[13]
Spirits	0	5
Rye	3	5
Stockfish	1	5

Table 25: Cointegrating relations found in VEC-rank-testing 1832 – 1871.

[13] No eligible series available for the northern region

The VEC-rank test indicate two cointegrating equations for oat, none for spirits, three for rye and 1 for stockfish in the period 1832 – 1871. These results are consistent with the results from the two-step Engle-Granger tests. The price of rye has the highest number of cointegrating relationships, and the price of spirits have little or no covariation.

1832 - 1850		
Commodity	Maximum rank	Towns
Oat	2	4[14]
Spirits	***[15]	5
Rye	2	5
Stockfish	3	5

Table 26: Cointegrating relations found in VEC-rank-testing 1832 – 1850

When the first sub sample is considered separately, two cointegrating equations are found for oat, two for rye and three for stockfish. The test is inconclusive for spirits. The results for the 1832 – 1850 period are a bit more ambiguous. As for oat, the Engle-Granger test shows no significant cointegrating relationships at a five percent significance level, while the Johansen test indicates two cointegrating equations. Also, the two-step test implies that the cointegration is stronger for rye, while the result of Stata routine is that stockfish has the highest number of cointegrating relations.

1851-1871		
Commodity	Maximum rank	Towns
Oat	2	5
Spirits	1	4[16]
Rye	2	5
Stockfish	3	5

Table 27: Cointegrating relations found in VEC-rank-testing 1851 – 1871

The number of cointegrating relations for the price of oat 1851-1871 is two. For spirits there is only one cointegrating equation, while there are two for rye and three for stockfish. These results are quite consistent with the Engle-Granger tests, in which the price of spirits had the lowest number of cointegrating relationships, followed by the price of oat. The price of rye and the price of stockfish had the highest number of significant relationships in the Engle-Granger tests.

[14] No eligible series for the northern region

[15] Test is inconclusive

[16] No eligible series available for the southern region

6.4 Summary

As suggested in section 5.3, convergence can be viewed as a transition from one cointegrating equilibrium to another. Such a movement can be caused by a reduction in transaction costs. It is also likely that the price of more frequently traded goods will equalise at a quicker pace then the price of typical local commodities.

The negative signs convergence regressions show that the level of the prices has become more equal for almost all of the commodities. For 25 of the 43 convergence regressions the coefficient is significant.

	Growth rate 1832 - 1871	Growth rate 1832 - 1850	Growth rate 1851 - 1871
Oat	-0.0016	-0.0196**	-0.0247***
	(-0.36)	(-2.28)	(-3.14)
Spirits	-0.0092**	-0.0087	-0.0072
	(-2.17)	(-1.03)	(-1.2)
Rye	-0.0134***	-0.0135	-0.0075
	(-3.29)	(-1.04)	(-0.68)
Stockfish	-0.0074	-0.0236**	-0.0229**
	(-1.07)	(-2.32)	(-2.64)

Table 28: Results of convergence regressions, oat, spirits, rye and stockfish

*Note: * Significant at a 10% level ** Significant at a 5% level ***Significant at a 1% level*

The regression coefficients are all negative for the commodities tested for cointegration. Half of these coefficients are significant at a five percent significance level or higher. The results are somewhat inconsistent. Oat and stockfish have significant price convergence in both sub samples, but not when the entire period is analysed. The exact opposite is the case for the prices of spirits and rye. Only the period 1832 – 1871 show significant convergence in prices. However, the results for the entire period are less reliable due to the low significance of the growth rates.

The results for the two cointegration tests are summarised in table 29 below. The cointegration tests at least partially support the theory that the price adjustment mechanism was stronger for the more frequently traded goods then for the typical local ones. The price of rye shows significant cointegration for all of the samples. The prices of stockfish also appear to cointegrate, although the result Johansen test for the entire period (1832 - 1871) is a bit conflicting. The two remaining goods were classified as local goods. There is no significant cointegration for the price of spirits in any of the periods. The prices of oat do

cointegrate when the entire period is considered, but not when the two shorter samples are analysed. This is puzzling, but one explanation may be that extreme values are given more weight when the period is shorter.

	Commodity	**Johansen** Maximum rank/Towns	**Dickey-Fuller** Number of significant relationships/city pairs
1832-1871	Oat	2/4	9/10
	Spirits	0/5	2/10
	Rye	3/5	10/10
	Stockfish	1/5	5/10
1832 - 1850	Oat	2/4	0/10
	Spirits	***/5	1/10
	Rye	2/5	7/10
	Stockfish	3/5	5/10
1851-1871	Oat	2/5	3/10
	Spirits	1/4	2/10
	Rye	2/5	6/10
	Stockfish	3/5	6/10

Table 29: Summary of the results of the cointegration tests.

The results give limited support to the notion of convergence on the way to cointegration. The prices of rye significantly cointegrate for all three samples, but the convergence regression coefficient is significant for the whole period. However, the estimated growth rates for the price of rye are most likely unreliable, as the prices are very volatile. The prices do not significantly converge for the two sub samples. The results of the convergence regressions are similar for the price of spirits. On the other hand, the prices of spirits do not appear to cointegrate. The results of the convergence regressions for oat and stockfish are also similar. Both sub samples show significant convergence, but the entire period does not. The results of the cointegration tests are quite different for the two commodities.

It is important to keep in mind that the convergence regressions involve a significantly larger number of time series then the cointegration tests. All eligible time series are used for the regressions, while the cointegration tests are preformed on a limited number of towns.

7. Conclusions

The convergence regressions show that there was price integration in the Norwegian commodity markets in the 19th century. All except two of the convergence regression coefficients are negative, implying that the price growth rate is lower in towns with high initial prices. This supports the theory that the price differentials were diminished as transaction costs were reduced. The prices of barley and salt show significant convergence for all three samples. These two commodities are both classified as traded goods. Linen is the only good that does not show significant convergence for any of the three samples.

Of the two subsets, the first period (1832 – 1850) has the highest number of significant convergence regression coefficients, implying that the convergence was strongest in the first part of the period. The results for the entire period (1832 – 1871) imply even stronger convergence. However, these results may be less reliable then the others, as many of the estimated growth rates for this period are not significant.

Cointegration tests reveal that there was a fixed relationship between the prices in different locations. Of the four commodities tested for cointegration, the prices of rye and stockfish show strong signs of cointegration for all three of the samples. These two commodities were classified as traded goods. The other two commodities were typical local goods. The results for these goods are more conflicting. This supports the assumption that there was a stronger relationship between the prices of goods that were more frequently traded then others. There is a tendency towards stronger cointegration in the last part of the period, implying integration in the commodity markets.

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Appendix A - Maps

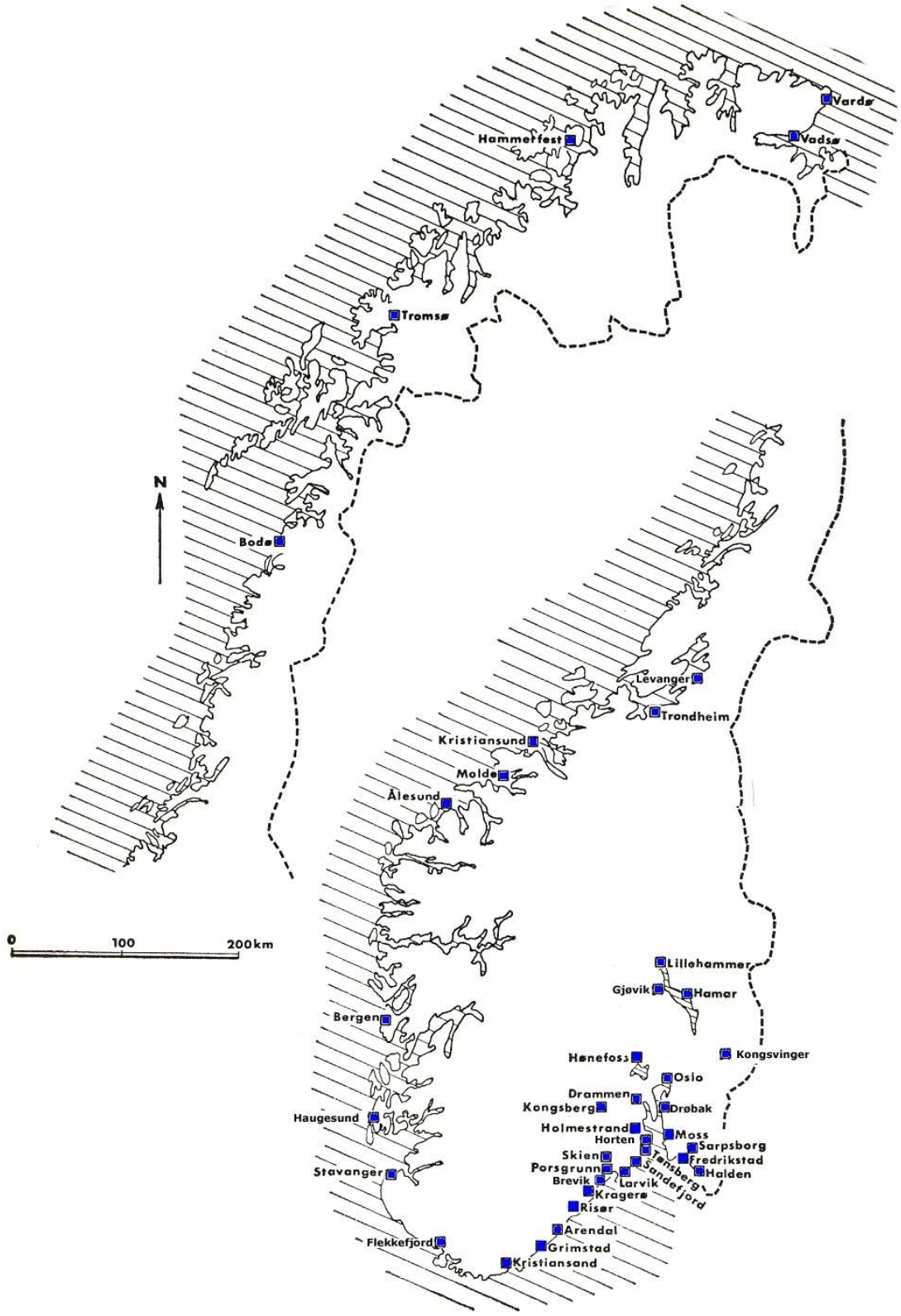


Figure A-1: Map over Norway, with the 40 towns included in the dataset marked.

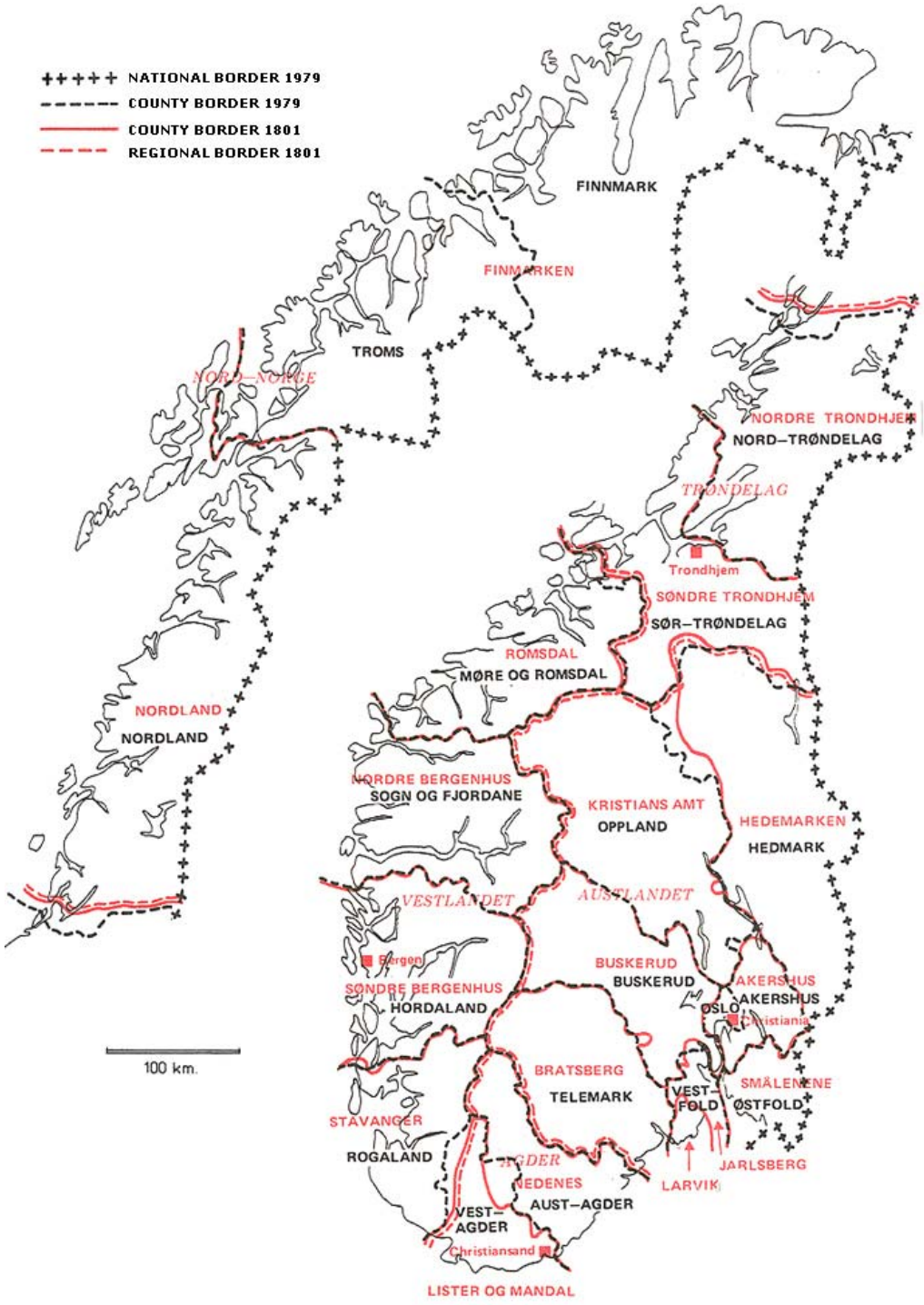


Figure A-2: Map of the Norwegian administrative divisions. The map is made by Jørgen H. Marthinsen of the National Archival Services of Norway, available at http://digitalarkivet.uib.no/norkart/. Modifications: The original Norwegian legend is replaced by an English legend.

Appendix B – Graphical presentation of time series

The two cities with most consistent time-series for the full period are Skien and Fredrikstad. Only these two cities have full series for all commodities, except wool. Other series have gaps for one or more commodities. Therefore, these two cities are chosen for graphs describing the entire period. Fredrikstad and Skien are both in the Eastern part of the country, and on approximately the same degree of latitude. They are, however, divided by a fjord; Oslofjorden. While Fredrikstad was an active seaport town during the 19th century, Skien had been made less available for merchant ships by changes in ship technology and land development. Several smaller port towns had grown nearby Skien though (e.g. Porsgrunn and Brevik), making goods transported by sea easily available. As these two cities are quite close, a stronger correlation is to be expected between the prices in these two cities then in cities in different parts of the country.

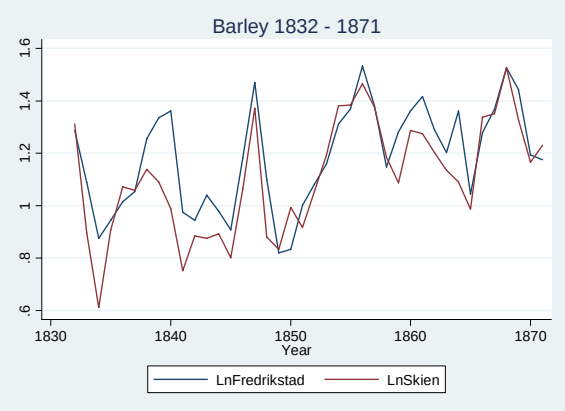
When analysing the two sub-samples, however, there are many more cities with complete series. When possible, one town from each region has been selected for graphs representing a sub-sample. These have been chosen because there is a consistent time-series available for as many of the commodities as possible. When these cities don't have a complete series, a nearby town is selected. In some cases, no towns in the region have a full time-series. If no suitable series is found (i.e. with enough observations), the region is dropped.

	Region				
Sample	East	South	West	Middle	North
1832 - 1871	Fredrikstad Skien				
1832 - 1850	Tønsberg	Grimstad[1] Christiansand[2]	Stavanger[3] Bergen[4]	Trondheim	Bodø[5]
1851 - 1871	Lillehammer	Flekkefjord[6] Christiansand[7] Arendal[8]	Bergen	Levanger[9]	Tromsø[10]

1: All commodities except wheat
2: Wheat
3: All commodities except stockfish
4: Stockfish
5: No series eligible for wheat
6: All commodities except tar, spirits and wool
7: Tar and spirits
8: Wool
9: No series eligible for hemp, wheat and linen
10: No series eligible for wheat

Table B-1: Time series graphed in Appendix B

1832 – 1871


Barley 1832 - 1871
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1.2
1.4
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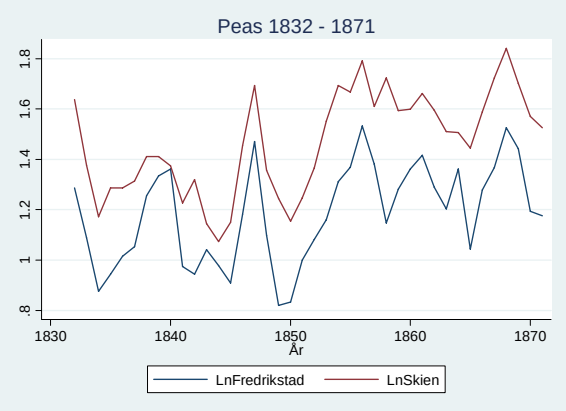
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien


Peas 1832 - 1871
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1
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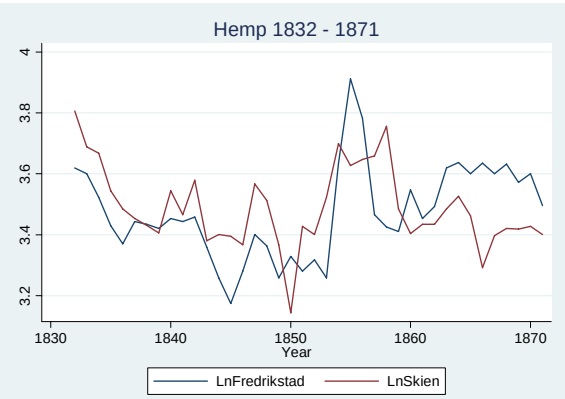
1.6
1.8
1830
1840
1850
1860
1870
År
LnFredrikstad
LnSkien


Hemp 1832 - 1871
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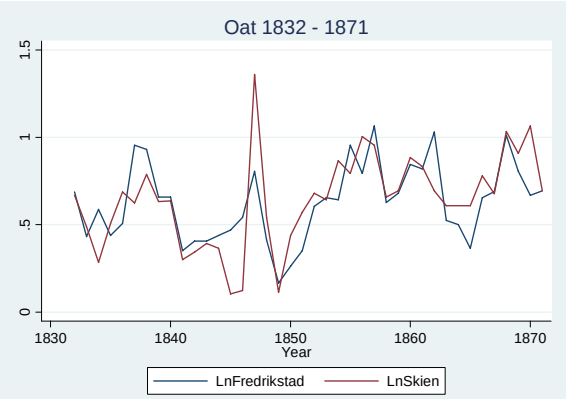
3.6
3.8
4
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien


Oat 1832 - 1871
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1
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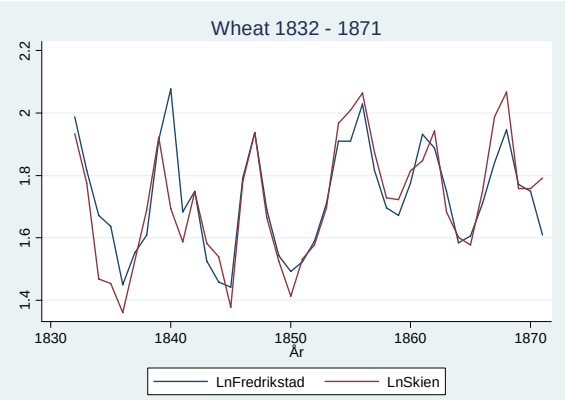
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien


Wheat 1832 - 1871
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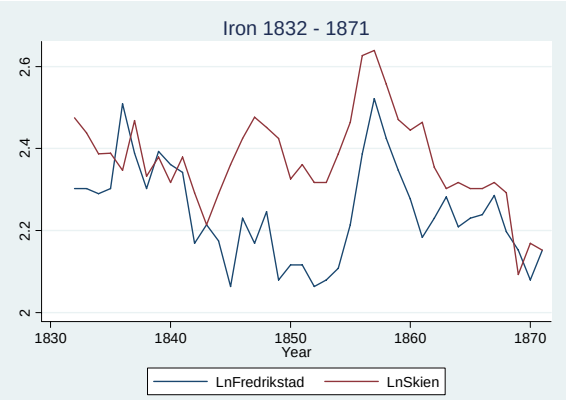
1.6
1.8
2
2.2
1830
1840
1850
1860
1870
År
LnFredrikstad
LnSkien


Iron 1832 - 1871
2
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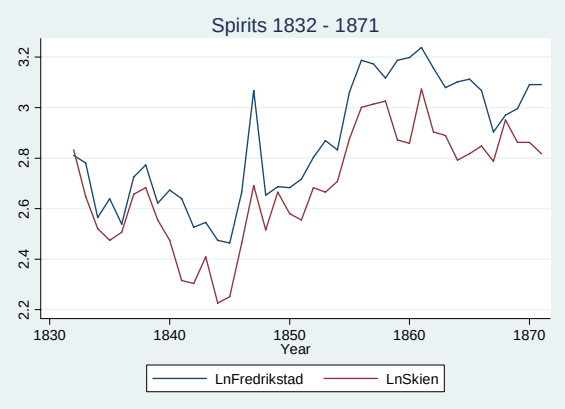
2.6
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien


Spirits 1832 - 1871
2.2
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2.8
3
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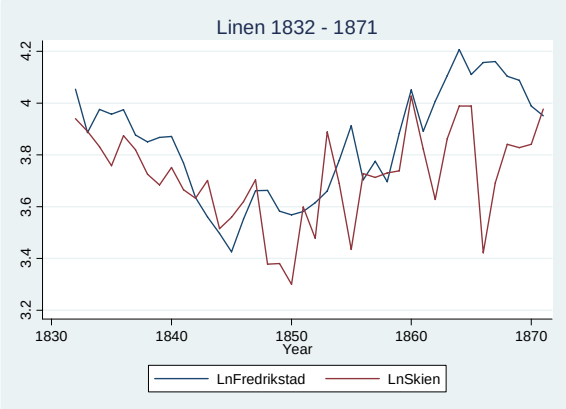
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien


Linen 1832 - 1871
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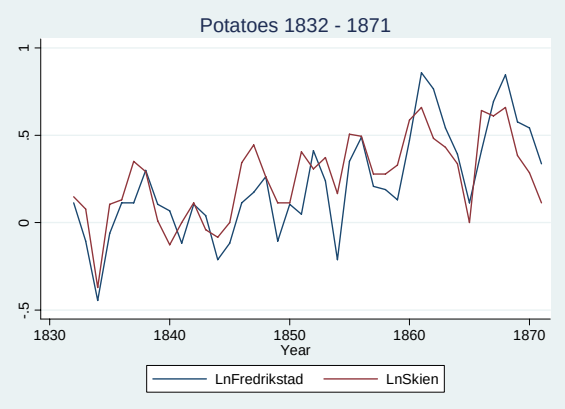
1860
1870
Year
LnFredrikstad
LnSkien


Potatoes 1832 - 1871
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1840
1850
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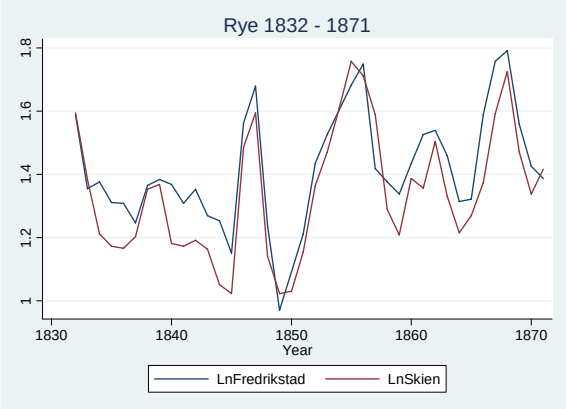
1870
Year
LnFredrikstad
LnSkien


Rye 1832 - 1871
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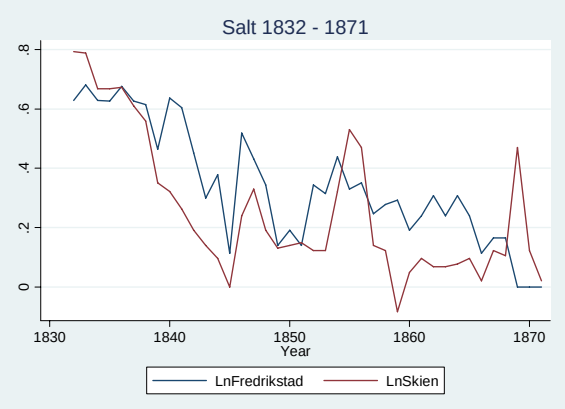
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien


Salt 1832 - 1871
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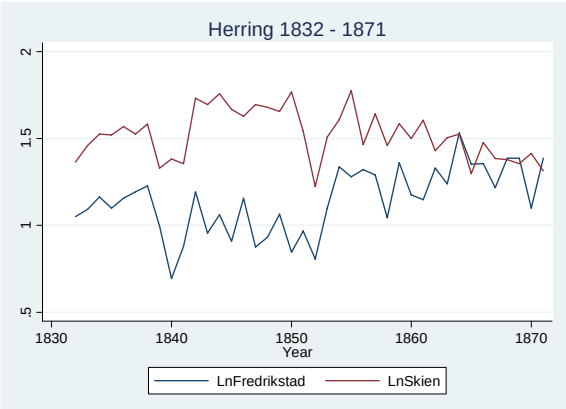
.8
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien


Herring 1832 - 1871
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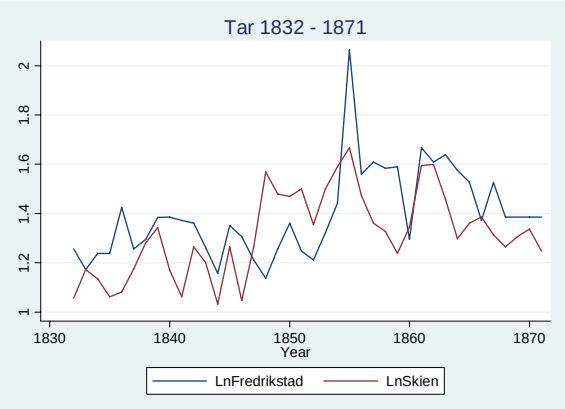
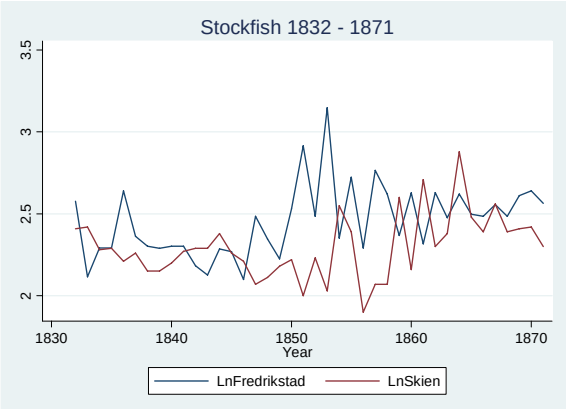
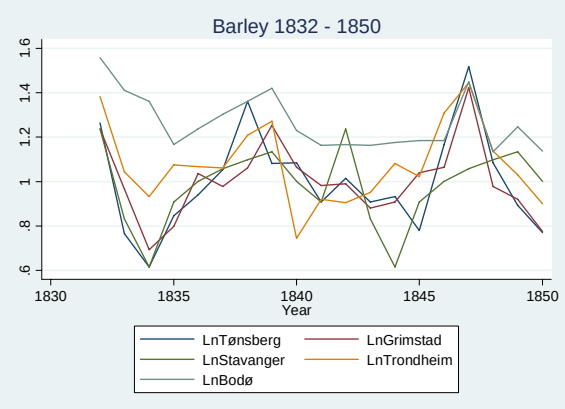
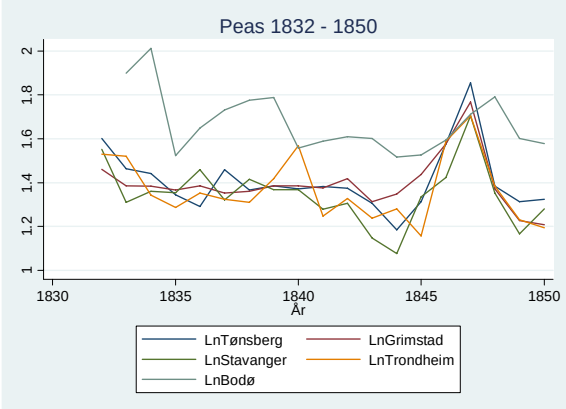
1.5
2
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien

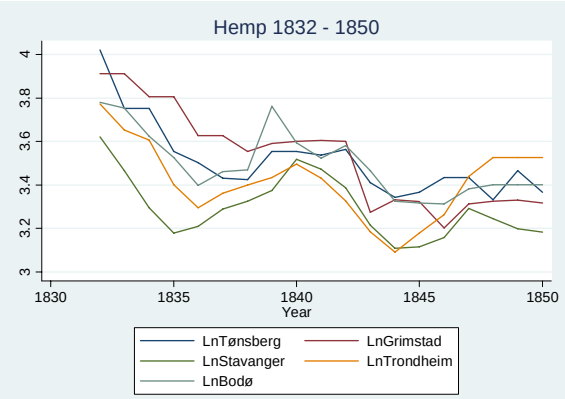

Tar 1832 - 1871
1
1.2
1.4
1.6
1.8
2
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien

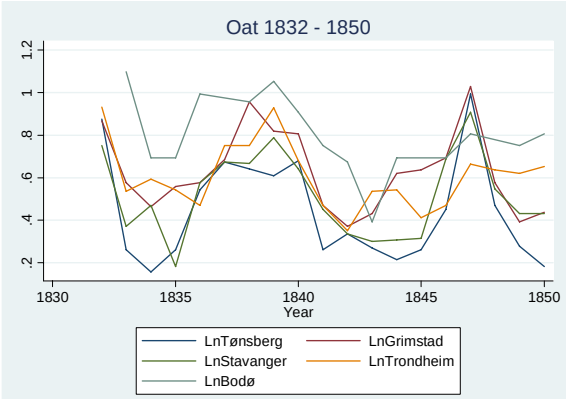

Stockfish 1832 - 1871
2
2.5
3
3.5
1830
1840
1850
1860
1870
Year
LnFredrikstad
LnSkien

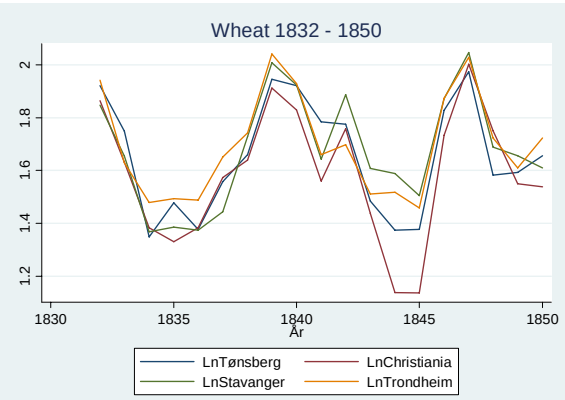
1832-1850

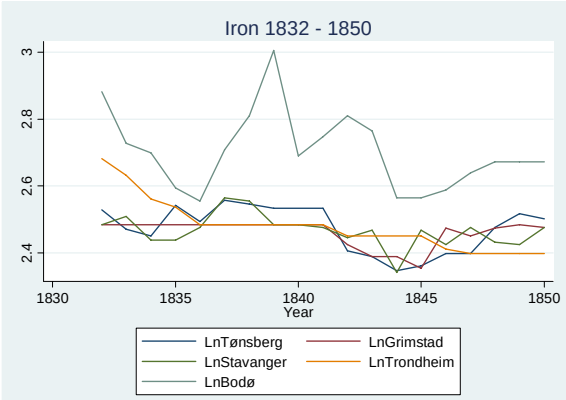

Barley 1832 - 1850
.6
.8
1
1.2
1.4
1.6
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

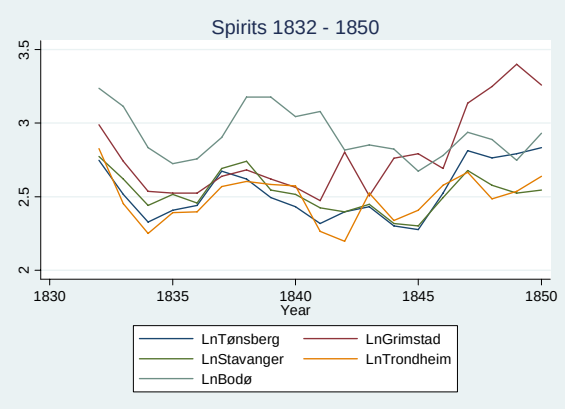

Peas 1832 - 1850
1
1.2
1.4
1.6
1.8
2
1830
1835
1840
1845
1850
År
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

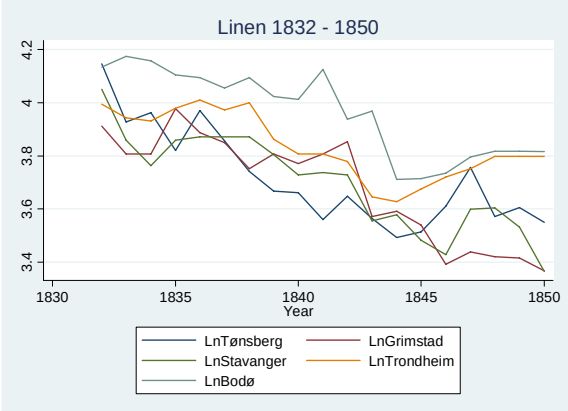

Hemp 1832 - 1850
3
3.2
3.4
3.6
3.8
4
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

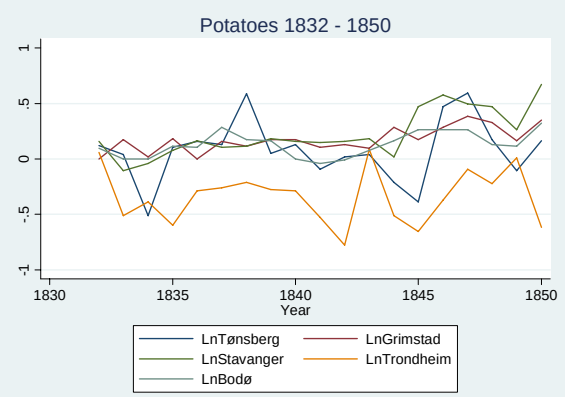

Oat 1832 - 1850
.2
.4
.6
.8
1
1.2
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

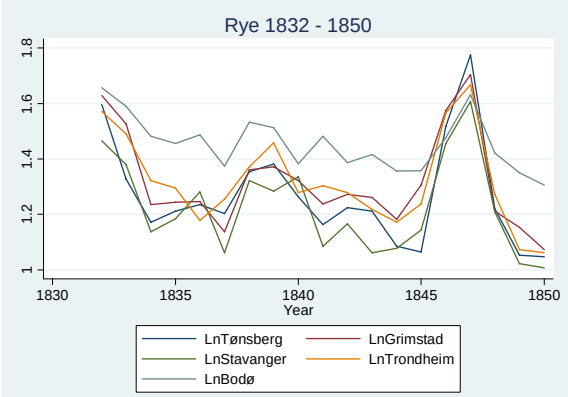

Wheat 1832 - 1850
1.2
1.4
1.6
1.8
2
1830
1835
1840
1845
1850
År
LnTønsberg
LnChristiania
LnStavanger
LnTrondheim

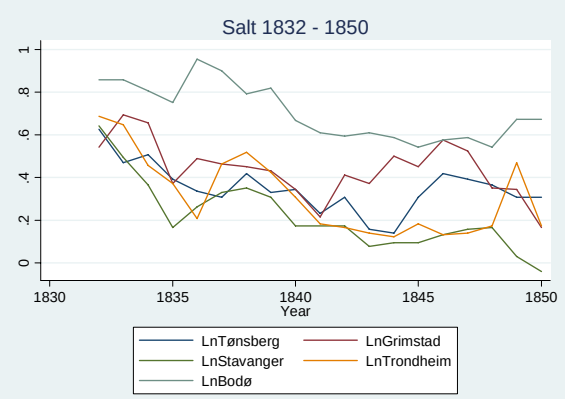

Iron 1832 - 1850
2.4
2.6
2.8
3
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

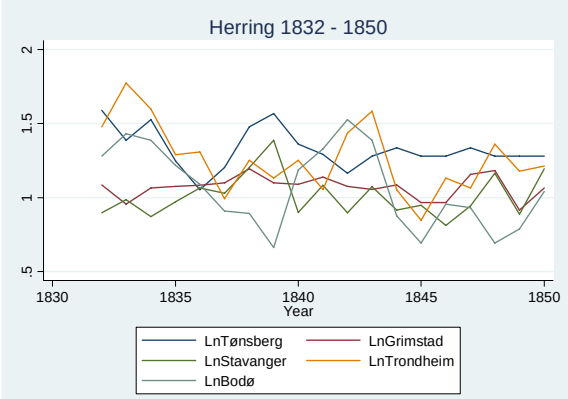

Spirits 1832 - 1850
2
2.5
3
3.5
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

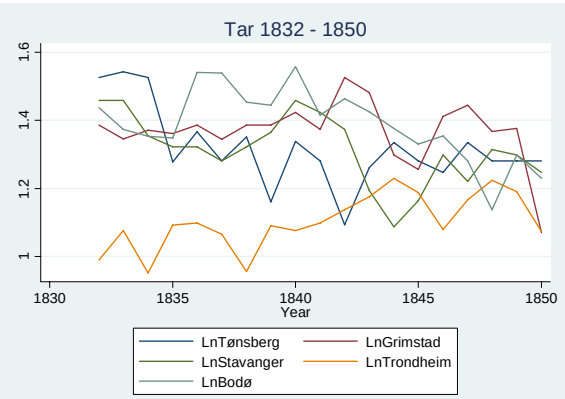

Linen 1832 - 1850
3.4
3.6
3.8
4
4.2
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

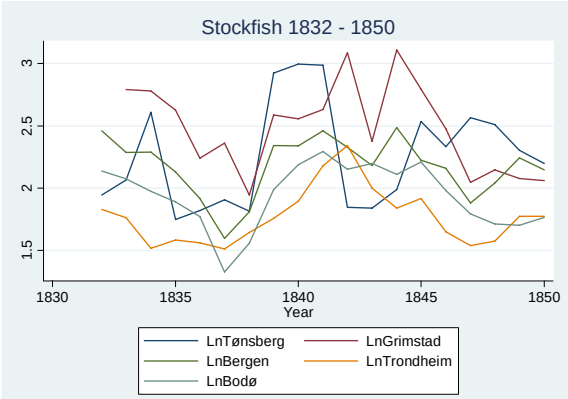

Potatoes 1832 - 1850
-1
-.5
0
.5
1
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø


Rye 1832 - 1850
1
1.2
1.4
1.6
1.8
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

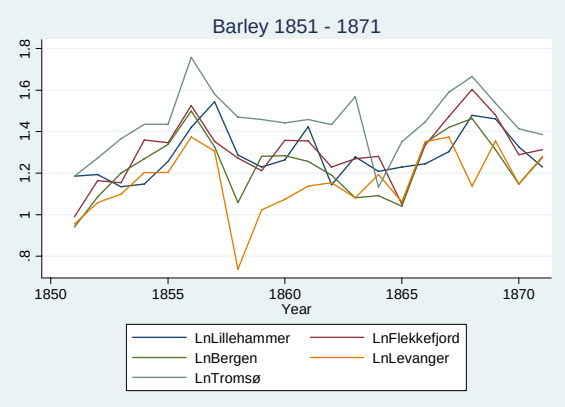

Salt 1832 - 1850
0
.2
.4
.6
.8
1
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

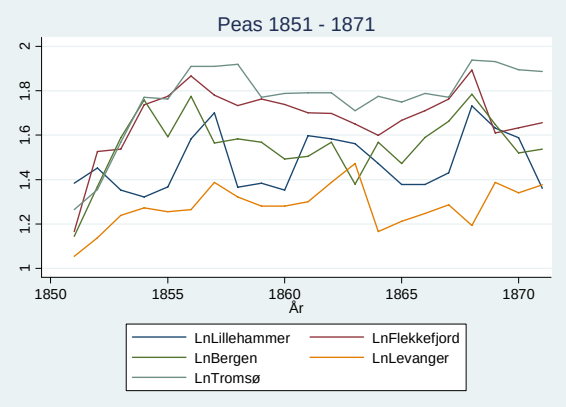

Herring 1832 - 1850
.5
1
1.5
2
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

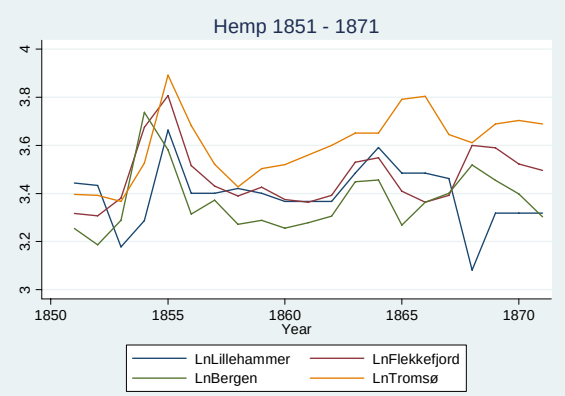

Tar 1832 - 1850
1
1.2
1.4
1.6
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnStavanger
LnTrondheim
LnBodø

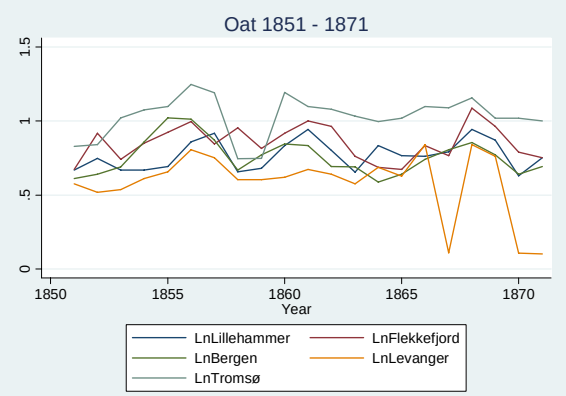

Stockfish 1832 - 1850
1.5
2
2.5
3
1830
1835
1840
1845
1850
Year
LnTønsberg
LnGrimstad
LnBergen
LnTrondheim
LnBodø

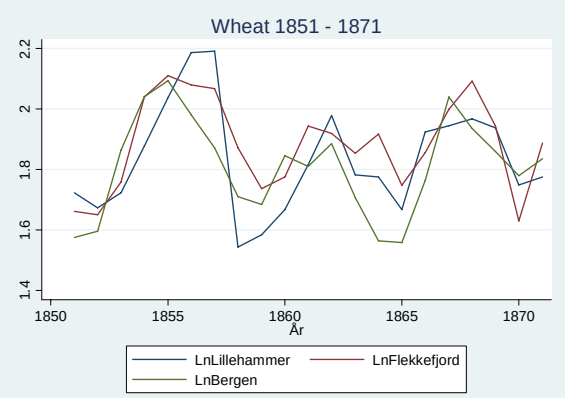
1851-1871

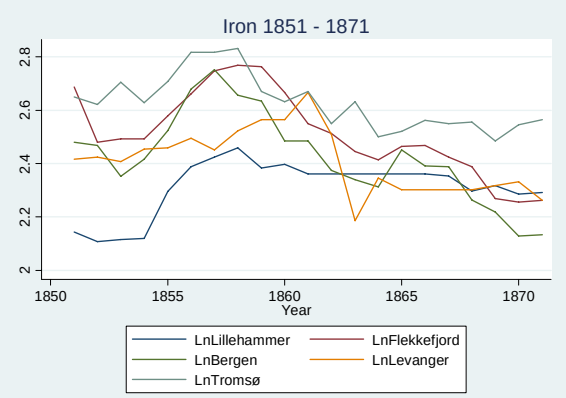

Barley 1851 - 1871
.8
1
1.2
1.4
1.6
1.8
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø

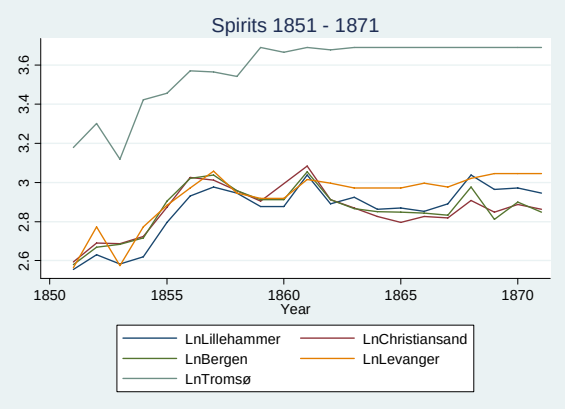

Peas 1851 - 1871
1
1.2
1.4
1.6
1.8
2
1850
1855
1860
1865
1870
År
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø

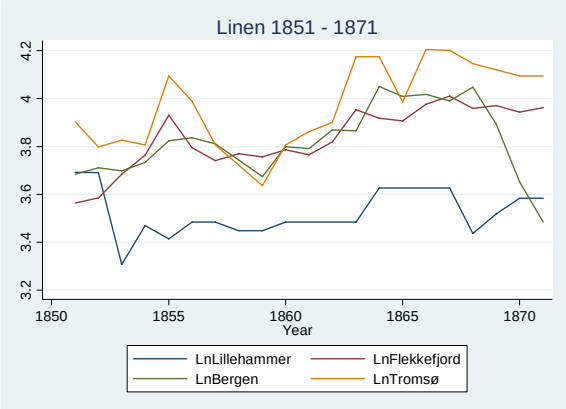

Hemp 1851 - 1871
3
3.2
3.4
3.6
3.8
4
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnTromsø

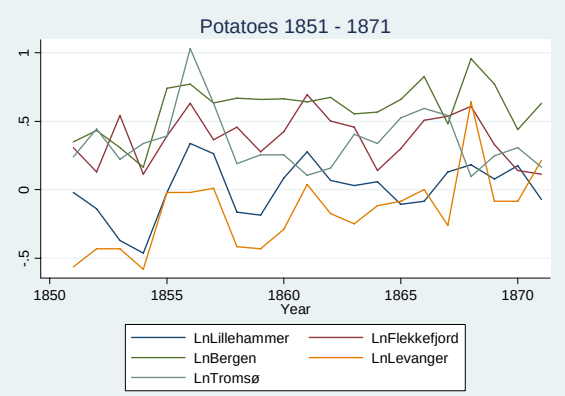

Oat 1851 - 1871
0
.5
1
1.5
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø

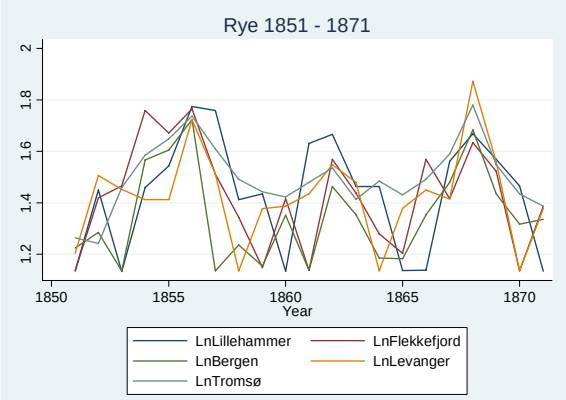

Wheat 1851 - 1871
1.4
1.6
1.8
2
2.2
1850
1855
1860
1865
1870
År
LnLillehammer
LnFlekkefjord
LnBergen

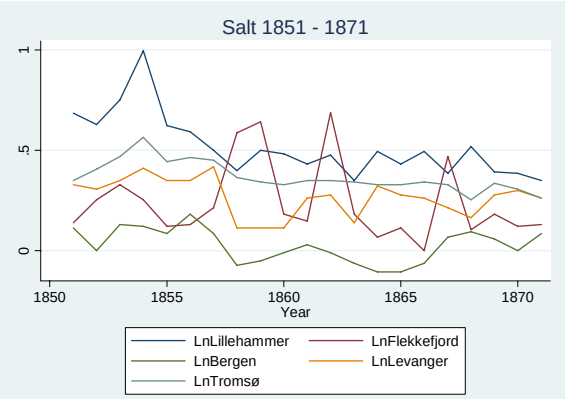

Iron 1851 - 1871
2
2.2
2.4
2.6
2.8
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø

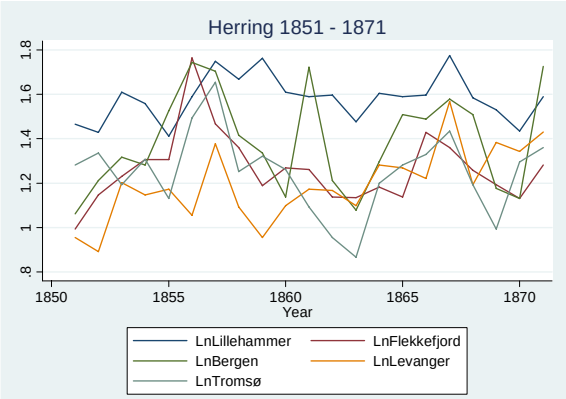

Spirits 1851 - 1871
2.6
2.8
3
3.2
3.4
3.6
1850
1855
1860
1865
1870
Year
LnLillehammer
LnChristiansand
LnBergen
LnLevanger
LnTromsø

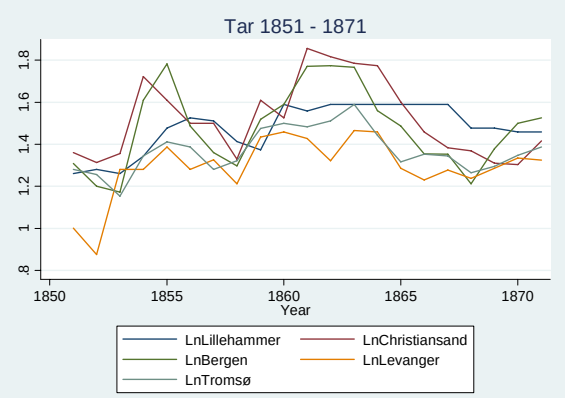

Linen 1851 - 1871
3.2
3.4
3.6
3.8
4
4.2
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnTromsø

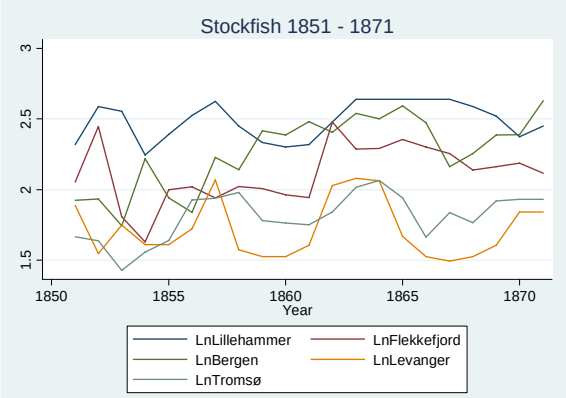

Potatoes 1851 - 1871
-.5
0
.5
1
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø

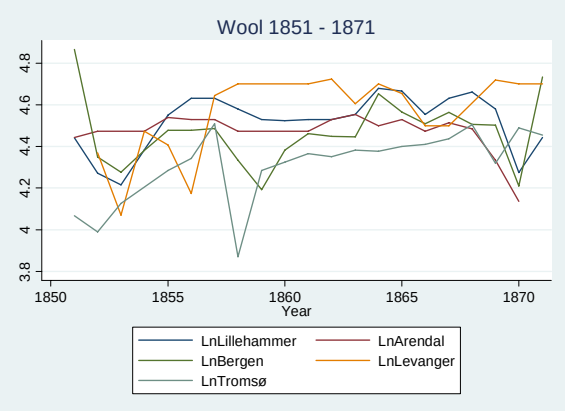

Rye 1851 - 1871
1.2
1.4
1.6
1.8
2
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø


Salt 1851 - 1871
0
.5
1
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø


Herring 1851 - 1871
.8
1
1.2
1.4
1.6
1.8
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø

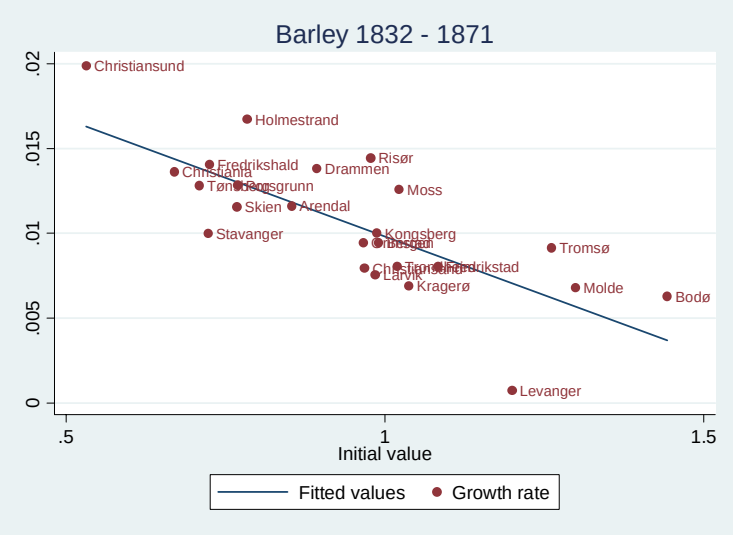

Tar 1851 - 1871
.8
1
1.2
1.4
1.6
1.8
1850
1855
1860
1865
1870
Year
LnLillehammer
LnChristiansand
LnBergen
LnLevanger
LnTromsø

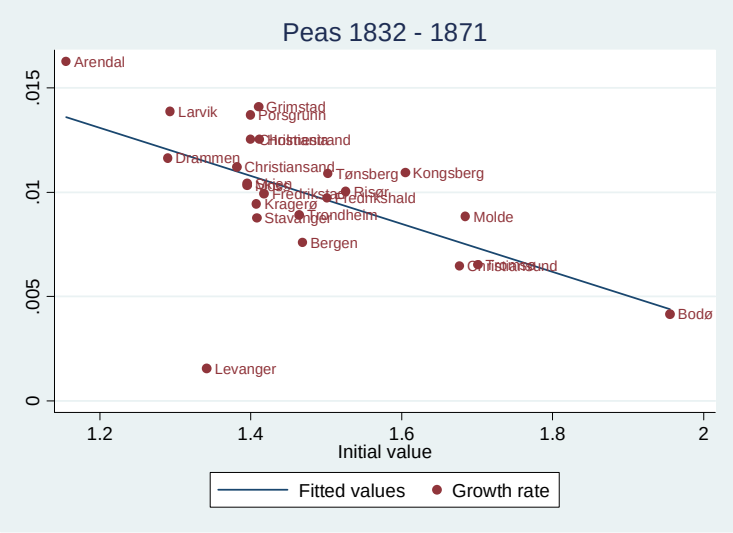

Stockfish 1851 - 1871
1.5
2
2.5
3
1850
1855
1860
1865
1870
Year
LnLillehammer
LnFlekkefjord
LnBergen
LnLevanger
LnTromsø

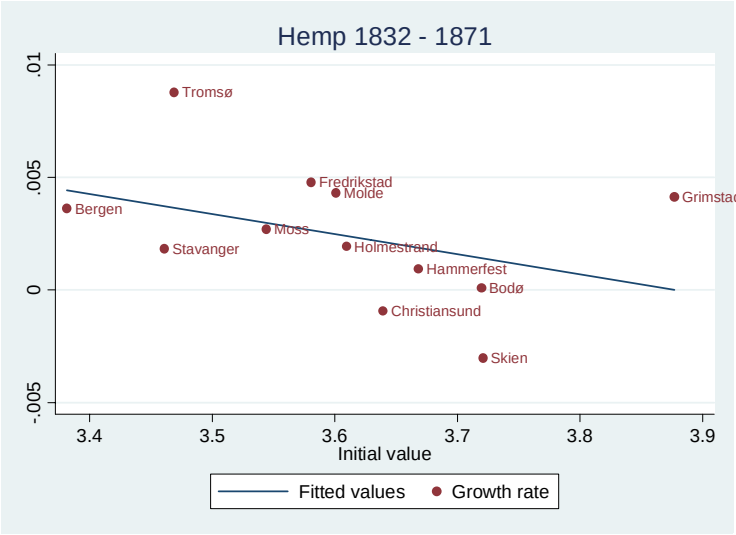

Wool 1851 - 1871
3.8
4
4.2
4.4
4.6
4.8
1850
1855
1860
1865
1870
Year
LnLillehammer
LnArendal
LnBergen
LnLevanger
LnTromsø

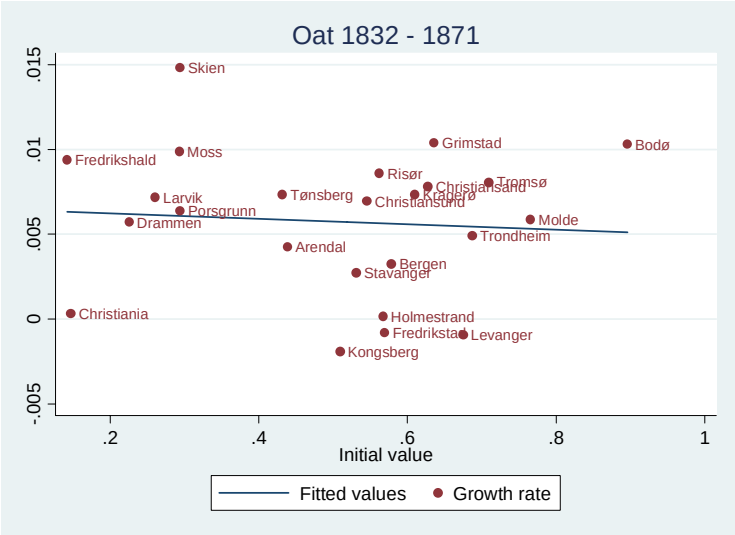
Appendix C – Regresssion fits, convergence regressions

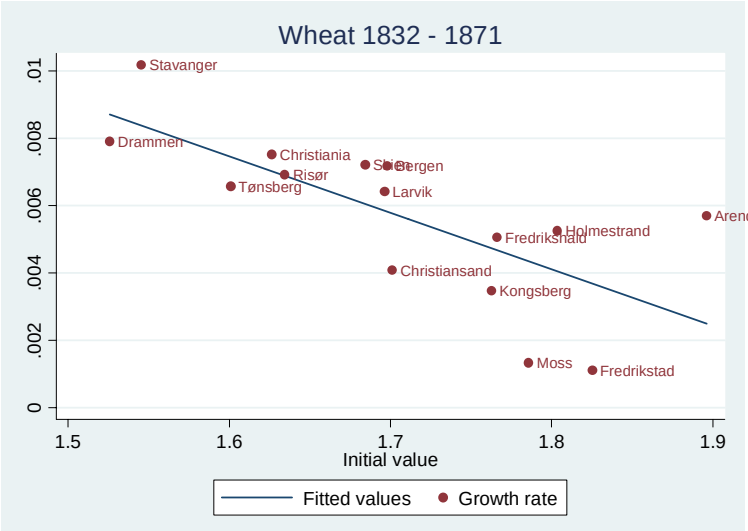
1832-1871

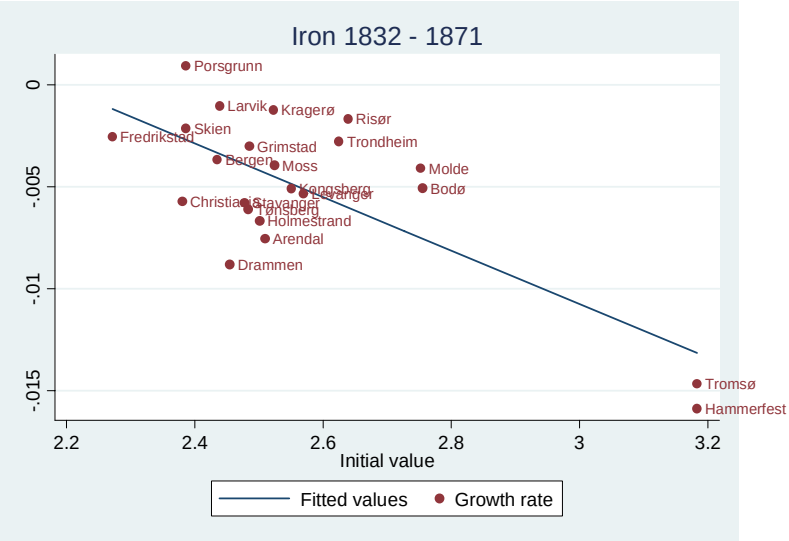


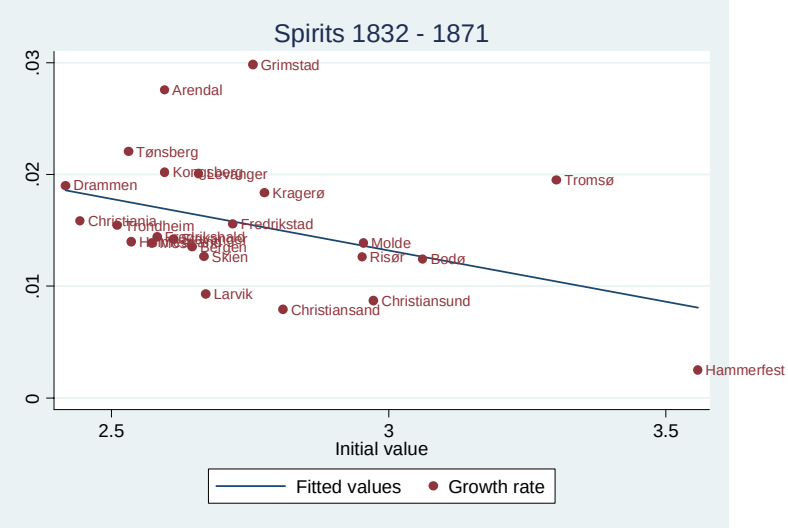


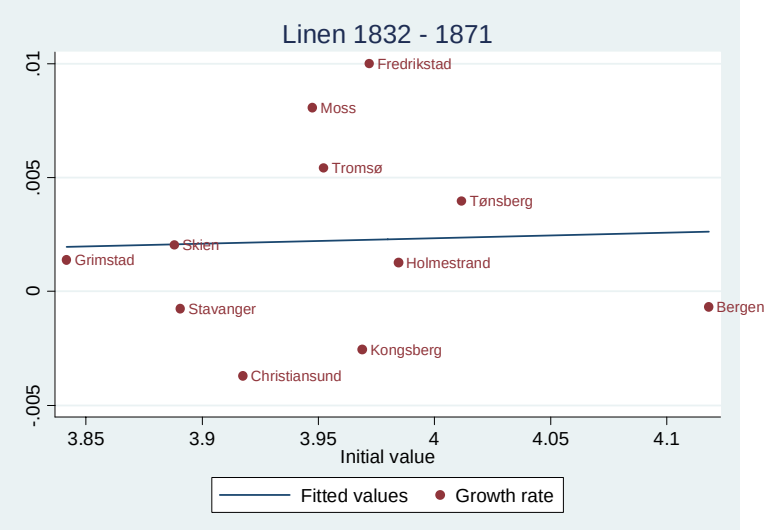

Hemp 1832 - 1871
.01
.005
0
-.005
Tromsø
Fredrikstad
Molde
Grimstad
Bergen
Moss
Stavanger
Holmestrand
Hammerfest
Bodø
Christiansund
Skien
3.4
3.5
3.6
3.7
3.8
3.9
Initial value
Fitted values
Growth rate


Oat 1832 - 1871
.015
.01
.005
0
-.005
Skien
Grimstad
Bodø
Fredrikshald
Moss
Risør
Tromsø
Christiansand
Larvik
Tønsberg
Kragerø
Porsgrunn
Christiansund
Molde
Drammen
Trondheim
Arendal
Bergen
Stavanger
Christiania
Holmestrand
Fredrikstad
Levanger
Kongsberg
.2
.4
.6
.8
1
Initial value
Fitted values
Growth rate


Wheat 1832 - 1871
.01
.008
.006
.004
.002
0
Stavanger
Drammen
Christiania
Skien
Bergen
Risør
Tønsberg
Larvik
Arendal
Holmestrand
Fredrikshald
Christiansand
Kongsberg
Moss
Fredrikstad
1.5
1.6
1.7
1.8
1.9
Initial value
Fitted values
Growth rate


Iron 1832 - 1871
Porsgrunn
Larvik
Kragerø
Risør
Skien
Fredrikstad
Grimstad
Trondheim
Bergen
Moss
Molde
Bodø
Christiania
Stavanger
Tønsberg
Holmestrand
Arendal
Drammen
Tromsø
Hammerfest
0
-.005
-.01
-.015
2.2
2.4
2.6
2.8
3
3.2
Initial value
Fitted values
Growth rate


Spirits 1832 - 1871
Grimstad
Arendal
Tønsberg
Drammen
Kragerø
Tromsø
Christiania
Fredrikstad
Molde
Risør
Bodø
Skien
Larvik
Christiansand
Christiansund
Hammerfest
0
.01
.02
.03
2.5
3
3.5
Initial value
Fitted values
Growth rate


Linen 1832 - 1871
Fredrikstad
Moss
Tromsø
Tønsberg
Skien
Grimstad
Holmestrand
Stavanger
Bergen
Kongsberg
Christiansund
-.005
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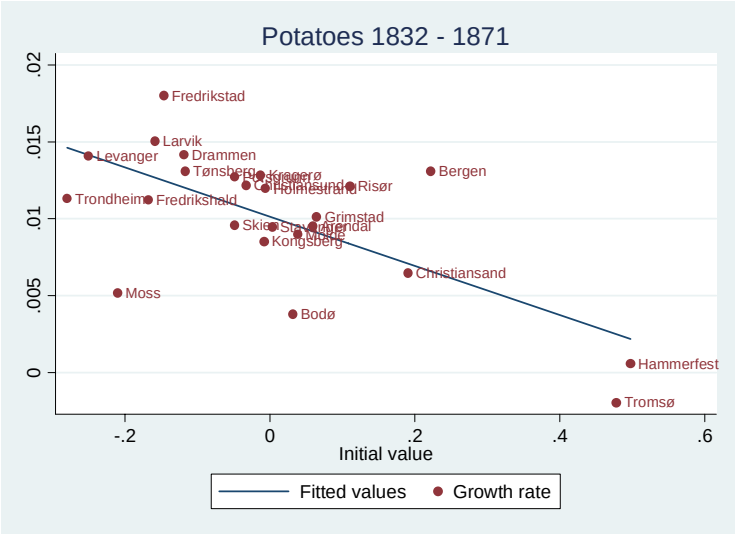
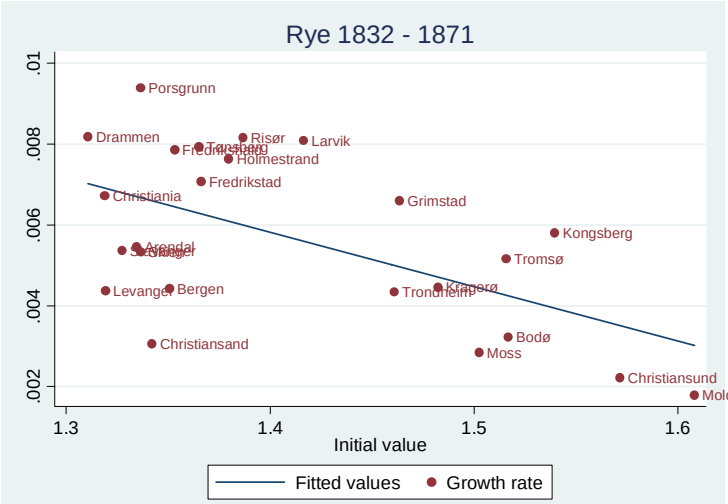
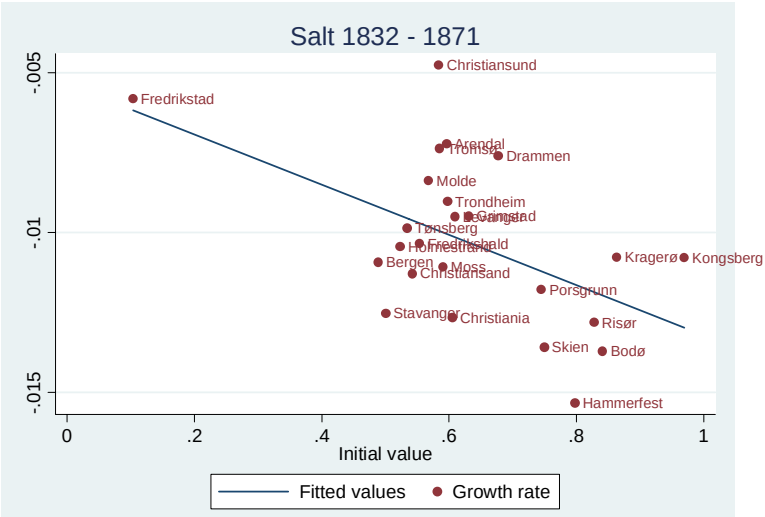
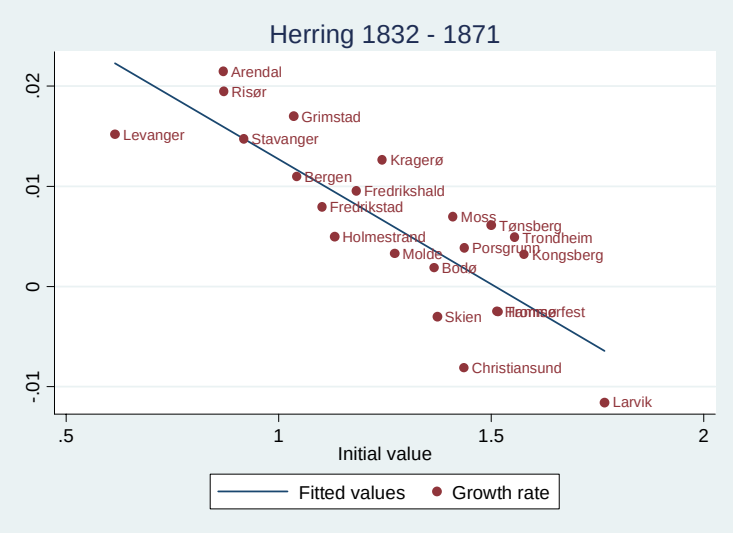
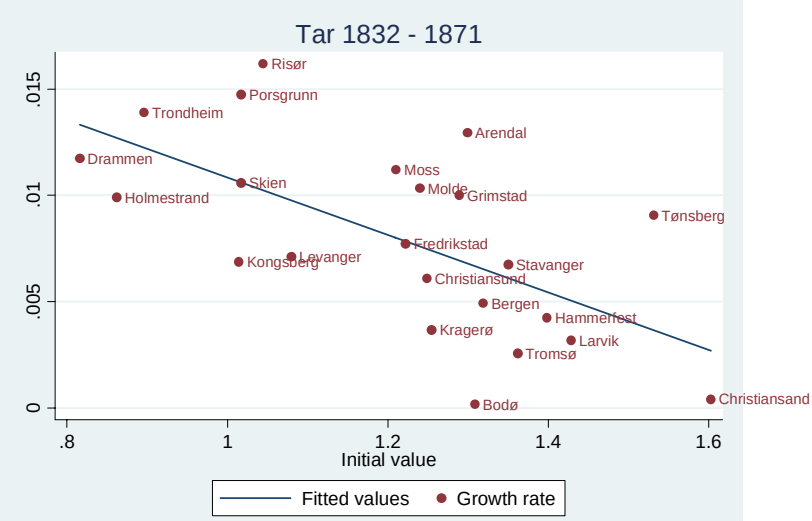
.005
.01
3.85
3.9
3.95
4
4.05
4.1
Initial value
Fitted values
Growth rate


Potatoes 1832 - 1871
.02
.015
.01
.005
0
Fredrikstad
Larvik
Levanger
Drammen
Tønsberg
Bergen
Risør
Trondheim
Fredrikshald
Grimstad
Skien
Kongsberg
Christiansand
Moss
Bodø
Hammerfest
Tromsø
-.2
0
.2
.4
.6
Initial value
Fitted values
Growth rate


Rye 1832 - 1871
.01
.008
.006
.004
.002
Porsgrunn
Drammen
Risør
Larvik
Holmestrand
Fredrikstad
Christiania
Grimstad
Kongsberg
Tromsø
Levanger
Bergen
Trondheim
Bodø
Moss
Christiansand
Christiansund
Molde
1.3
1.4
1.5
1.6
Initial value
Fitted values
Growth rate


Salt 1832 - 1871
-.005
-.01
-.015
Christiansund
Fredrikstad
Drammen
Molde
Trondheim
Tønsberg
Kragerø
Kongsberg
Bergen
Christiansand
Porsgrunn
Stavanger
Christiania
Risør
Skien
Bodø
Hammerfest
0
.2
.4
.6
.8
1
Initial value
Fitted values
Growth rate


Herring 1832 - 1871
Arendal
Risør
Grimstad
Levanger
Stavanger
Kragerø
Bergen
Fredrikshald
Fredrikstad
Moss
Tønsberg
Trondheim
Holmestrand
Porsgrunn
Kongsberg
Molde
Bodø
Skien
Hammerfest
Christiansund
Larvik
.02
.01
0
-.01
.5
1
1.5
2
Initial value
Fitted values
Growth rate


Tar 1832 - 1871
Risør
Porsgrunn
Trondheim
Arendal
Drammen
Moss
Skien
Molde
Holmestrand
Grimstad
Tønsberg
Fredrikstad
Kongsberg
Levanger
Stavanger
Christiansund
Bergen
Hammerfest
Kragerø
Larvik
Tromsø
Bodø
Christiansand
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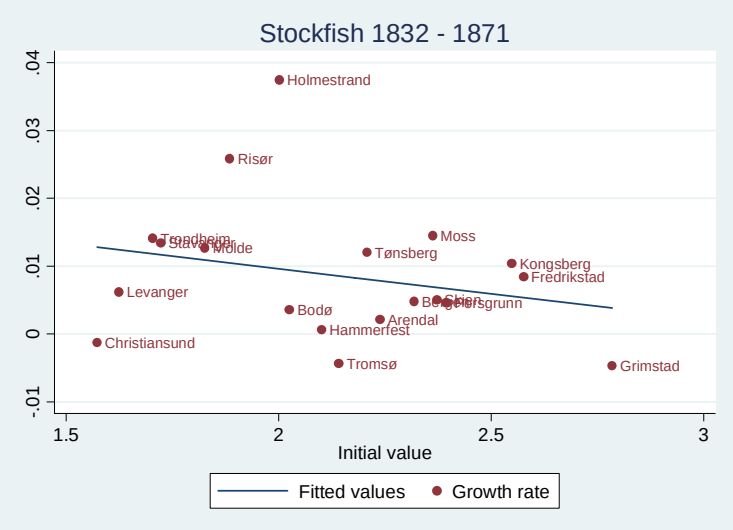
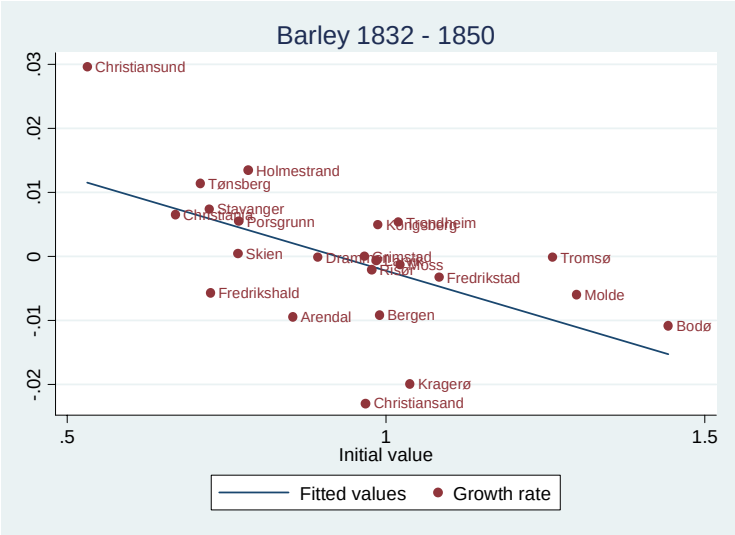
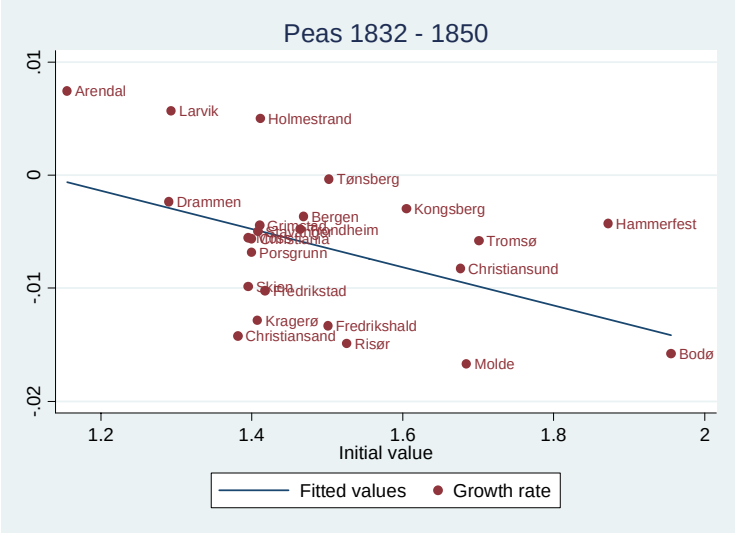
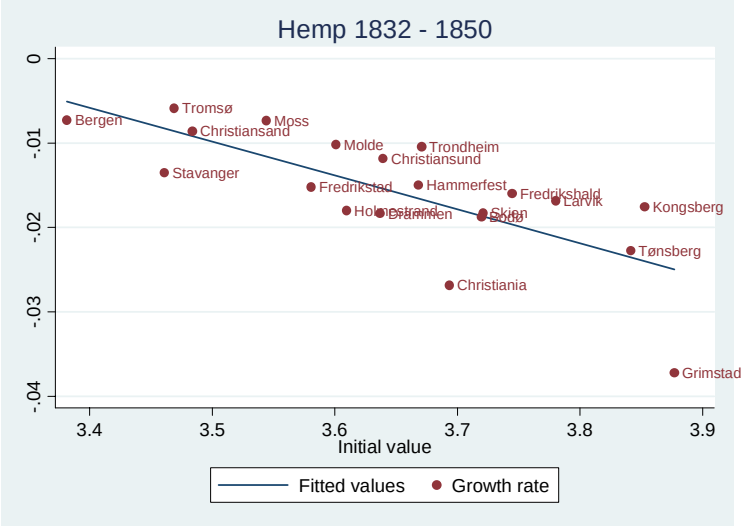
.01
.005
0
.8
1
1.2
1.4
1.6
Initial value
Fitted values
Growth rate

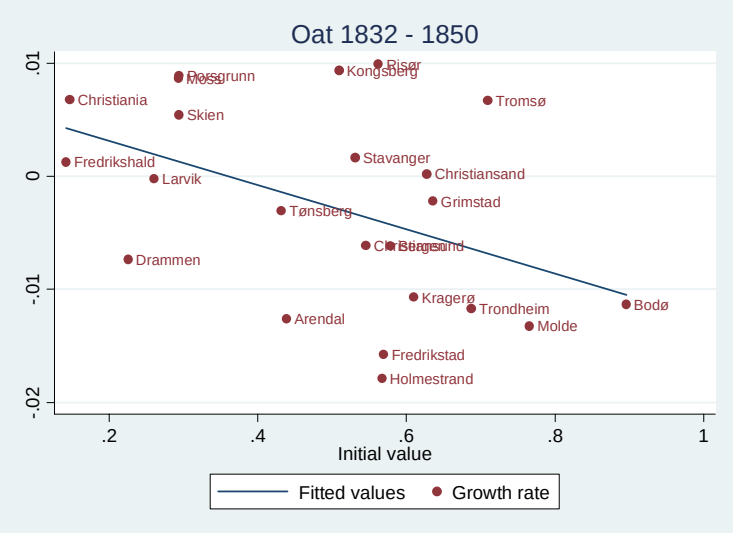

Stockfish 1832 - 1871
Holmestrand
Risør
Moss
Tønsberg
Kongsberg
Fredrikstad
Levanger
Bodø
Arendal
Hammerfest
Christiansund
Tromsø
Grimstad
.04
.03
.02
.01
0
-.01
1.5
2
2.5
3
Initial value
Fitted values
Growth rate

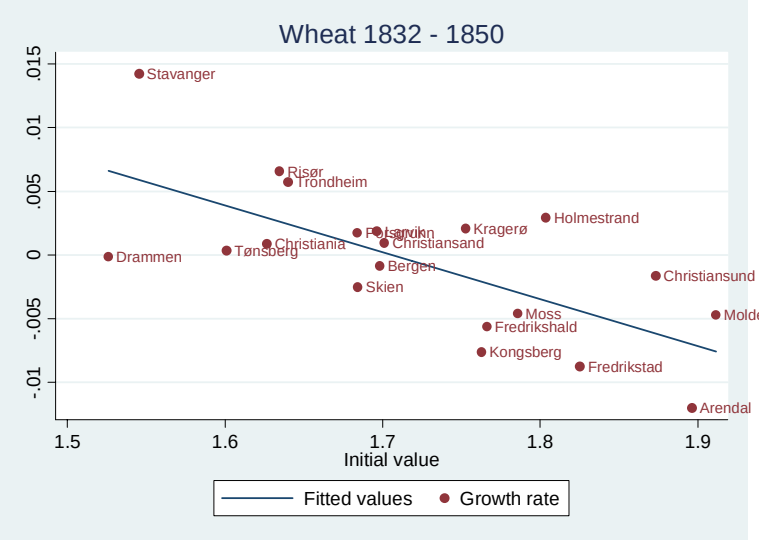
1832-1850

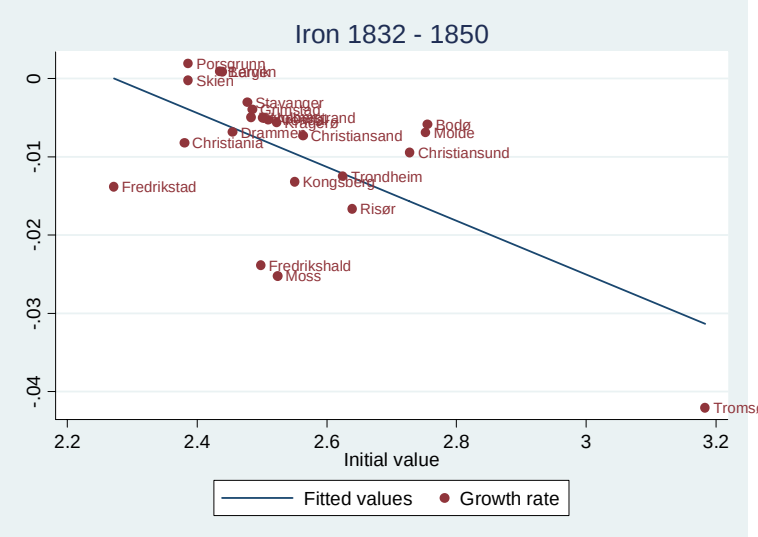

Barley 1832 - 1850
Christiansund
Holmestrand
Tønsberg
Stavanger
Porsgrunn
Trondheim
Skien
Tromsø
Fredrikstad
Molde
Fredrikshald
Arendal
Bergen
Bodø
Kragerø
Christiansand
.03
.02
.01
0
-.01
-.02
.5
1
1.5
Initial value
Fitted values
Growth rate

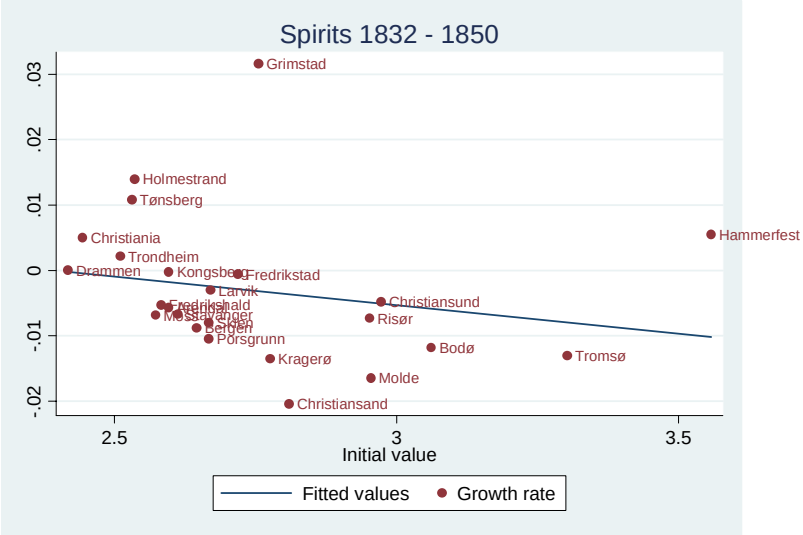

Peas 1832 - 1850
Arendal
Larvik
Holmestrand
Tønsberg
Drammen
Kongsberg
Bergen
Hammerfest
Tromsø
Porsgrunn
Christiansund
Skien
Fredrikstad
Kragerø
Fredrikshald
Christiansand
Risør
Molde
Bodø
.01
0
-.01
-.02
1.2
1.4
1.6
1.8
2
Initial value
Fitted values
Growth rate

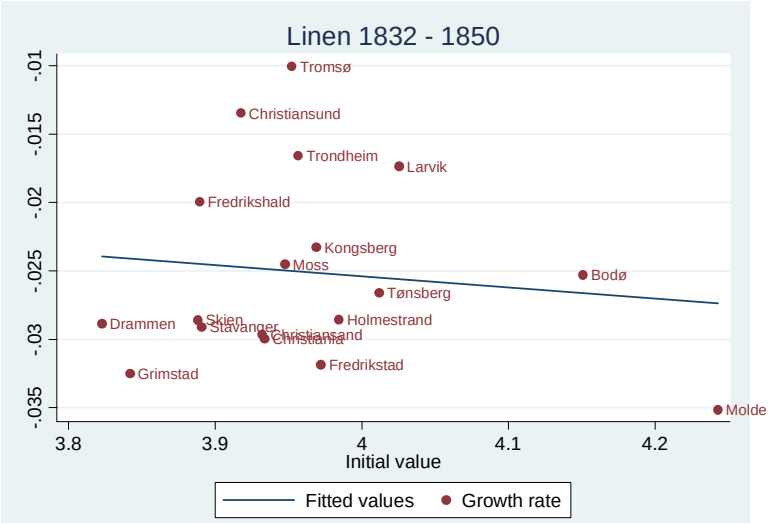

Hemp 1832 - 1850
Tromsø
Bergen
Moss
Christiansand
Molde
Trondheim
Christiansund
Stavanger
Fredrikstad
Hammerfest
Fredrikshald
Larvik
Kongsberg
Holmestrand
Skien
Tønsberg
Christiania
Grimstad
0
-.01
-.02
-.03
-.04
3.4
3.5
3.6
3.7
3.8
3.9
Initial value
Fitted values
Growth rate

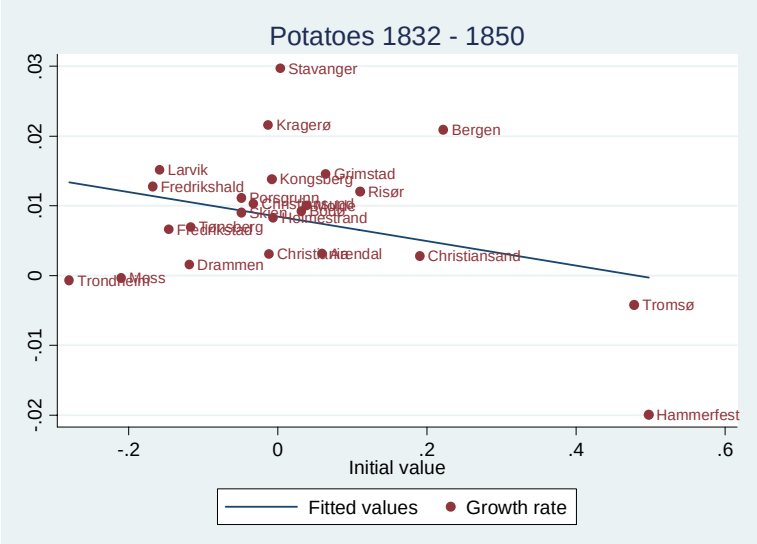

Oat 1832 - 1850
Porsgrunn
Kongsberg
Risør
Christiania
Tromsø
Skien
Stavanger
Fredrikshald
Larvik
Christiansand
Grimstad
Tønsberg
Drammen
Kragerø
Trondheim
Bodø
Arendal
Molde
Fredrikstad
Holmestrand
.01
0
-.01
-.02
.2
.4
.6
.8
1
Initial value
Fitted values
Growth rate

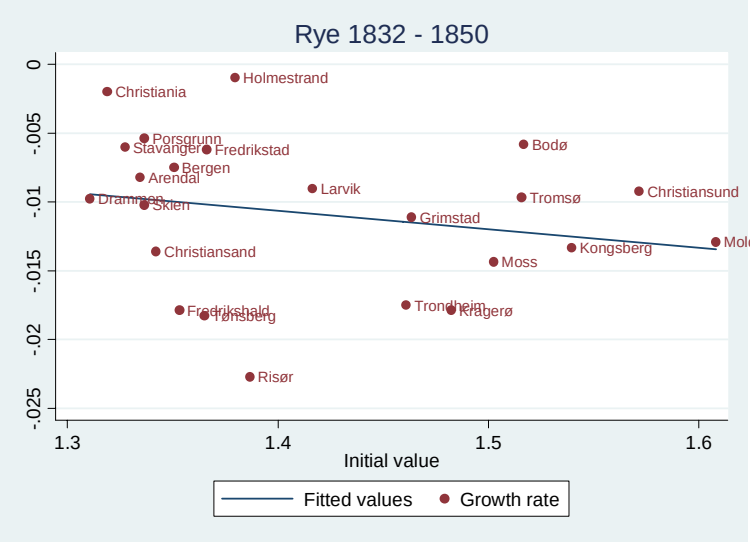

Wheat 1832 - 1850
Stavanger
Risør
Trondheim
Holmestrand
Kragerø
Christiania
Christiansand
Drammen
Tønsberg
Bergen
Christiansund
Skien
Moss
Molde
Fredrikshald
Kongsberg
Fredrikstad
Arendal
.015
.01
.005
0
-.005
-.01
1.5
1.6
1.7
1.8
1.9
Initial value
Fitted values
Growth rate


Iron 1832 - 1850
Porsgrunn
Skien
Stavanger
Bodø
Molde
Christiania
Christiansand
Christiansund
Fredrikstad
Trondheim
Kongsberg
Risør
Fredrikshald
Moss
Tromsø
0
-.01
-.02
-.03
-.04
2.2
2.4
2.6
2.8
3
3.2
Initial value
Fitted values
Growth rate


Spirits 1832 - 1850
Grimstad
Holmestrand
Tønsberg
Christiania
Trondheim
Drammen
Kongsberg
Fredrikstad
Larvik
Christiansund
Risør
Bergen
Porsgrunn
Kragerø
Bodø
Tromsø
Molde
Christiansand
Hammerfest
.03
.02
.01
0
-.01
-.02
2.5
3
3.5
Initial value
Fitted values
Growth rate


Linen 1832 - 1850
Tromsø
Christiansund
Trondheim
Larvik
Fredrikshald
Kongsberg
Moss
Bodø
Tønsberg
Drammen
Skien
Stavanger
Holmestrand
Christiansand
Fredrikstad
Grimstad
Molde
-.01
-.015
-.02
-.025
-.03
-.035
3.8
3.9
4
4.1
4.2
Initial value
Fitted values
Growth rate


Potatoes 1832 - 1850
Stavanger
Kragerø
Bergen
Larvik
Fredrikshald
Kongsberg
Grimstad
Risør
Porsgrunn
Holmestrand
Fredrikstad
Christiansand
Drammen
Moss
Tromsø
Hammerfest
.03
.02
.01
0
-.01
-.02
-.2
0
.2
.4
.6
Initial value
Fitted values
Growth rate


Rye 1832 - 1850
Holmestrand
Christiania
Porsgrunn
Stavanger
Fredrikstad
Bodø
Bergen
Arendal
Larvik
Tromsø
Christiansund
Drammen
Skien
Grimstad
Molde
Kongsberg
Christiansand
Moss
Fredrikshald
Tønsberg
Trondheim
Kragerø
Risør
0
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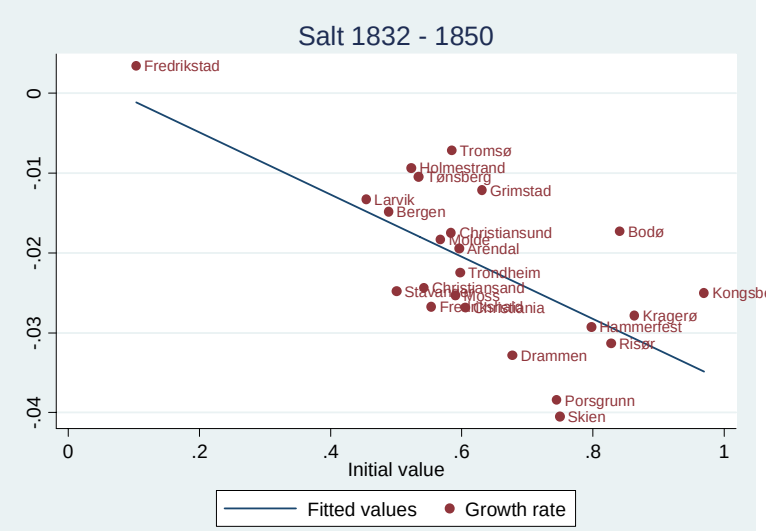
-.01
-.015
-.02
-.025
1.3
1.4
1.5
1.6
Initial value
Fitted values
Growth rate


Salt 1832 - 1850
Fredrikstad
Tromsø
Holmestrand
Tønsberg
Grimstad
Larvik
Bergen
Christiansund
Bodø
Molde
Arendal
Trondheim
Kongsberg
Kragerø
Hammerfest
Risør
Drammen
Porsgrunn
Skien
0
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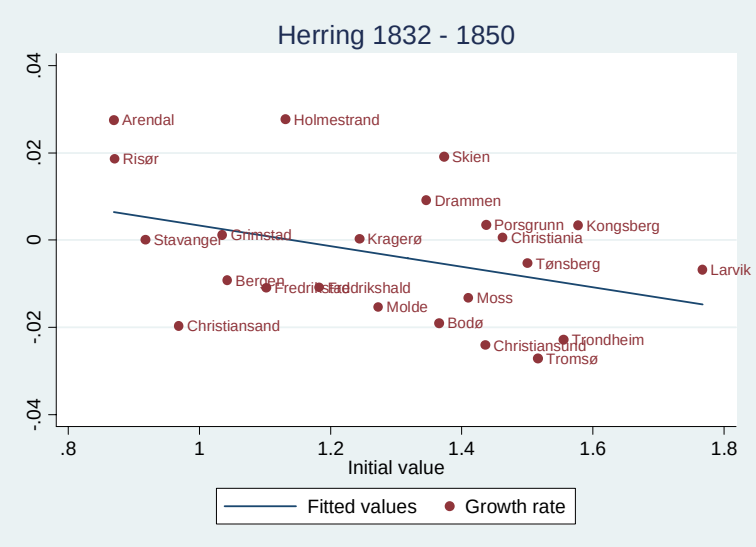
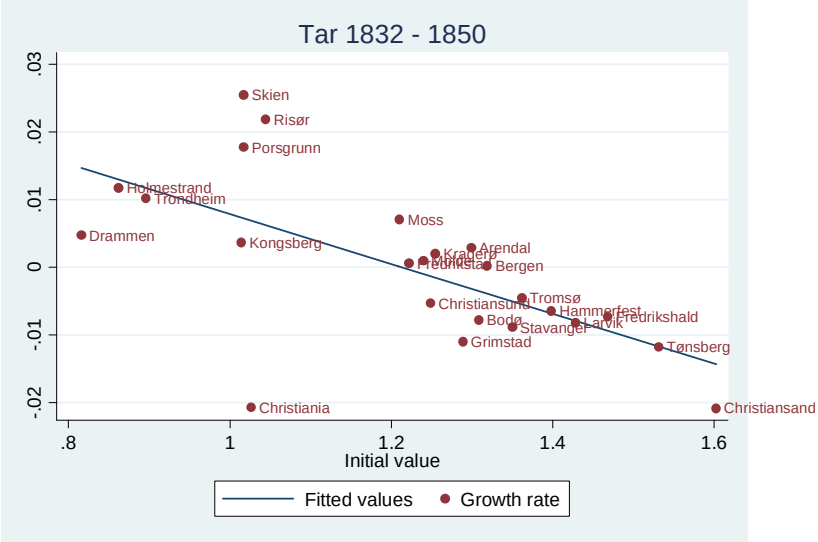
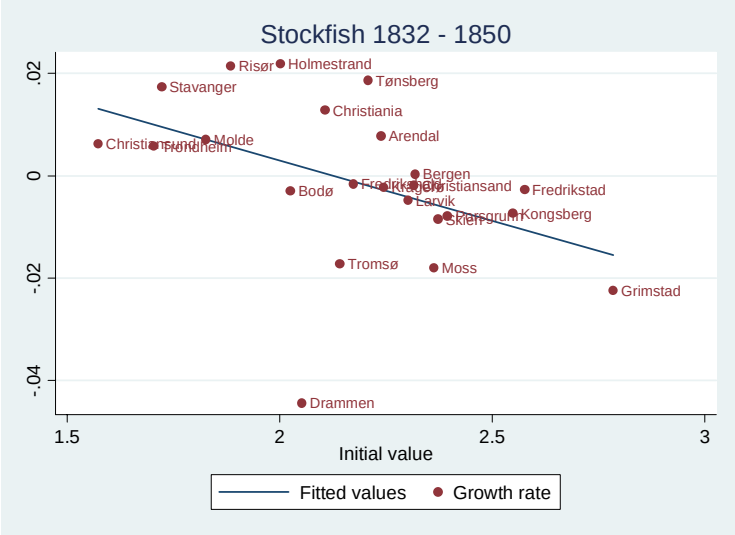
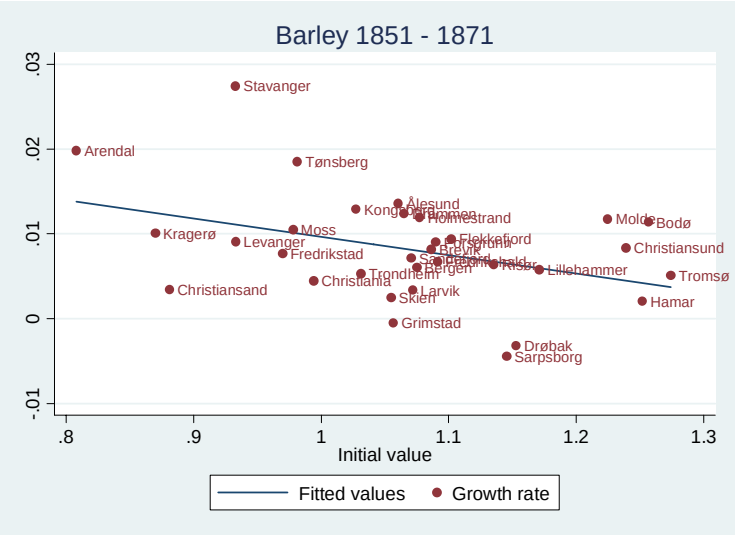
-.02
-.03
-.04
0
.2
.4
.6
.8
1
Initial value
Fitted values
Growth rate

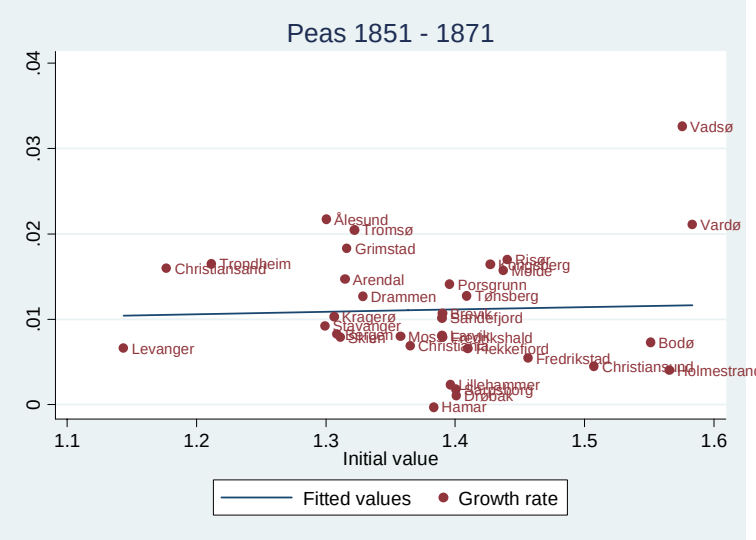

Herring 1832 - 1850
Arendal
Holmestrand
Risør
Skien
Drammen
Porsgrunn
Kongsberg
Stavanger
Grimstad
Kragerø
Christiania
Tønsberg
Larvik
Bergen
Moss
Molde
Christiansand
Bodø
Trondheim
Tromsø
.04
.02
0
-.02
-.04
.8
1
1.2
1.4
1.6
1.8
Initial value
Fitted values
Growth rate

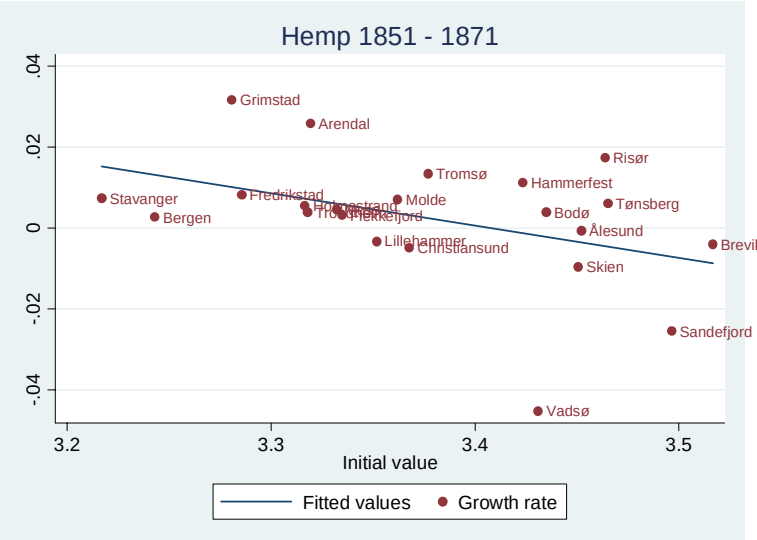

Tar 1832 - 1850
Skien
Risør
Porsgrunn
Holmestrand
Trondheim
Moss
Drammen
Kongsberg
Arendal
Kragerø
Fredrikstad
Bergen
Tromsø
Christiansund
Hammerfest
Bodø
Larvik
Fredrikshald
Stavanger
Grimstad
Tønsberg
Christiania
Christiansand
.03
.02
.01
0
-.01
-.02
.8
1
1.2
1.4
1.6
Initial value
Fitted values
Growth rate

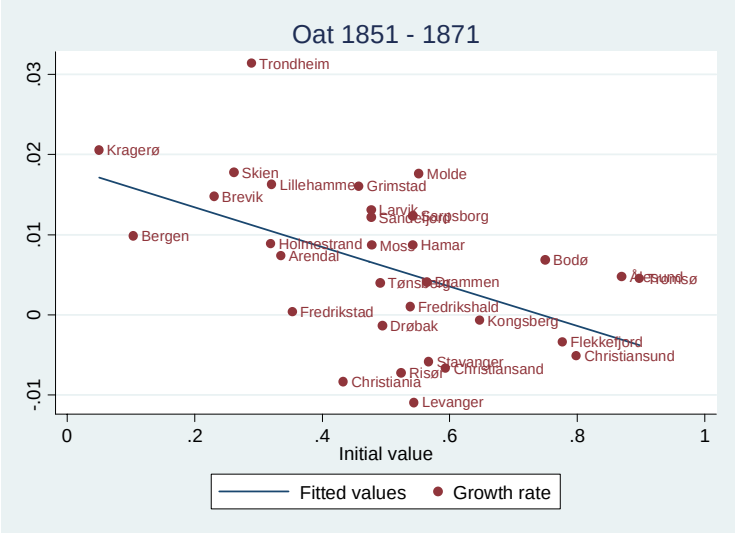

Stockfish 1832 - 1850
Risør
Holmestrand
Tønsberg
Stavanger
Christiania
Arendal
Molde
Bergen
Bodø
Fredrikstad
Larvik
Kongsberg
Tromsø
Moss
Grimstad
Drammen
.02
0
-.02
-.04
1.5
2
2.5
3
Initial value
Fitted values
Growth rate

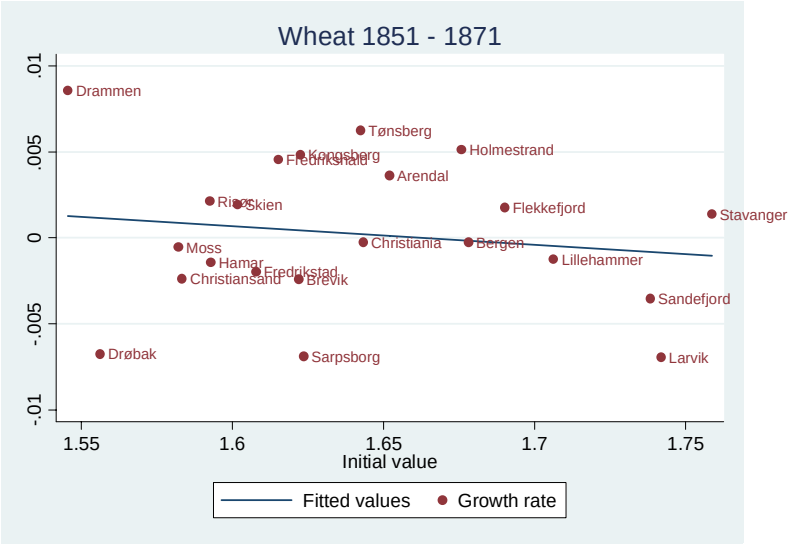
1851-1871

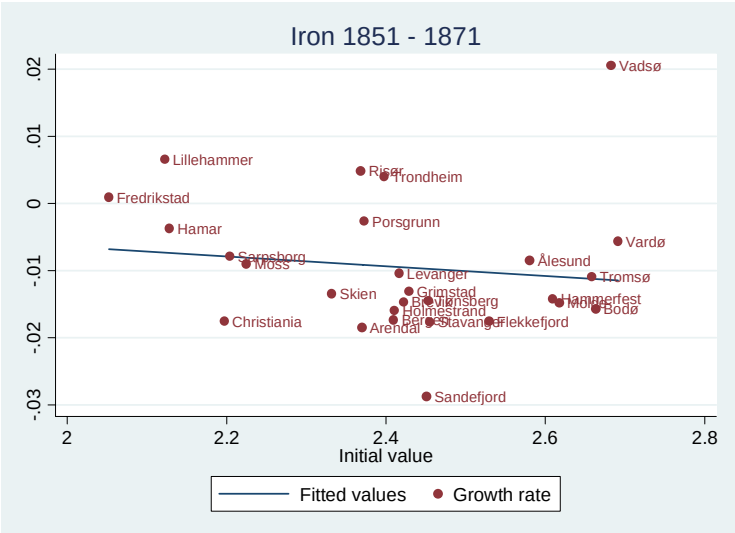

Barley 1851 - 1871
Stavanger
Arendal
Tønsberg
Ålesund
Kongsberg
Drammen
Holmestrand
Molde
Bodø
Kragerø
Moss
Levanger
Flekkefjord
Fredrikstad
Christiansund
Bergen
Risør
Lillehammer
Tromsø
Trondheim
Christiansand
Christiania
Larvik
Skien
Hamar
Grimstad
Drøbak
Sarpsborg
.03
.02
.01
0
-.01
.8
.9
1
1.1
1.2
1.3
Initial value
Fitted values
Growth rate

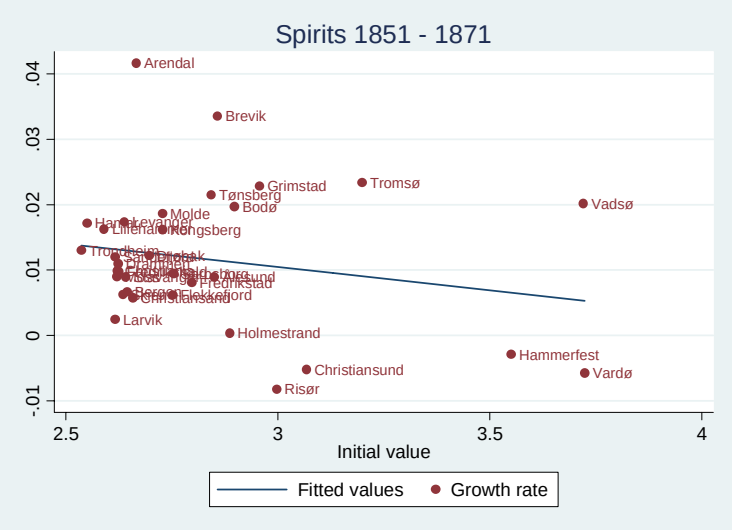

Peas 1851 - 1871
Vadsø
Ålesund
Vardø
Tromsø
Grimstad
Risør
Kongsberg
Trondheim
Christiansand
Molde
Arendal
Porsgrunn
Drammen
Tønsberg
Kragerø
Stavanger
Sandefjord
Levanger
Bodø
Fredrikstad
Christiansund
Holmestrand
Lillehammer
Drøbak
Hamar
.04
.03
.02
.01
0
1.1
1.2
1.3
1.4
1.5
1.6
Initial value
Fitted values
Growth rate

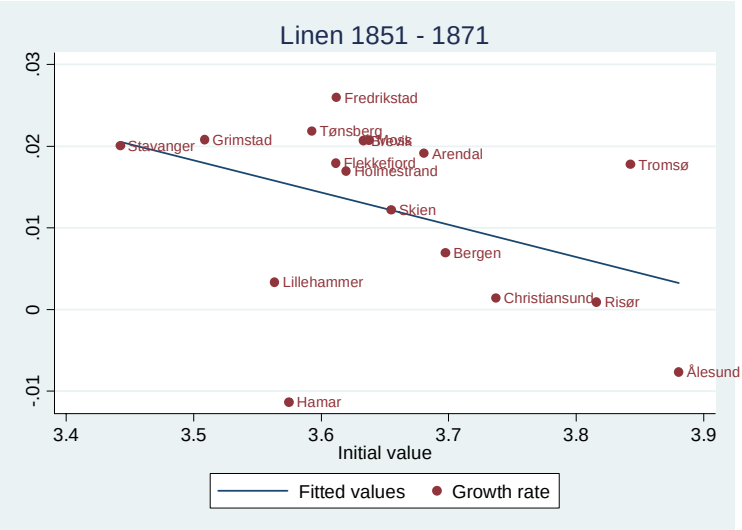

Hemp 1851 - 1871
Grimstad
Arendal
Risør
Tromsø
Hammerfest
Stavanger
Fredrikstad
Molde
Tønsberg
Bergen
Bodø
Ålesund
Lillehammer
Brevik
Christiansund
Skien
Sandefjord
Vadsø
.04
.02
0
-.02
-.04
3.2
3.3
3.4
3.5
Initial value
Fitted values
Growth rate

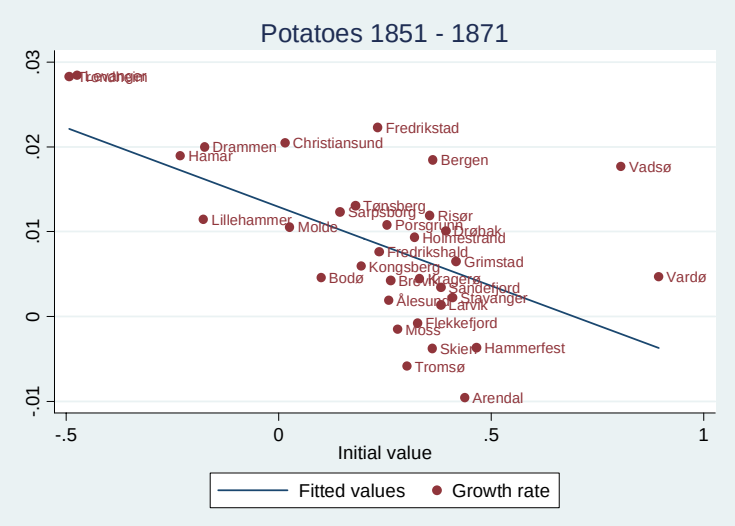

Oat 1851 - 1871
Trondheim
Kragerø
Skien
Molde
Lillehammer
Grimstad
Brevik
Larvik
Sandefjord
Sarpsborg
Bergen
Holmestrand
Moss
Hamar
Arendal
Bodø
Ålesund
Tromsø
Tønsberg
Drammen
Fredrikstad
Fredrikshald
Drøbak
Kongsberg
Flekkefjord
Christiansund
Stavanger
Risør
Christiansand
Christiania
Levanger
0
.2
.4
.6
.8
1
Initial value
-.01
0
.01
.02
.03
Fitted values
Growth rate

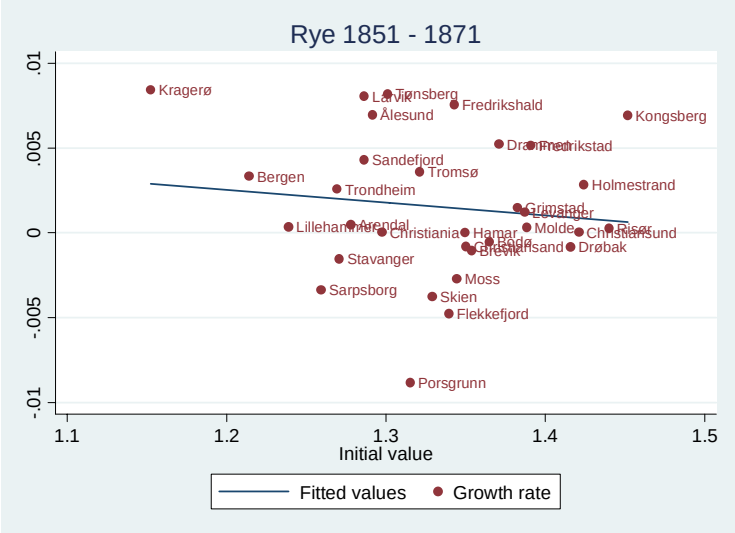

Wheat 1851 - 1871
Drammen
Tønsberg
Holmestrand
Kongsberg
Fredrikshald
Arendal
Risør
Skien
Flekkefjord
Stavanger
Moss
Christiania
Bergen
Hamar
Lillehammer
Fredrikstad
Christiansand
Brevik
Sandefjord
Drøbak
Sarpsborg
Larvik
1.55
1.6
1.65
1.7
1.75
Initial value
-.01
-.005
0
.005
.01
Fitted values
Growth rate

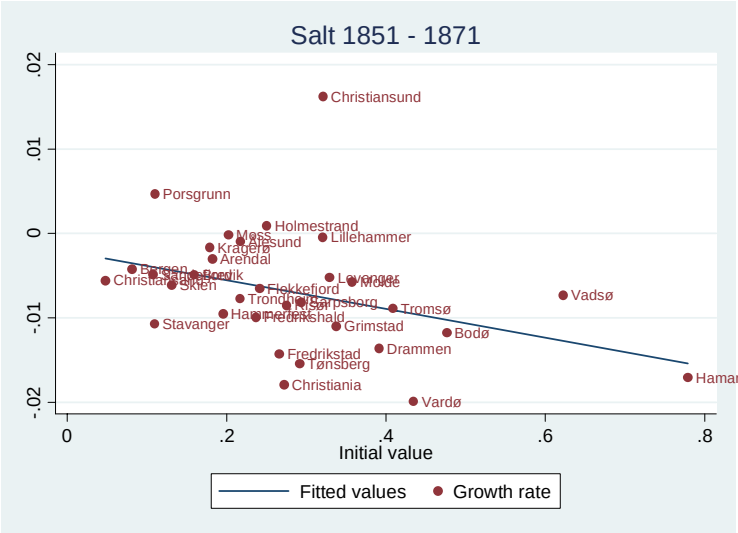

Iron 1851 - 1871
Vadsø
Lillehammer
Risør
Trondheim
Fredrikstad
Porsgrunn
Hamar
Vardø
Sarpsborg
Moss
Ålesund
Levanger
Tromsø
Skien
Grimstad
Tønsberg
Holmestrand
Hammerfest
Bodø
Christiania
Arendal
Stavanger
Flekkefjord
Sandefjord
2
2.2
2.4
2.6
2.8
Initial value
-.03
-.02
-.01
0
.01
.02
Fitted values
Growth rate

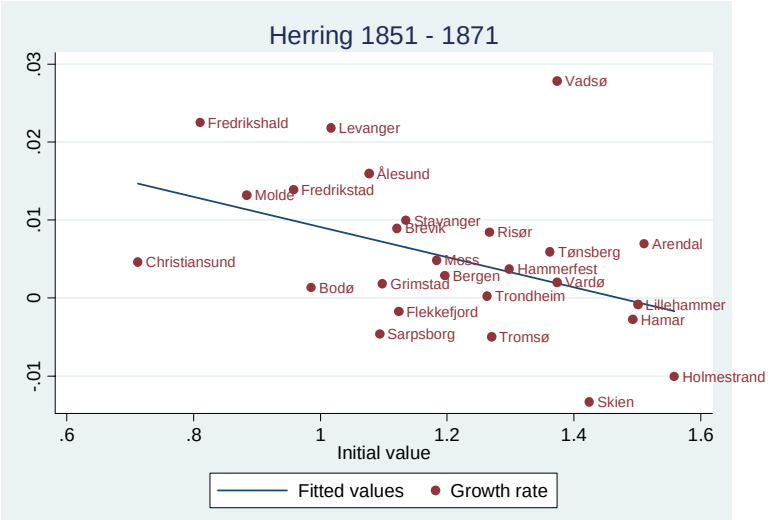

Spirits 1851 - 1871
Arendal
Brevik
Grimstad
Tromsø
Tønsberg
Vadsø
Bodø
Molde
Kongsberg
Larvik
Holmestrand
Hammerfest
Christiansund
Vardø
Risør
-.01
0
.01
.02
.03
.04
2.5
3
3.5
4
Initial value
Fitted values
Growth rate

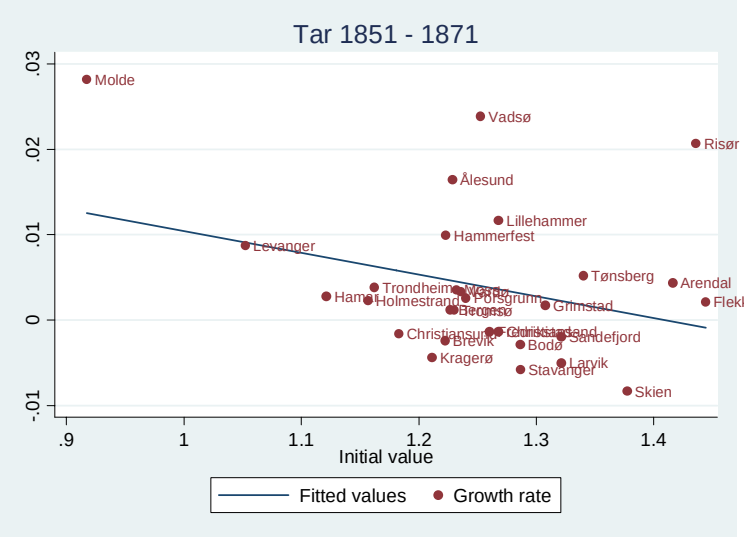

Linen 1851 - 1871
Fredrikstad
Tønsberg
Grimstad
Stavanger
Arendal
Flekkefjord
Holmestrand
Tromsø
Skien
Bergen
Lillehammer
Christiansund
Risør
Ålesund
Hamar
-.01
0
.01
.02
.03
3.4
3.5
3.6
3.7
3.8
3.9
Initial value
Fitted values
Growth rate

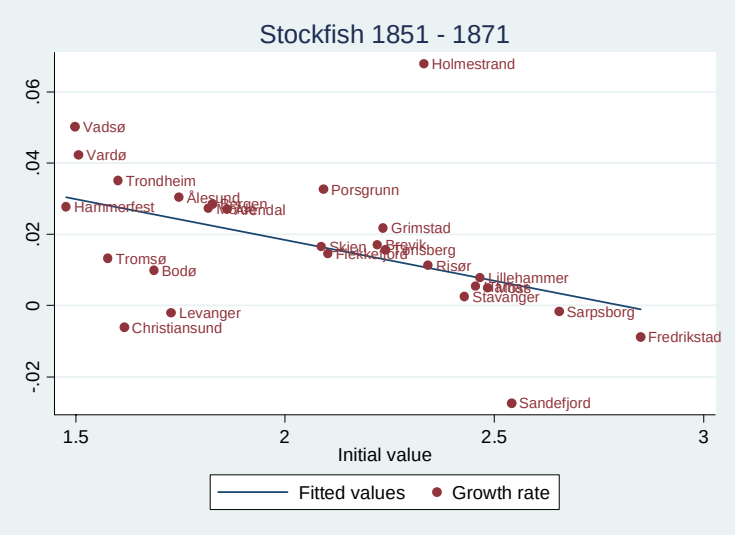

Potatoes 1851 - 1871
Fredrikstad
Drammen
Christiansund
Hamar
Bergen
Vadsø
Tønsberg
Lillehammer
Molde
Risør
Holmestrand
Fredrikshald
Grimstad
Kongsberg
Bodø
Vardø
Flekkefjord
Moss
Skien
Hammerfest
Tromsø
Arendal
-.01
0
.01
.02
.03
-.5
0
.5
1
Initial value
Fitted values
Growth rate

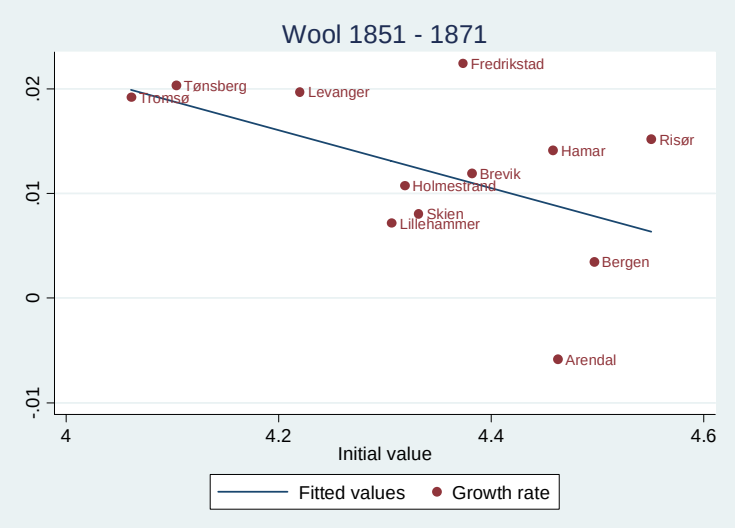

Rye 1851 - 1871
Kragerø
Larvik
Tønsberg
Fredrikshald
Ålesund
Kongsberg
Drammen
Fredrikstad
Sandefjord
Bergen
Tromsø
Trondheim
Holmestrand
Grimstad
Levanger
Lillehammer
Arendal
Christiania
Hamar
Molde
Risør
Christiansund
Bodø
Brevik
Kristiansand
Drøbak
Stavanger
Moss
Sarpsborg
Skien
Flekkefjord
Porsgrunn
.01
.005
0
-.005
-.01
1.1
1.2
1.3
1.4
1.5
Initial value
Fitted values
Growth rate


Salt 1851 - 1871
Christiansund
Porsgrunn
Holmestrand
Lillehammer
Ålesund
Kragerø
Arendal
Levanger
Molde
Flekkefjord
Vadsø
Tromsø
Stavanger
Grimstad
Bodø
Drammen
Fredrikstad
Tønsberg
Christiania
Hamar
Vardø
.02
.01
0
-.01
-.02
0
.2
.4
.6
.8
Initial value
Fitted values
Growth rate


Herring 1851 - 1871
Vadsø
Fredrikshald
Levanger
Ålesund
Molde
Fredrikstad
Stavanger
Brevik
Risør
Arendal
Tønsberg
Christiansund
Moss
Hammerfest
Bergen
Vardø
Bodø
Grimstad
Trondheim
Lillehammer
Flekkefjord
Hamar
Sarpsborg
Tromsø
Holmestrand
Skien
.03
.02
.01
0
-.01
.6
.8
1
1.2
1.4
1.6
Initial value
Fitted values
Growth rate


Tar 1851 - 1871
Molde
Vadsø
Risør
Ålesund
Lillehammer
Hammerfest
Levanger
Tønsberg
Arendal
Flekkefjord
Grimstad
Sandefjord
Bodø
Larvik
Kragerø
Stavanger
Skien
.03
.02
.01
0
-.01
.9
1
1.1
1.2
1.3
1.4
Initial value
Fitted values
Growth rate


Stockfish 1851 - 1871
Holmestrand
Vadsø
Vardø
Trondheim
Porsgrunn
Hammerfest
Grimstad
Tromsø
Bodø
Risør
Levanger
Sarpsborg
Christiansund
Fredrikstad
Sandefjord
.06
.04
.02
0
-.02
1.5
2
2.5
3
Initial value
Fitted values
Growth rate


Wool 1851 - 1871
Fredrikstad
Tønsberg
Levanger
Tromsø
Risør
Hamar
Brevik
Holmestrand
Skien
Lillehammer
Bergen
Arendal
.02
.01
0
-.01
4
4.2
4.4
4.6
Initial value
Fitted values
Growth rate