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Grain market integration in Sweden, 1732–1914

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Abstract

With new datasets being compiled and new methods introduced, the last two decades have seen a surge in papers investigating historic market integration. These papers have, however, mainly been concerned with international market integration. By applying a variety of statistical measures, including principal component analysis and coefficients of variation, to historical grain prices in Sweden this paper adds insight to the ongoing debate on the development and timing of national market integration. The findings of this paper indicate that the market integration process in Sweden was gradual rather than sudden and that Sweden started integrating early in comparison with other European countries. The fact that Sweden, at the same time, was relatively poorly integrated in the international market suggests that the main driving forces behind Swedish integration are to be found within Sweden. Improved transports, liberal domestic trade policies, and harsh agricultural conditions are possible explanations.

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1 Introduction

The prevailing view among leading economists and economic historians has long been that markets play a crucial role in the economic development of a country (see for instance Keller and Shiue 2007a). Well integrated markets create bigger incentives for specialization, capital accumulation, and technological change and are thus essential to economic development (North and Thomas 1973). Examining market structures will not only give a measure on how integrated and homogeneous an economy is but also tell us something about the relative importance of the different factors at play in an economy.[1]

Economic historians disagree on how the integration process unfolded, with scholars split between proponents of the theory of stepwise regional and national market integration and proponents of the so-called "big-bang" hypothesis, according to which European market integration happened very suddenly in the early 1800s (Chilosi et al. 2013). Market integration is also at the center of another debate that has increasingly occupied economic historians the last decade, namely the question of whether or not industrialization must be preceded by well functioning markets (the so-called "Smithian origin of the industrial revolution"). This theory has been supported by Studer (2009) but criticized by Keller and Shiue (2007b). Students of this idea have, however, mainly compared market integration across countries. There is thus, as Bateman (2011) points out, a need for further studies on the relation between within-country market integration and growth. As a matter of fact, recent research seems to indicate that domestic market integration "seems relatively more strongly correlated with growth" (Bateman 2011).

Against this background, the overarching purpose of this thesis is to contribute to the small but growing literature on the process of national market integration. I intend to do so by studying how market integration developed in Sweden. The scarcity of reliable historical data makes studies of historical market integration rather descriptive in nature. As such, adding another case study to the literature makes for better comparisons and so clarifies which factors that generally matter for domestic market integration. Thus, the main question of this paper is to find out when and how the different regions in Sweden integrated into one national market.

It is common to study grain prices when looking at historical market integration.[2] This is in part because of practical reasons (it tends to be easier to find historical data on grains than on other commodities) but in part also because grain dominated national output historically (Bateman 2011). Although grain has a high bulk-to-value ratio (i.e. farmers need cheap and

[1]For instance, O'Rourke and Williamson (2005) connect the rising wage to land rent ratios in 19$^{\text{th}}$ century England to increased market integration.

[2]Other markets, in particular textile, might, however, be better suited for the study of the "Smithian origin of the industrial revolution". See e.g. Daudin (2010).

high capacity transports in order to profit from grain trade) it can still be transported long distances (unlike e.g. eggs), thus making a good proxy of market integration in general (Chilosi et al. 2013). In addition, grains are relatively homogeneous products and consequently well suited for estimation of national or international market integration.

The good access to reliable historical price data makes Sweden a good object for students of historical market integration and the relative scarcity of such studies on Swedish data makes this quest relevant for our understanding of markets and industrialization. Other conditions that make Sweden suited for studies of historical grain market integration are that the Swedish domestic grain market grew rapidly in the late 18$^{\text{th}}$ century and that Swedish agriculture at the same time became more market-oriented (Edvinsson 2005). In addition, Sweden had, by the end of the 18$^{\text{th}}$ century, abolished all regulations of domestic grain trade (Åmark 1915). Although there exists a high quality data set containing yearly prices for grains and other commodities from 1732 onwards there has not been much research done on it.

This paper thus investigates grain market integration in Sweden in the 18$^{\text{th}}$ and 19$^{\text{th}}$ century and consequently tries to contribute to the ongoing discussions on the "Smithian origin of the industrial revolution" and on the nature of the European market integration processes. That is interesting for several reasons. First of all, Andersson and Ljungberg (2015) find that the Baltic Sea region was economically integrated by the mid 19$^{\text{th}}$ century. Should Sweden turn out to be less or equally internally integrated at this time this would strengthen the point made by Chilosi et al. (2013) that economic markets were not necessarily decided by political borders even for such a solid nation entity as Sweden. Furthermore, finding out when Sweden became economically integrated would, together with data on e.g. growth and infrastructure, also add insights to the ongoing debate on the Smithian growth process mentioned above and shed light on the importance of factors such as long geographical distances, foreign imports, and technological progress.

Estimating measures of market integration in Sweden would also reveal whether economic integration of this vast country happened quickly or gradually over a long period of time. Furthermore, an estimate of market integration in Sweden would also provide a relatively reliable measure that can be used to compare the Swedish economy with that of other countries in this period.[3]

Jörberg, who compiled the data set that will be used in this paper, and Bengtsson (1975) have written a brief paper in which they calculate coefficients of rye price variation for 11 Swedish

[3]The number of papers on national market integration is, for reasons of lacking data, a lot smaller than the number of papers looking into international market integration. See the literature review for the most important papers discussing market integration within nations.

provinces during five periods between 1732 and 1914. Price convergence alone is, however, as Gibson and Smout (1995) point out, an insufficient measure of grain market integration, as price volatility can change due to other factors than changed market integration, such as technical improvements in agriculture, changed climatic variability, or changed political and social stability. Therefore, I will complement a rolling coefficient of variation with a panel regression, a measure of the so-called σ-convergence, and a rolling correlation coefficient to reliably estimate price convergence and price volatility, two measures of market integration that together give us a more complete picture of the market integration process. I will also investigate further Jörberg and Bengtsson's (1975) hypothesis that the south of Sweden was in fact more integrated with Denmark than with Sweden by using Danish grain data and principal component analysis. Principal component analysis is "the latest evolution of the co-movement approach" (Federico 2012) and will as such discern how Swedish regions integrated. Another hypothesis put forward by Jörberg and Bengtsson (1975) that deserves a closer look is that the market integration process was in part driven by international trade relations. By including data from two of the most important grain exporting harbors, namely Danzig (today's Gdańsk) and Königsberg (today's Kaliningrad)[4] in the data set also this question will be analyzed by the principal components analysis. While Sweden imported grain in the 18$^{\text{th}}$ century it basically ceased imports from 1820 to 1850, providing interesting comparisons (Åmark 1915).

The remainder of the paper proceeds as follows. In Section 2 I give an overview of the literature on grain market integration. In Section 3 I define market integration and outline the estimation strategies. In Section 4 I discuss and describe the data used. Finally, Section 5 contains results and Section 6 concludes.

[4]In the 1700s, Sweden's grain imports came predominantly from Russia, Danzig, Prussia and Swedish Pomerania. While Königsberg was Prussia's most important harbor, I have not found data for Russia and Swedish Pomerania.

2 Literature Review

2.1 Grain market integration within nation states

Lack of price data as well as constantly changing borders have restricted the number of papers on national market integration. Nevertheless there has been research done on some Western European countries, India, parts of China, and the US in the late 19th century. Gibson and Smout (1995) emphasize that credible estimation of a nation's market integration requires a multitude of statistical techniques. To the previous research on Scottish grain market integration they add correlation coefficients for pairs of Scottish cities and draw the conclusion that the market integration was a lengthy and far from straightforward process, spanning from 1640 to 1780. Brunt and Cannon (2013) use weekly wheat prices from English and Welsh towns and an error correction model (ECM) to estimate the wheat market integration between 1770 and 1820. They also regress different measures of market integration on transport and information variables and find that market integration remains high and stable through the Napoleonic wars and the rapidly improving infrastructure. Federico (2007) uses similar data and methods to investigate when and why Italy became economically integrated and concludes that Italy was well integrated already before the *Risorgimento* and that the years following the unification were actually marked by market disintegration. Moreover, the results indicate that the price convergence was mainly driven by improved maritime transportation that opened up for international competition. Railway construction and trade liberalization mainly affected northern Italy.

In the early 1990s the French economist Bertrand M. Roehner compiled and published biweekly wheat prices for 53 French cities 1825–1913. Roehner (1994) and Ejrnæs and Persson (2000) use this data for market integration analyses. Roehner finds that market integration in France was not a long-term evolution, but rather an "accélération brutale" that took place in the period 1820–1855 (Roehner 1994, p. 358). Remarkably, this integration was very much a intranational one, as French grain markets did not integrate with the world market until later. Arguing that price convergence possibly mirrors a decrease in transport costs and not increased market integration Ejrnæs and Persson include transport costs in an threshold error correction model. Their results partly corroborate Roehner's findings: France saw increased grain market integration 1825–1835 and 1855–1865 and could on the whole be said to be well integrated by the end of the 19th century.

In a seminal paper Keller and Shiue (2007b) tackle Adam Smith's hypothesis that industrialization must be preceded by a well-integrated market. Keller and Shiue use grain price cointegration to compare the spatial integration in Western Europe and China, two advanced preindustrial economies that became industrialized 150 years apart. Keller and Shiue find that the markets in Western Europe were only marginally better integrated than the markets in China but that market integration in Western Europe increased rapidly in the decades following the industrial revolution. On the other hand, England, which industrialized first, had a pre-industrialization market integration that was a lot higher than in China and in the rest of Europe. Another study on this theme is Studer's (2008) paper on markets in 18$^{\text{th}}$ and 19$^{\text{th}}$ century India. A national grain market did not emerge in India until the very end of the 19$^{\text{th}}$ century, and even then Studer deems it "incomplete," suggesting that India was lagging behind Western Europe already in the 18$^{\text{th}}$ century.

In a paper that Federico (2012) called "pioneering, but sadly neglegted," Sánchez-Albornoz (1974) has gathered annual wheat and barley prices from 1857 to 1890 for 48 Spanish provinces. To the conventional statistical methods that had hitherto been used Sánchez-Albornoz add factor analysis where the provinces constitute the variables. The factor analysis reveals that the Spanish economic regions were congruent with the old historical regions. In 1975 Jörberg and Bengtsson (1975) published a paper based on the newly compiled price data. They use rye prices and a small sample of Swedish provinces to investigate market integration. Based on coefficients of variation for the periods 1732–1798 and 1799–1869 and correlations between Malmö and Copenhagen and Göteborg and Amsterdam they conclude that Sweden had become well integrated by the first half of the 19$^{\text{th}}$ century and that the role of international trade in this proces needs further investigation. The other paper focusing solely on Swedish market integration was published in 2016 by Crucini and Smith. They use commodity price data from Jörberg to regress price dispersion on distances between the biggest market towns in the provinces. They find that effect of distance on price dispersion diminished during the 18$^{\text{th}}$ and 19$^{\text{th}}$ century, albeit not monotonically. Although Jörberg (1972a, 1972b), Jörberg and Bengtsson (1975), and Crucini and Smith (2016) have laid the foundation for studies of Swedish market integration there is still need for further research. To begin with, Jörberg uses only rye for a limited amount of provinces and the only grain Crucini and Smith include in their price basket is wheat. This could be problematic, as conclusions based on wheat prices not necessarily apply to other grains (Bateman 2011). The debate on European market integration would also benefit from having a preciser measure of when Sweden integrated than the one given by Jörberg and a closer look at potential periods of slowed down market integration suggested by Crucini and Smith.

2.2 Grain market integration across nation states

In a literature survey Federico (2012) sums up the main results and methodological insights that have been made on the topic of historical market integration. The number of papers published are evenly distributed between time periods and national/international approaches. Federico also makes a clear distinction between market efficiency and "the law of one price" and argues that the latter is much more relevant for understanding long term growth. Federico notes that the results are somewhat ambiguous on both the process and the timing of the European market integration. For instance, Persson (1999) sees evidence of an emerging common European wheat market already in the 18$^{\text{th}}$ century. The main view is, however, that market integration between the major European countries started only in the early 19$^{\text{th}}$ century and was completed around hundred years later (Federico 2012). Integration across nations also increased in the early 1800s but then slowed down or reversed due to protectionist policies. These insights have been arrived at through different methods and for different markets. Jacks (2005), for instance, examines wheat prices in 19$^{\text{th}}$ century Europe and USA through an error correction model and price convergence for city pairs. Federico and Persson (2007) add Sweden to Jacks' data set and the coefficient of variation and price variance decomposition to his methodology and arrive at the same conclusions. Bateman (2011) analyzes market integration in Europe with a wheat price data set that ranges from the 14$^{\text{th}}$ to the 18$^{\text{th}}$ century. Over the course of this long period Europe experienced waves of integration and disintegration. In her conlusion she ties in to the debate on market integration and growth, stating that there is no clear relationship between economic growth and the integration of any one country into the European market.

Despite the fact that increasingly large data sets call for more sophisticated statistical methods there has not been many published papers on historical grain market integration that make use of factor analysis as initiated by Sánchez-Albornoz. Chilosi et al. (2013) apply principal component analysis (PCA) on the biggest grain price data set compiled to date (a set that nonetheless excludes Scandinavian data) to sketch out the European market integration development from the early 1600s onward. They use the geographical regions suggested by the PCA as units of observation in the rest of the study. Interestingly enough, these regions often ignore political borders already in the 1700s. They then use conventional methods, such as coefficients of variation and measurements of price volatility, to discern the market integration development and find that European markets integrated gradually and stepwise over a long period of time. On national level England and the Netherlands are among the first to integrate, and Chilosi et al. conjecture that political centralization and maritime transport are important factors behind this. Related to PCA is the dynamic factor model used by Uebele (2011) on a dataset consisting of Western European and American wheat prices. Like Chilosi et al., Uebele finds that some countries (e.g. the UK) integrated nationally first and internationally thereafter and that some countries experienced the reverse (e.g. Austria-Hungary). At the end of the 1800s Sweden belonged to the least internationally integrated Western European countries. As possible explanations for the fact that the largest increases in European market integration happened in the first half of the 19th century, and not in the second half (when transports improved the most) Uebele mentions more liberal trade politics, better organization, and "non-revolutionary transport infrastructure improvements" (Uebele, 2011 p. 238).

3 Model

3.1 Definition of market integration

As is conventional in the literature on historical market integration this paper will use the definition of market integration that the French economist Cournot formulated in his *Recherches sur les principles mathématiques de la théorie des richesses* published in 1838.[5] Using Cournot's definition allows for comparisons with the results found in other papers, something that is highly preferable given our research question. As quoted by Federico, Cournot defines an integrated market as "an entire territory of which the parts are so united by the relations of unrestricted commerce that prices take the same level throughout with ease and rapidity" (Federico 2012). There are thus two aspects in this definition of market integration, namely how far apart the prices in the different areas are (in other words, if the "law of one price" applies) and how fast they return to equilibrium after a shock (i.e. how efficient the market is). The "law of one price" can be easily formalized as follows. Two markets are integrated if:

$$|P_i - P_j| \leq T_{ij} \tag{1}$$

where T_{ij}, in the literature called "commodity points," is the cost of moving goods[6] from market i to market j. Should the price difference between the two markets exceed the transport cost this differential should be arbitraged away. In practice this means that, given low transport costs, we should then see prices converge. The condition for two markets can be extended to three or more markets:

$$|P_i - P_k| \leq T_{ik} \quad \text{and} \quad |P_j - P_k| \leq T_{jk} \quad \text{and} \quad |P_i - P_j| \leq |T_{ik} - T_{jk} \tag{2}$$

[5]There are, of course, other definitions of market integration, see e.g. Samuelson (1952) and (Fama) 1970. One can also imagine a market integration definition that considers population, so that Sweden can be considered integrated when a certain share of its population faces similar prices. As Sweden was a very rural society well into 1800s, with only three cities having more than 10 000 inhabitants in the early 1800s (SCB 2015), measuring market integration using only geographical units would not greatly change the conclusions. Using only provinces is also standard within the literature.

[6]Although the cost of moving goods is most easily thought of as actual transportation cost, it could also be insurance cost, storage cost or unobserved costs such as information costs or risk aversion from the agents.

Still, price convergence between any two markets is not necessarily the result of increased trade due to, say, lower transport costs or lower tariffs only. It could also come from increased market efficiency, increased indirect arbitrage (i.e. arbitrage between two markets that are not trading directly with each other), or agents in one market has information on price development in the other market and consequently makes preventive price changes. Without extensive data on actual trade flows we can only make conjectures about the causes of price convergence.

As the "law of one price" is almost never met in practice we run into problems of deciding how small the price difference between two markets must be for the two markets to be considered integrated. Some economists (e.g. Moser et al. 2009) suggest that the "law of one price" holds when the price difference equals the transport cost and call this "perfect integration." This would, however, lead us to consider markets with a one percent price difference and markets with a 1000 percent price difference as equally integrated, which does not make sense. Estimating and analyzing historical market integration will thus be a task of comparison: across countries and over time (O'Rourke and Williamson 2004). In addition, as historical data on trade flows, transportation costs, climate, and other factors that affect price dynamics are very limited, we cannot control for these when assessing the market integration. We must thus be careful when interpreting our results.

It is very difficult to gauge the market efficiency directly as transport costs, information costs, and the traders' assessment of the risk of price can scarcely be precisely estimated. Consequently, market efficiency will here be gauged indirectly, through statistical analysis of the price series. Ideally we would like to have monthly or weekly data to measure market efficiency as annual data obviously will not capture the speed of adjustment to a price shock if it is under a year (Taylor 2001). No method can measure price convergence and market efficiency simultaneously. As our annual data is not ideal for measurements of market efficiency, this paper will focus on the first condition of market integration. This condition is clearly separable from the second condition,[7] which could be considered as a measure of the *degree of market integration*, and also much more important than market efficiency for long-term economic growth (Goodwin and Solakoglu 2005, Federico 2012). Also, Federico (2012) notes that works on historical domestic integration are heavily skewed towards measures of market efficiency, leaving a gap to fill for studies targeting price convergence. Nonetheless, I will complement the measures of price convergence with blunt measures of price volatility and price comovement to estimate market efficiency. Although blunt, these measures make for a fuller picture of the market integration development than if I would have only looked at price convergence. In this paper I will thus

[7]Prices could return slowly to an equilibrium level or return fast to a non-equilibrium level.

use a variety of models, each with its respective advantages and disadvantages, to look at price convergence and volatility. Should prices converge and volatility fall this would strongly indicate integrating markets. One must also keep in mind that the development of the "law of one price" and market efficiency do not necessarily go hand in hand (markets might be efficient even though trading costs are high), making the question of market integration still more complex.

3.2 Price convergence and the "law of one price"

One way of measuring the extent to which the "law of one price" holds is to look at price convergence. An often used method to capture the price dispersion across markets is to compute the coefficient of variation (CV) in each time period. This coefficient of variation (the standard deviation divided by the mean) has the advantage that it is dimensionless and thus easily comparable over time and space. It is also insensitive to indirect arbitrage. Moreover, the CV is robust to errors in the data and quality differences between markets[8] and between time periods, a problem that can be serious in analyses of historical price data (Federico 2011, 2012). Federico (2011) shows that this potential bias is bigger for markets that are already well integrated and that these effects tend to offset each other and be compensated for by time-invariant price differentials. When calculating the CVs the observed prices are assumed to be in equilibrium. This assumption is likely to hold for annual average prices (Federico 2012). As the yearly coefficients of variation refer to cross-sections of markets they constitute a time series of their own, on which we can apply standard econometric methods. One can look at the annual CVs as they are or, provided that this series is trend-stationary,[9] run the log-linear regression:

$$\ln(\mathrm{CV_t}) = \alpha + \sigma \mathrm{TIME} + \epsilon_t \tag{3}$$

, to calculate the rate of price convergence. Decreasing CVs (i.e. statistically significant negative σ-values), or so-called sigma convergence, point to increasing market integration as prices will stabilize if national output varies less than province output, which is usually the case for grains (Bateman 2011). Should we discover breaks in this time series these could imply historical events with consequences for market integration. To test for breaks I will use the model developed by Bai and Perron (2003). This model starts from the basic regression model:

$$y_t = x_t^{\intercal} \beta_t + e_t \tag{4}$$

[8]For example, a quality improvement in a high-price market or a worsening in a low-price market would lead to an upward bias in price dispersion.

[9]A stationary, not trend-stationary, series would, by definition, imply that markets are not integrating or disintegrating.

, where y_t is the dependent variable at time t, x_t is a vector of regressors and β_t is a vector of coefficients, that potentially vary over time. Assuming we have m breakpoints, and thus $m+1$ time segments, where the βs change we can rewrite (4) as:

$$y_t = x_t^\intercal \beta_t + e_j \qquad (t = t_{j-1}+1, ..., \quad j = 1, ..., m+1) \tag{5}$$

, where j is the so-called segment index, $\mathscr{I}_{m,n} = \{i = i_1, ..., i_m\}$ and denotes the set of breakpoints, with $i_0 = 0$ and $i_{m+1} = n$. We then test the null hypothesis that regression coefficients remain constant:

$$H_0 = \quad \beta_t = \beta_0 \quad (t = 1, ..., n) \tag{6}$$

against the alternative hypothesis that at least one coefficient changes over time. The number of breakpoints are not given exogenously, but estimated by minimizing the residual sum of squares (RSS) from Equation (4). Given the number of breaks the optimal breakpoints are then arrived at using a dynamic programming approach, where the optimal breakpoints satisfy:

$$RSS(\mathscr{I}_{m,n}) = \min_{mn_h \leq i \leq n-n_h} \left[RSS(\mathscr{I}_{m-1,i}) + rss(i+1, n) \right] \tag{7}$$

Comparing the different number of break dates, I then choose the model with the lowest BIC-value, as recommended by Zeileis et al. (2003).

Yet another way of exploiting geographical dispersion is to examine the percentage price gaps between all possible pairs of provinces and see whether they converge to zero or not. This can be done through compiling these differences[10] for each year to a data set on which we then run a fixed effects panel regression similar to equation (3), using time dummies as explanatory variable.[11] The estimated coefficients for the time dummies would then depict the development of the average percentage price gap. Extracting the average price gap trend this way, as opposed to simply graphing the mean pair difference, allows us to control for the fact that the province pairs, that depend on the data at hand, drop in and out over time. This method does, however, as Bateman (2011) points out, hinge on the assumption that all provinces trade with each other, directly or through a third province. What is more, Federico (2012) highlights that the interpretation of the results is not straightforward. An insignificant coefficient for a time dummy could mean either that there was no change in price difference across all the pairs or that some pairwise differences rose while others declined, implying integration in some areas and

[10]Given that we have n geographical units, that gives $\frac{\binom{n}{n-2}}{2}$ combinations.

[11]Following Bateman (2011) I will use 20-year intervals as time dummies.

disintegration in others. It will thus serve primarily as a complement to the CVs.

3.3 Price volatility, price comovement, and market efficiency

As has already been established, this paper cannot use the speed of adjustment back to equilibrium price after a shock to gauge market efficiency. Hence, we must turn to other methods. This entails an assumption that Swedish grain markets adjust to price shocks within a year. This is an assumption that also Chilosi et al. (2013) and Uebele (2011) make.[12] Market efficiency can, then, be estimated by simply looking at price volatility in the individual provinces.[13] This follows from the reasoning that a more efficient national market should make provinces less vulnerable to supply or demand shocks, leading to decreased price volatility (Persson 1999). This measure of market efficiency is, however, not unproblematic. Decreasing price volatility could, for instance, follow from climatic changes (better weather implies less variability in harvest yields) or from cost reduction in grain storage. Also, in some cases a more efficient market (meaning more exposure to shocks in other provinces or abroad) could lead to increased price volatility (Chilosi et al. 2013). It is thus important to interpret price volatility together with price comovement. Price volatility will be measured with the average 11 years rolling coefficient of variation of prices in each province. To avoid spurious correlation (which could be caused by e.g. inflation) we here use differenced price series. Price comovement will be estimated using the average 21-years rolling correlation between the prices in the provinces and the average price. To avoid spurious correlation, coming from e.g. inflation, the price series were first differenced.

3.4 Principal component analysis

Principle component analysis is a statistical technique that can be used to investigate interrelationships between numerical variables and classify these variables in terms of their common underlying dimensions. The only assumption of PCA is that there indeed is some underlying structure in the variables. This assumption is of course untestable. To find this underlying factor[14] that affects several variables, PCA searches for strong correlations between the different variables. To avoid spurious correlation we will here use differenced data. It then creates a new variable, a factor, that is a linear combination of the correlated variables and that explains as much as possible of the variance in the dataset. It then removes this variance and creates a new

[12]Bateman (2011) and Federico (2011) showed that grain markets in 18th century Western Europe and 19th century Italy adjusted to shocks in a matter of months and weeks respectively.

[13]A decline in price volatility would not only imply market integration but would also be an important welfare improvement, especially in a pre-industrial society where price instability was a common cause of civil unrest (Ravallion 1987).

[14]In the case of price dynamics, such a factor could be political borders, trade routes, geography, distance, etc.

factor that explains as much as possible of the remaining variance and so on. I use standardized data[15] as there is no reason to believe that provinces with big variance in price are more important than provinces with small variances. To be able to say something about what structure permeates the dataset I look at the component "loadings," i.e. the correlation coefficients between individual variables and the component. As a rule of thumb, loadings higher than 0.5 make for meaningful interpretation and loadings higher than 0.7 indicate a well-defined structure. The benefit of PCA is thus that it condenses the information contained in the original variables into a smaller set (called principal components) of factors with a minimal loss of information. There is a number of ways to decide the number of principal components that suffice to summarize the original dataset. I will here follow follow the so-called latent root criterion, which recommends keeping principal components with an eigenvalue bigger than 0.7. Like Chilosi et al. I will use the varimax method when rotating component matrix. The benefit of using PCA in this paper is twofold: by applying it to different time periods it allows to see when the provinces integrated and by including the Danish market in the PCA we can see whether the Danish market is connected to any Swedish province or whether it forms a market (or a principal component) of its own.

4 Data

The Swedish data used in this paper has been collected from the book *A History of Prices in Sweden 1732–1914*, in which economic historian Lennart Jörberg has compiled price data on grains and a number of other commodities for the years 1732 through 1914. The prices come from so-called price scales that formed the basis for tax and tithe payments.[16] These prices are, however, very close to the actual market prices (Jörberg 1972a). The grain price data is divided into three different currencies, daler silvermynt with 32 öre per daler (1732–1775), riksdaler specie with 48 shilling per riksdaler (1776–1802) and kronor (1803–1914), and two different weight units, barrel (1732–1802) and hectoliter (1803–1914). In this paper the pre-1803 data has been converted to kronor per hectoliter, following the conversion rates laid out by Jörberg.[17] The grain price data consists of annual averages collected in market towns in 34 provinces[18] around *Thomasmäss*, i.e. at the end of December. Grain trade, unlike some other

[15] I.e. we subtract the mean from each observation and then divide it by the respective standard deviation.

[16] The price scales were uniform, and thus comparable across provinces and over time (Jörberg 1972a).

[17] Any potential errors that are found in the original sources or come from the price conversion will be assumed to be randomly distributed.

[18] Although Finland was a part of Sweden until 1809 and Norway and Sweden formed a union 1814–1905 there are no Finnish or Norwegian provinces included. The lack of Finnish data could pose a problem when investigating whether Swedish market integration was affected by foreign trade, as one could suspect that Swedish–Finnish trading patterns remained also after 1809. It should thus also be kept in mind that when talking about, and

commodities, took place throughout the year, making also average prices informative (Brunt and Cannon 2014). The grains used in this paper are wheat, rye, barley, and oats. It is standard in the literature to use wheat only, but by adding three grains we increase the generalizability (Bateman 2011). In the cases where an odd year misses a value a price has been imputed through linear interpolation.[19] Danish price data come from the book *A History of Prices and Wages in Denmark 1660–1800* by Friis and Glamann. These data consist of annual average prices in skilling per barrel (*tønde*) for rye, oats, and barley. Barley and rye prices in Danzig and Königsberg (both in English pence per England grain quarter) 1732–1800 have been taken from the Allen-Unger Global Commodity Prices Database. Previous studies have established that although grains across northern European countries might not be entirely homogeneous the measurement errors stemming from this fact are negligible (see e.g. Rogoff et al. 2001). In addition, the relative grain quality did not change until the end of the 19$^{\text{th}}$ century when "industrial" varieties of seeds were introduced (Federico 2011). The time span and frequency allow for examination of the "law of one price" but might not be ideal for measures of market efficiency.[20] As already mentioned, annual prices will not capture the speed of adjustment to a price shock if it is under a year. Moreover, Taylor (2001) shows that parameters estimated from average prices (such as, for instance, an annual price that consists of the average of the monthly prices) will suffer from *temporal aggregation* and thus be inconsistent. This bias would then lead us to under-estimate the speed of adjustment back to equilibrium prices.

comparing, Swedish historical market integration I mean the geographical entity that constitutes today's Sweden.

[19] Changing imputation method to Kalman smoothing, which is used by e.g. Persson (2009), does not change the results considerably.

[20] For price convergence annual data is even preferable to high frequency data. See e.g. Brunt and Cannon (2014) p. 112 and Federico (2012) p. 482 and pp. 487–488.

Table 1: Price series.

Province	Barley	Oats	Rye	Wheat
1 Stockholm	1732–1914*	1732–1914*	1732–1914*	1732–1914*
2 Uppsala	1732–1914	1732–1914*	1732–1914	1732–1914*
3 Södermanland	1732–1914	1732–1914	1732–1914	1732–1914
4 Östergötland	1732–1914	1732–1914*	1732–1914	1732–1914
5 Jönköping	1733–1740* 1750–1914*	1732–1914	1732–1914*	1855–1914
6 Kronoberg	1744–1914	1732–1914*	1732–1914*	–
7 Kalmar	1732–1914*	1732–1914*	1732–1914*	1776–1914
7a Öland	1820–1914	1820–1914	1820–1914 1820–1914	
8 Gotland	1732–1914*	1732–1914*	1732–1914*	1738–1748 1840–1914
9 Blekinge	1732–1914*	1845–1914	1732–1914*	1742–1757 1849–1914
10 Kristianstad	1869–1914	1869–1914	1869–1914	1869–1914
10a Kristianstad	1732–1868*	1732–1868*	1732–1868*	1839–1868
10b Ängelholm	1732–1868*	1732–1868*	1732–1868*	1839–1868
10c Simrishamn	1732–1868*	1732–1868	1732–1868*	1839–1868
11 Malmöhus	1732–1914*	1732-1914*	1732-1914*	1877-1914
12 Halland	1732–1914	1732–1914	1732–1914	1732–1914
13 Göteborg Bohus	1732–1914	1732–1914	1732–1914	1853–1914
14 Ästerborg	1732–1914*	1732–1914*	1732-1914*	1830–1914
15 Skaraborg	1732–1914*	1732–1914	1732-1914*	1732-1914*
16 Värmland	1732–1914	1732–1914	1732–1914	1732–1803 1851–1914
17 Örebro	1886–1914	1886–1914	1886–1914	1886–1914
17a Närke	1732–1885	1732–1885	1732–1885	1732–1885
17b Nora/Linde/Karlskoga	1732–1885	1732–1885*	1732–1885	1732–1885
18 Västmanland	1732–1914	1732–1914*	1732–1914	1732-1914*
19 Kopparberg	1732–1914*	1732–1914*	1732-1914*	1741–1782* 1837–1914
20a Gästrikland	1732–1914*	1732–1914*	1732-1914*	1732-1914*
20b Hälsingland	1732–1914*	1732–1914*	1732–1914*	1742–1914
21 Västernorrland	1774–1914	1773–1802 1839–1914	1774–1914	1743–1756*
21a Medelpad	1732–1773*	1732–1773* 1803-1839	1732–1773*	–
21b Ångermanland	1732–1773*	1732–1773*	1732–1773*	–
22a Härjedalen	1776–1914	1819–1884	1776–1914	–
22b Jämtland	1732–1766* 1794–1914*	1742–1769* 1791-1914*	1732–1769* 1794-1914*	1743–1756*
23 Västerbotten	1732–1914*	–	1732-1767* 1794–1914	–
24 Norrbotten	1757–1774 1811–1914	–	1752–1767 1811–1914	–
Copenhagen	1732–1800*	1732-1800*	1732–1914*	–
Danzig	1732–1800*	–	1732–1800	–
Königsberg	1732–1800	–	1732–1800	–

Price series with an * have occasional missing values.

Figure 1: The provinces of Sweden. Source: Jörberg (1972a).

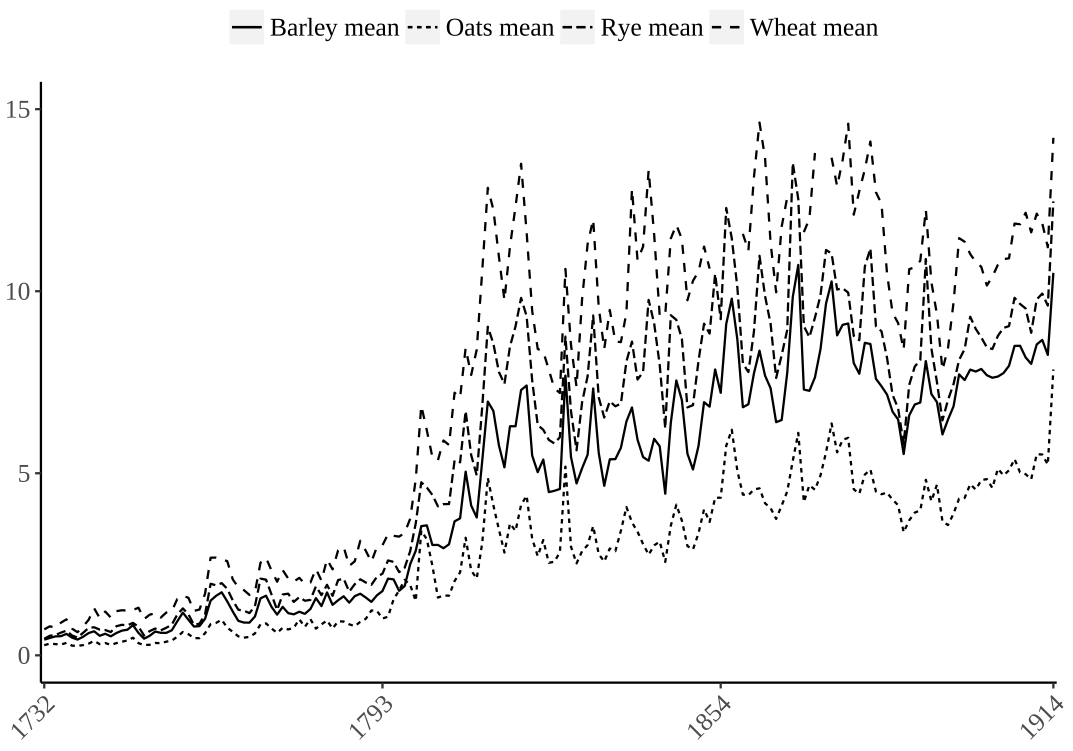

Figure 2: Mean prices, kronor per hectoliter, 1732–1914.

4.1 Summary characterization of the data

A starting point for further data examination is to look at yearly average prices. These are depicted in Figure 2. Wheat is clearly the most expensive grain and oats is just as clearly the cheapest one. It is also evident that there is high conformity in the grain price movements. Population growth and wars caused sharply rising grain prices and high inflation at the end of the 18$^{\text{th}}$ and beginning of the 19$^{\text{th}}$ century (Schön 1997). Another interesting question is to see how the relative prices changed over time, which can be measured via correlations as below:

$$corr(p_{i,y}, p_{i,y+1}) = \frac{\sum_i (p_{i,y} - \bar{p}_y)(p_{i,y+1} - \bar{p}_{y+1})}{\sqrt{\sum_i (p_{i,y+1} - \bar{p}_{y+1})^2 \sum_i (p_{i,y+1} - \bar{p}_y)^2}} \tag{8}$$

, where $p_{i,y}$ is the natural logarithm of the price in province i in year y. Should the relative prices in the different provinces stay the same over time the value of the statistic would be one. These correlations for consecutive pairs of years are plotted in Figure 3. In general the correlations are positive, meaning few changes in relative price. The relative prices of wheat did, however, vary in the first half of the 19$^{\text{th}}$ century.

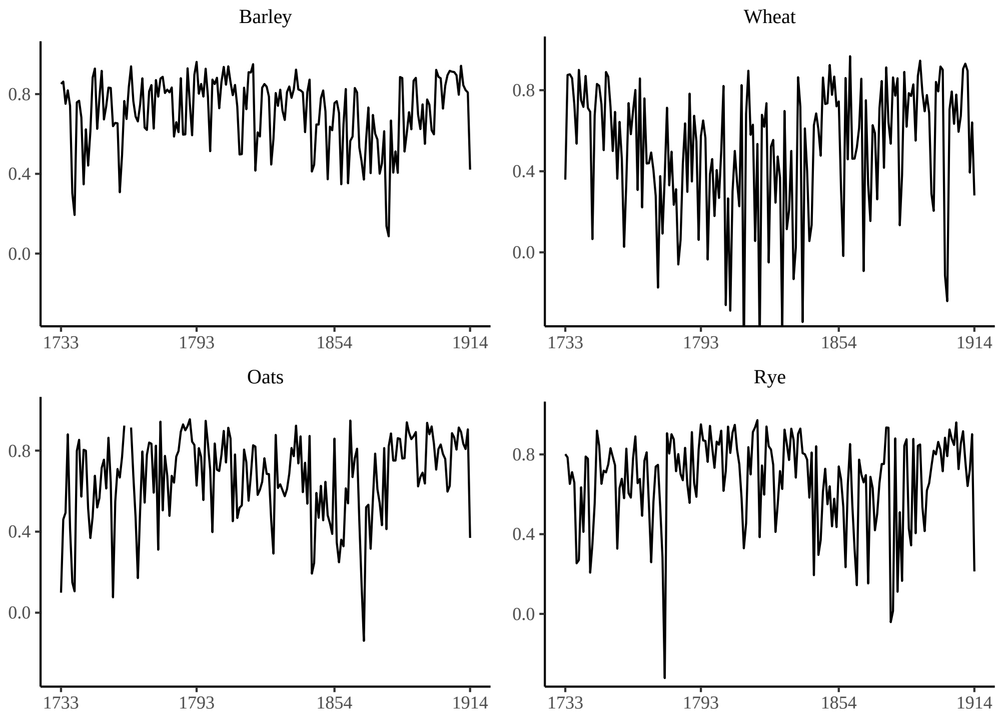

Figure 3: Year-on-year correlations between prices.

This approach is aspatial, however, and says little about any spatial interdependence that might exist and that might influence results. This is a concern as market integration, at least in trade of physical goods, is inherently spatial and likewise influenced by geography (e.g. production conditions, transaction costs). A widely used tool to show the role of geography in the data (see e.g. Keller and Shiue 2007c) is the so-called Moran's I-statistic, which is calculated for each year:

$$I_k = \frac{N \sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij} z_i z_j}{2J_k \sum_{i=1}^{N} z_i^2} \quad , i \neq j \tag{9}$$

, where N is the number of provinces, $w_{ij} = 1$ if provinces i and j are adjacent[21] and zero otherwise, p_i is the log price in province i, $\bar{p}$ is the average log price, $z_i = p_i - \bar{p}$ and J_k is the number of non-zero values of w_{ij}. Moran's I-statistic measures spatial autocorrelation and ranges between -1, indicating negative spatial autocorrelation (i.e. high-price provinces and low-price provinces are clustered together), and 1, indicating positive spatial autocorrelation (i.e. high-price provinces are surrounded by low-price provinces and vice versa). The z_I-score for the I-statistic is:

$$z_I = \frac{I - E[I]}{\sqrt{V[I]}} \tag{10}$$

, where the null hypothesis is that the spatial distribution of high and low-price provinces is random. Table 2 displays p-values for the I-statistic for the years 1732 and 1914, the first and last year in our sample. For barley and rye prices the null hypothesis can be rejected on the 5 percent significance level. For the other grains and the other year we cannot reject the null hypothesis. This means that we have reason to believe that Swedish barley and rye prices have gone from being spatially autocorrelated to randomly distributed. Lack of spatial autocorrelation could indicate national market integration, assuming that the regional markets were found in geographical clusters. As grain trade was limited to designated market towns before 1775 the provinces used by Jörberg might not be the optimal for calculations of Moran's I. For instance, the biggest market town in Kopparberg, Falun, is closer to the province of Uppsala than to the neighbouring province Härjedalen. Therefore, Moran's I was also calculated using the distances[22] between the biggest market town in each province as the weight matrix w_{ij}. The resulting p-values can be found in Table 13 in the appendix and are very similar to those obtained using the provinces as geographical units.

Table 2: P-values for Moran's I.

Year	Barley	Oats	Rye	Wheat
1732	0.000	0.336	0.000	0.085
1914	0.115	0.151	0.245	0.713

[21] I have also counted provinces that are separated by a lake as adjacent, so that e.g. Skaraborg and Östergötland are adjacent.

[22] The distances were calculated as the crow flies, not based on actual roads. The distances were calculated using latitude and longitude coordinates and not spherical coordinates. This should not be a problem in this case, as the distances are not very long.

5 Results

5.1 Price convergence

The coefficients of variation are plotted in Figure 4. All grains show a clear downward trend and have coefficients below 0.2 by the beginning of the 19th century. In the latter half of the 19th century all price series oscillate around 0.1. The CVs for wheat and rye are markedly lower than the other CV:s, especially in the 18th century. The fact that the CVs are lowest for the two most expensive grains could reflect that transport costs matter. Nominal transport costs are the same but the *relative* cost is smaller for the more expensive grain. Hence, the trade barriers are smaller and wheat and rye will integrate first. Should this rationale explain why wheat and rye prices converge earlier this would imply that transportation costs were important to market integration already before the arrival of the big canals and the railway. These new transportation methods did, however, lower the transport costs (Thorburn 2000), which could possibly explain why the CVs of the two cheaper grains, barley and oats, catch up with rye and wheat in the second half of the 19th century. There is, on the other hand, a possibility that the relatively lower wheat price CVs can be explained by the fact that the sample composition differs from that of the other three grains. Should, for instance, the wheat prices in Västerbotten, Norrbotten, and Härjedalen, provinces that lack wheat price data,[23] be very different from the wheat prices in the rest of Sweden, the CVs would be higher.

To test for breaks in the data I fit a constant to the data and use the Bai and Perron test. The results, depicted in figure 5, are ambiguous.[24] The mean does indeed change over time but there seems to be no clear break year across the grains. The price series for barley and wheat both have breaks in the 1760s whereas oats and rye prices have a first break a decade later, in the beginning of a period of high inflation and grain price increases. Both barley and oats prices show breaks in the 1830s and around 1870, starting years for the new canals and railroads respectively. Moreover, around 1830 oats started to be exported in large quantities, which could perhaps lead to foreign demand leveling out prices also within Sweden (Berg 2007). This quick rise in oats exportation[25] did, however die out very rapidly after the 1870s as cheap American grains entered the world market (Fridlizius 1957, O'Rourke 1997). The late break points in the barley and oats series imply that although Sweden, like Jörberg and Bengtsson (1975) claim, was well-integrated already in the middle of the 1800s, market integration was still improving

[23] Jörberg does not state why there is no wheat price data for these provinces. Should, however, the lack of wheat price data come from the fact that wheat does not grow this far north, it could imply that wheat trade with the northern provinces was not very extensive.

[24] The mean values for the different periods as well as the 95% confidence intervals for the break years and BIC and RSS-values can be obtained from the author.

[25] In the late 1870s oats was the second most exported Swedish item (Fridlizius 1957).

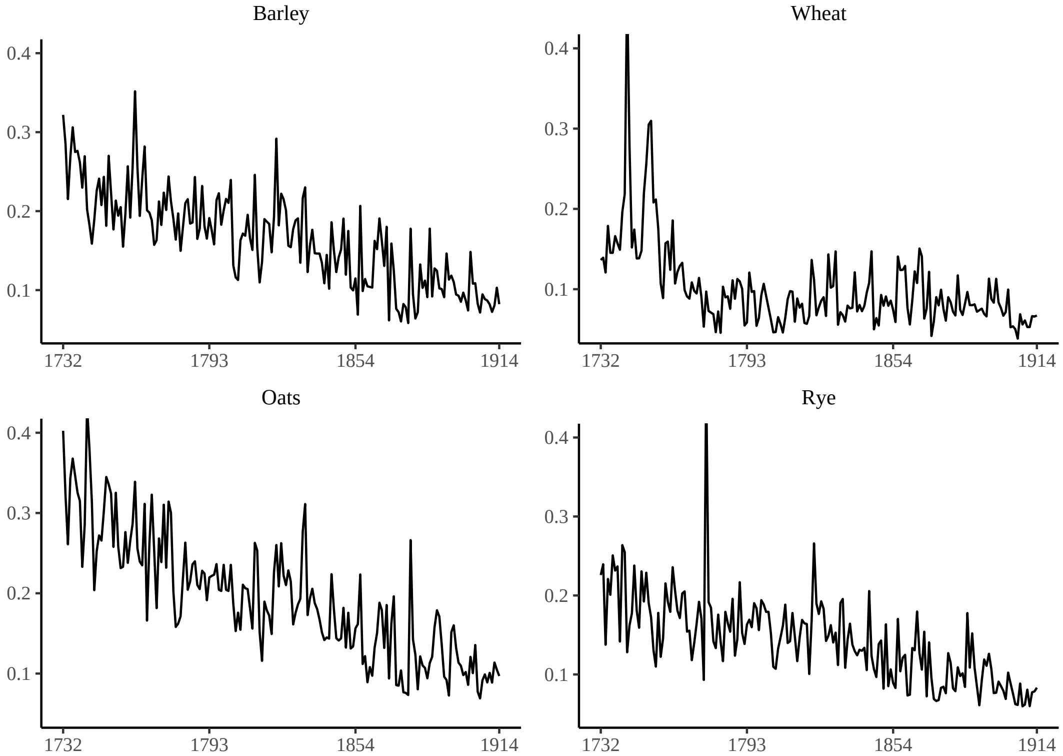

Figure 4: Coefficients of variation.

well into the late 1800s.

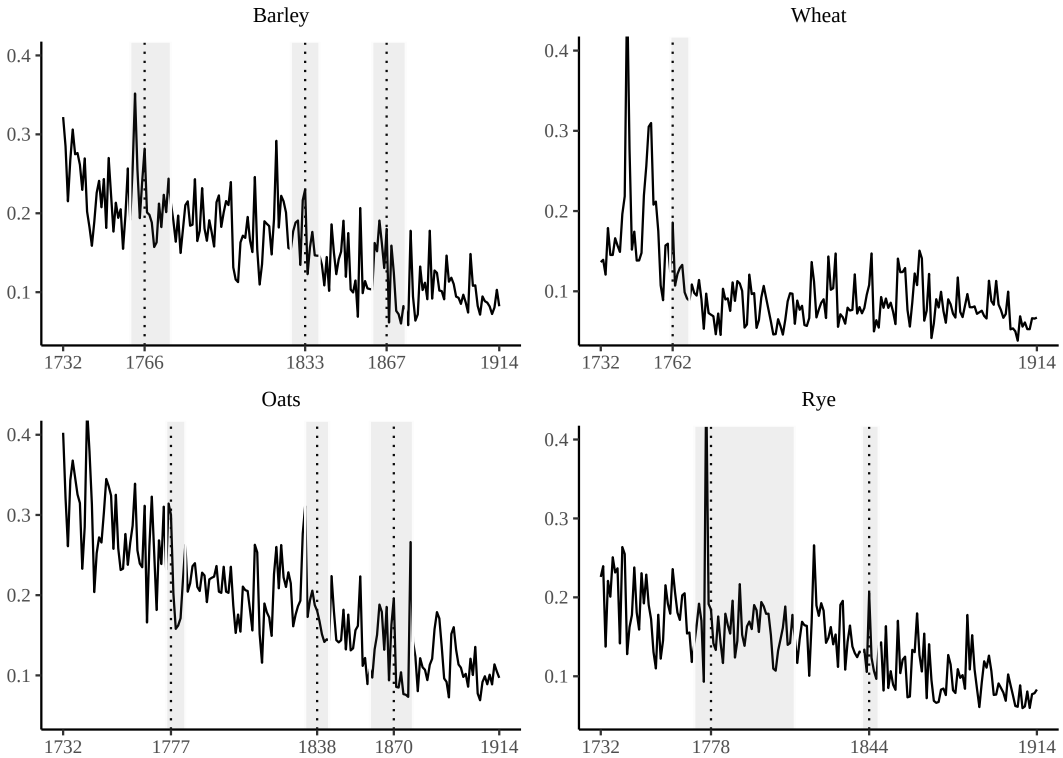

Figure 5: Structural breaks with 95% confidence intervals.

Next, I fit a model where I regress the CVs on time to see whether the rates of change vary over time. Now, the test detects no breaks for barley and rye prices, meaning that the prices convergence seems to have been a steady process in these two cases. For the oats coefficient there is a break in 1820, but the change of coefficient is minuscule. Also for wheat prices there is a break, and also this time it occurs in 1762, where the coefficient goes from being negative to being positive.

Table 3: Structural breaks.

Oats Periods	Oats Intercept	Oats Coefficient	Wheat Periods	Wheat Intercept	Wheat Coefficient
1732–1820	3.5085	-0.0018	1732–1762	-0.3152	0.0003
1821–1914	2.6269	-0.0013	1763–1914	0.2721	-0.0001

Next, I proceed to calculate the sigma convergence. First, I estimate the following regression and conduct an ADF-test to check for stationarity in the series:

$$\Delta Y_t = \alpha Y_{t-1} + \beta \Delta Y_{t-1} + \epsilon_t \tag{11}$$

As the grain prices are autocorrelated[26] I include a lagged differenced variable in the regression. The number of lags was chosen based on the AIC-criterion and inspection of the partial autocorrelation function. As can be seen in table 8 in the Appendix, we can reject the null hypothesis of a unit root on a 5 percent significance level for all log CV series. All CV-series are, however, trend-stationary (see Table 9 in the appendix), so I can proceed with estimating the rates of sigma convergence, which are shown in Table 4. The length of the time dummies have, following Federico (2011), been kept at around 30–40 years.[27] From table four we can also note that the price convergence seems to have been a steady process, as the coefficients are negative for all periods. For wheat, the coefficients for the periods between 1774–1884 are not statistically significant, which could imply that market integration was indeed so well developed that there was not much room for improvements. The coefficients of barley, oats, and rye increase in absolute values over the periods, which could mean that integration accelerated with infrastructural and technological progress. From a European perspective, Swedish price convergence appeared relatively early. Comparing with Federico's (2011) estimates for the 17$^{\text{th}}$ and 18$^{\text{th}}$ centuries, Sweden has, in absolute terms, smaller coefficients than, for instance, Spain, France, and Germany. At the same time the Swedish CVs are lower, indicating that the sigma values are smaller because

[26] The reason is probably that a big harvest would lower prices not only that year but also the coming years, as surplus grain can be stored (Nielsen 1997).

[27] Altering the break years slightly yields very similar results.

Sweden was already more integrated. United Kingdom and the Netherlands, on the other hand, have coefficients that are smaller in absolute terms, or positive, and CVs that are lower than for Sweden.

Table 4: σ-convergence.

	Rates of change			
	Barley	Oats	Wheat	Rye
1732–1774	-0.006^{***}	-0.008^{***}	-0.014^{***}	-0.006^{**}
	(0.002)	(0.002)	(0.004)	(0.003)
1775–1809	-0.006^{*}	-0.005^{*}	-0.006	-0.003
	(0.003)	(0.003)	(0.005)	(0.004)
1810–1852	-0.007^{**}	-0.006^{**}	-0.001	-0.008^{***}
	(0.003)	(0.036)	(0.003)	(0.003)
1853–1883	-0.011	-0.011	-0.009	-0.008
	(0.007)	(0.007)	(0.006)	(0.006)
1884–1914	-0.013^{***}	-0.012^{**}	-0.015^{***}	-0.018^{***}
	(0.004)	(0.004)	(0.004)	(0.004)

Note: *p<0.1; **p<0.05; ***p<0.01

Figure 6 shows the time dummy coefficients from the fixed effects regression on the pairwise percentage price gap. Table 12 in the appendix shows the regression output. All coefficients except one, the period 1862–1881 for barley, were statistically significant at the one percent level. Bateman (2011), who introduces this method in grain market research, uses 25-yearly intervals. As my data set covers a shorter time period I have here opted for intervals of 20 years to get a slightly more detailed view of the market integration process. The estimated price gaps on the whole confirm the picture of price convergence given by the CV:s. Over time all grains display a clear decrease in price gaps, albeit with a few small bumps on the way. Wheat prices again appear to be more uniform than the other grain prices, with the other price gaps nearing in the latter part of the 19$^{\text{th}}$ century. The rye price gaps stand out as being relatively high in the last three time periods. This somewhat runs counter the CV-series, where the rye CVs were mostly below those of barley and oats. This deviation from the CV-analysis might be explained by the limitations to this regressions as outlined in the methods section.

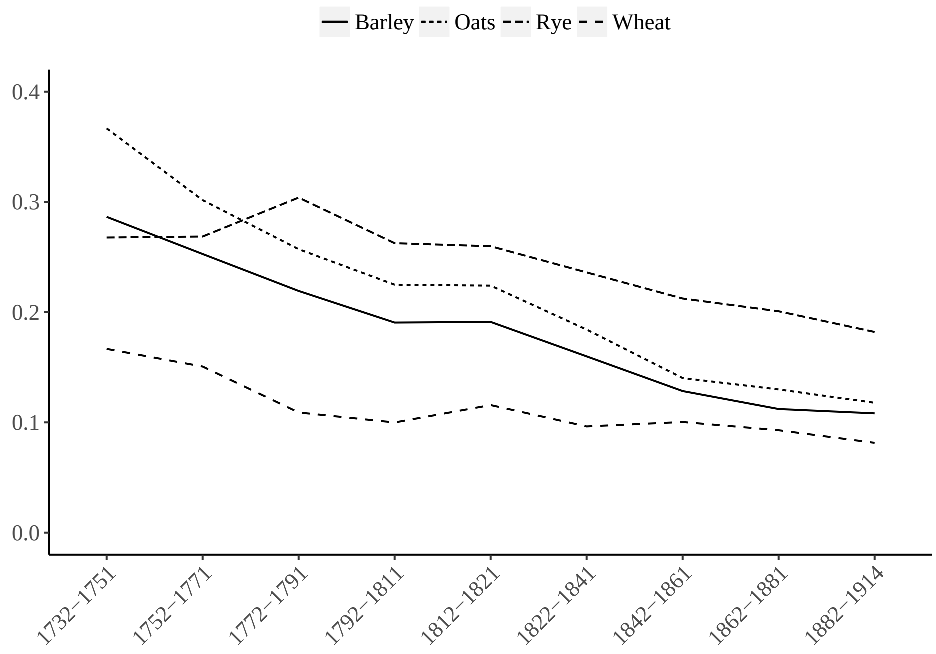

Figure 6: Percentage gap: fixed effects results.

5.2 Price volatility and price comovement

As can be seen in Figure 7 all four grain prices are very volatile, at least until the second half of the 19$^{\text{th}}$ century. Prices in the decades marked by high inflation, i.e. the 1760s and the 1790s, were particularly volatile. The volatility seems to become stabilized around a lower level some decades into the 1800s. These decades saw, simultaneously, low Swedish grain import quantities[28] (see Figure 9) and improved long-term grain storage capacity (Berg 2007). Like Edvinsson (2012) this thesis thus hypothesizes that imports were not a driving force behind grain price volatility and, consequently, market integration. Price comovement (Figure 8) rose sharply across all grains in the latter part of the 18$^{\text{th}}$ century. From the beginning of the 1800s little improvement was made and the rolling correlation coefficients hovered around 0.8. The sudden decline in oats price comovement coincides with the beginning of oats exportation. On a European-wide level Federico (2011) finds that higher price volatility actually contributed to an increased price comovement. Here we cannot draw any such conclusions about the interplay between price volatility and price comovement.

[28]In the 1700s, imported grains did not amount to more than 15% of the domestic harvest even during very poor harvest years (Åmark 1915).

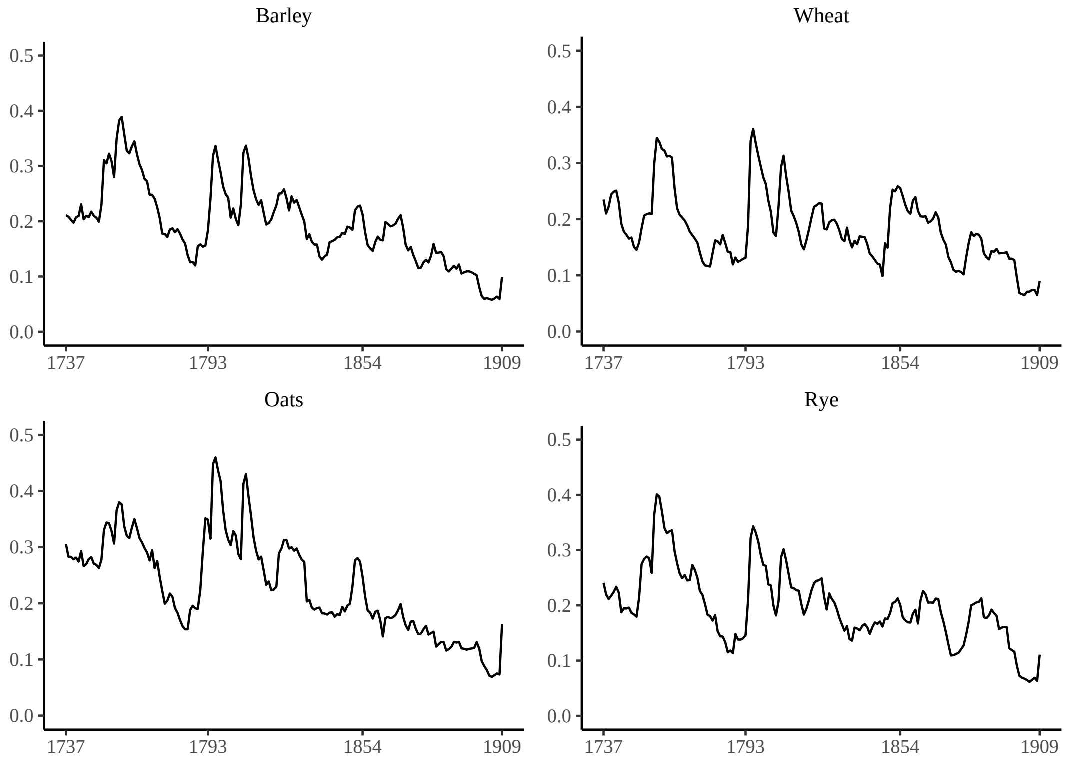

Figure 7: Average 11-years rolling coefficients of variation for provinces.

Figure 8: Average 21-years rolling correlation coefficients.

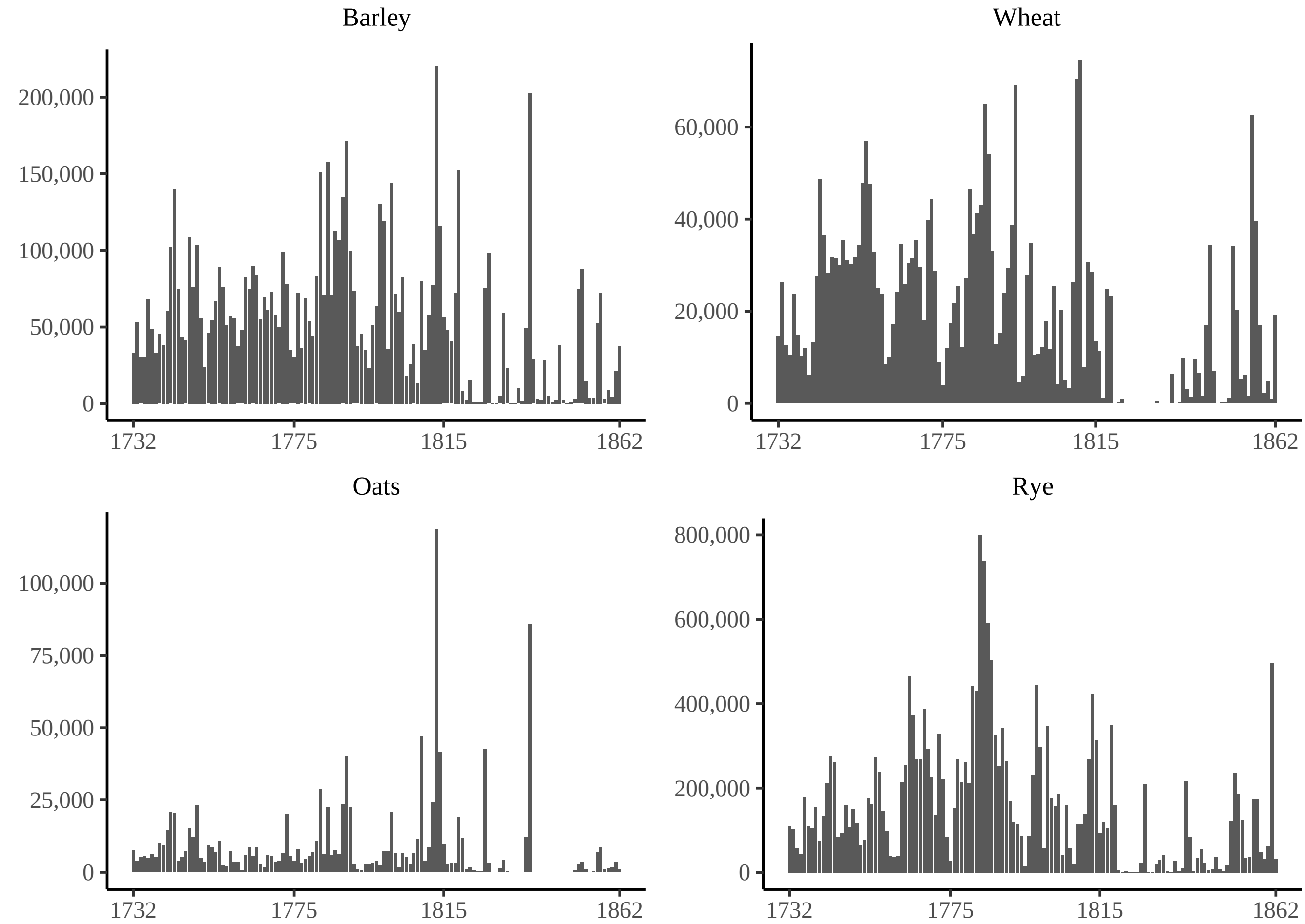

Figure 9: Annual imports in barrels (in Swedish: *tunnor*). Source: SCB (1972).

5.3 PCA – from many markets to one

As the previous results indicate that Sweden had begun the process of becoming one fully integrated market already by the end of the 18^{th} century, the fact that we only have Danish data from 1732–1800 is not a problem when we want to find out whether imports of Danish grains could have been a driving factor in Swedish price dynamics. We will apply PCA to four different time periods: 1732–1772, 1772–1800, 1800–1860, and 1860–1914.[29] Four periods are enough to distinguish a development in the geographical clustering without making the samples too small for PCA. The period 1732–1772, a part of the so-called Age of Liberty, was characterized by mercantilism but also by high inflation. With the coup d'état in 1772 Sweden was once again an autocratic kingdom. The following 30 years saw increased implementation of agricultural reforms (the so-called Great Partition or *storskiftet*), a new currency (accompanied by a depreciation) and removal of all barriers for domestic grain trade. During the period 1800–1860 agricultural production grew rapidly as a result of waves of enclosure and increased commercialization (Schön

[29]The results are robust also when we alter the break years slightly.

1997) and Sweden went from being a permanent net importer to being a net exporter of grain as a consequence. Finally, Sweden industrialized fully in the latter half of the 19th century, while at the same time abolishing protective tariffs (Persson 1999). The infrastructure improved thanks to the arrival of the telegraph and the building of the railway.

5.3.1 1732–1800: growing market regions

The eigenvalues for the principal components analysis of barley prices in the period 1732–1772 are shown in Table 5. Following the Kaiser criterion we chose to proceed with 8 principal components, that together explain 88 percent of the variance in the data set. The rotated principal components loadings (Table 6) clearly indicate that the there is clustering based on geographical proximity. The provinces that contribute the most to the first rotated principal component are Östergötland, Närke, Nora/Linde/Karlskoga, Västmanland, Gästrikland, Södermanland, and Kopparberg. These provinces are all situated in the middle of Sweden. The second component has high correlations with the southern provinces Malmöhus, Kristianstad Ängelholm, Halland, and Kronoberg. The third component seems to represent western Sweden, as the biggest loadings come from Göteborg Bohus, Älvsborg, Värmland, and, oddly enough, Simrishamn. Simrishamn started selling rye to Stockholm "at exceptionally low prices" already in 1810, a decade before the rest of Scania (Thorburn 2000). It is possible that the grain market in Simrishamn differed from the rest of Scania also in the 1700s. The remaining five components capture Norrland (Västerbotten, Medelpad, and Ångermanland), Copenhagen and Danzig, Königsberg, Gotland, and Jämtland. The fact that Gotland and Jämtland constitute components of their own indicate that they were not very well integrated with the rest of Sweden. The cases where a province contributes to two components could mean that the province belongs to both markets and that markets thus overlap. This would mean that, for instance, Stockholm takes part in both the middle Sweden market and the southern market. The PCA of rye and oats (there is not enough data for a meaningful application of PCA on wheat for the period 1732–1772) shows a similar picture, with the first rotated component[30] representing mid Sweden, including Stockholm and Hälsingland, the second component representing southern and western Sweden, the third component being Scania,[31] and the remaining components Copenhagen and Danzig, Königsberg, Jämtland, and Gotland.

For the period 1772–1800 we have seven barley principle components that have an eigenvalue that exceeds 0.7. However, the percentage of variance explained by the second principal component has risen and the groups have changed slightly. The first component now consists

[30]Eigenvalues and loadings can be found in the appendix.

[31]I.e. Malmöhus, Kristianstad, Ängelholm, and Simrishamn.

of all southern and western Swedish provinces and Danzig, whereas the second component has high loadings from the midparts of Sweden. The remaining components, like before, represent single provinces: Copenhagen and Gotland, Königsberg, Västerbotten, Härjedalen, and Västernorrland. Rye and oats prices follow the same geographical pattern. The only provinces not to belong to an all-Swedish market are Gotland and Stockholm, that form the second component, and Copenhagen. Uppsala, Södermanland, and Västmanland are also highly correlated with the second component. For rye prices there are now two larger geographical groupings: middle and southern Sweden. There is also a considerable overlap between these markets, as middle provinces such as Närke, Kronoberg, Östergötland, and Värmland contribute to both components. As in the previous time period, the foreign cities and the northernmost Swedish provinces separate themselves from the middle of Sweden. The number of principal components decreases for all grains, indicating a more integrated Sweden. In the case of oats this could also be the consequence of a smaller sample, as some provinces were removed due to lack of data.

Table 5: Eigenvalues, barley, 1732–1772.

	Eigenvalue	Percentage of variance	Cumulative percentage of variance
comp 1	16.50	53.24	53.24
comp 2	2.79	9.00	62.24
comp 3	1.98	6.40	68.65
comp 4	1.65	5.32	73.97
comp 5	1.43	4.60	78.57
comp 6	1.15	3.70	82.27
comp 7	0.88	2.84	85.11
comp 8	0.75	2.40	87.51
comp 9	0.64	2.05	89.57
comp 10	0.56	1.80	91.37
comp 11	0.43	1.39	92.76
comp 12	0.41	1.31	94.07
comp 13	0.38	1.24	95.31
comp 14	0.29	0.94	96.25
comp 15	0.25	0.82	97.07
comp 16	0.17	0.56	97.63
comp 17	0.14	0.46	98.09
comp 18	0.13	0.41	98.49
comp 19	0.12	0.38	98.87
comp 20	0.09	0.29	99.16
comp 21	0.07	0.22	99.38
comp 22	0.06	0.18	99.55
comp 23	0.04	0.14	99.70
comp 24	0.03	0.11	99.81
comp 25	0.02	0.08	99.89
comp 26	0.02	0.05	99.94
comp 27	0.01	0.04	99.98
comp 28	0.01	0.02	100.00
comp 29	0.00	0.00	100.00
comp 30	0.00	0.00	100.00
comp 31	0.00	0.00	100.00

Table 6: Factor loadings, barley, 1732–1772.

	RC1	RC3	RC5	RC2	RC6	RC4	RC7	RC8
Proportion var	0.20	0.19	0.14	0.13	0.08	0.05	0.05	0.04
Cumulative var	0.20	0.39	0.52	0.65	0.73	0.78	0.84	0.87
Cumulative proportion explained	0.23	0.44	0.60	0.74	0.83	0.90	0.95	1
1 Stockholm	0.58	0.02	0.22	0.55	0.14	0.13	0.34	0.11
2 Uppsala	0.59	0.12	0.44	0.23	0.01	0.15	0.32	0.11
3 Södermanland	0.68	0.26	0.25	0.30	0.31	0.08	0.32	0.01
4 Östergötland	0.84	0.23	-0.01	0.20	0.10	0.20	0.09	0.16
5 Jönköping	0.66	0.51	0.27	0.06	0.04	0.30	-0.11	0.08
6 Kronoberg	0.42	0.62	0.35	-0.06	-0.11	-0.13	-0.35	0.04
7 Kalmar	0.63	0.52	0.18	0.02	0.41	0.03	-0.18	0.06
8 Gotland	0.23	0.16	0.22	-0.06	0.17	0.12	0.77	0.12
9 Blekinge	0.21	0.36	0.26	0.38	0.32	0.64	-0.02	-0.06
10a Kristianstad	0.20	0.85	0.18	0.15	0.15	0.19	-0.00	0.15
10b Ängelholm	0.26	0.77	0.26	0.23	-0.04	0.03	0.33	-0.08
10c Simrishamn	0.26	0.32	0.86	0.13	0.14	0.02	0.08	0.07
11 Malmöhus	0.20	0.85	0.18	0.15	0.15	0.19	-0.00	0.15
12 Halland	0.26	0.77	0.26	0.23	-0.04	0.03	0.33	-0.08
13 Göteborg Bohus	0.26	0.32	0.86	0.13	0.14	0.02	0.08	0.07
14 Ästerborg	0.16	0.35	0.81	0.23	0.17	-0.01	0.14	-0.03
15 Skaraborg	0.36	0.74	0.41	0.01	0.21	-0.11	0.09	0.00
16 Värmland	0.43	0.41	0.53	-0.10	0.39	-0.17	0.15	-0.05
17a Närke	0.78	0.34	0.20	0.09	0.13	0.10	0.15	0.14
17b Nora/Linde/Karlskoga	0.75	0.30	0.25	0.31	0.28	-0.10	0.00	-0.02
18 Västmanland	0.69	0.25	0.25	0.35	0.33	0.08	0.26	0.00
19 Kopparberg	0.67	0.31	0.43	0.37	0.20	-0.04	0.11	0.00
20a Gästrikland	0.68	0.24	0.35	0.34	0.30	-0.05	0.11	-0.14
20b Hälsingland	0.62	0.35	0.13	0.56	0.11	0.01	-0.04	0.03
21a Medelpad	0.32	0.26	0.11	0.71	0.09	0.03	-0.09	0.39
21b Ångermanland	0.51	0.07	0.20	0.60	0.04	-0.03	-0.07	0.39
22b Jämtland	0.08	0.06	0.03	0.34	0.05	0.09	0.12	0.85
23 Västerbotten	0.21	0.10	0.11	0.83	0.20	-0.04	0.03	0.12
Copenhagen	0.26	0.23	0.10	0.25	0.82	0.12	0.01	0.18
Danzig	0.26	-0.07	0.30	0.14	0.72	-0.03	0.24	-0.07
Königsberg	0.09	0.05	-0.11	-0.12	-0.04	0.91	0.13	0.10

5.3.2 1800–1914: a uniform Swedish market

The trend with fewer principal components passing the Kaiser criterion and higher percentage of variance explained by the first principal component continues in the two periods spanning the 19^{th} century. Already in the first half of 1800s the first principal component accounts for around 70 percent of the variance in all prices. Moreover, the number over provinces that have high loadings for more than one component also continues to increase. The southern and western Swedish markets that can still be distinguished in the period 1800–1860 seem to merge in the last period, so that we, for all grains, are left with a first component consisting of almost entire Sweden. The remaining components explain only a small part of the price variance, and vary somewhat in their composition. The smallest component is, however, constructed by Jämtland and Härjedalen. The remaining components consist of different provinces for different grains, e.g. Närke and Nora/Linde/Karlskoga in the case of rye. All grains have in common that many provinces from the first all-Swedish component also correlate highly with the second component and the few provinces that differed slightly from the majority.

All in all, the principal component analysis shows that there is indeed a process of market integration going on already in the 18^{th} century. The markets that preceeded the national market were clearly, as we would have anticipated from the oblong shape of Sweden, based on geographical vicinity. Some other common features can be highlighted for all grains. First, it seems as if the northernmost provinces and Gotland integrated with other markets later than the rest of Sweden. Whereas the western, southern and middle part of Sweden grouped together, increasingly overlapping until merging completely in the last period, the northern provinces remained divided well into the 19^{th} century. Second, it is notable that Stockholm did not correlate highly with any component in the first two periods and rarely was among the overlapping markets in the last two periods. This indicates that its price dynamics differed slightly from the rest of middle Sweden. As Stockholm is not geographically isolated, like for instance Jämtland or Norrbotten, it is hard to see that it was not economically integrated with the rest of Sweden. This peculiarity can perhaps be explained by the fact that Stockholm had a big net grain deficit and thus had to import grain from the rest of Sweden as well as from abroad (Jörberg 1972b). This mixture of internal and foreign import might explain the lower correlations with the mid-Swedish group. The finding that Norrland and Stockholm stand out from the rest of Sweden are in line with Thorburn's (2000) analysis of rye transport in 18^{th} and 19^{th} Sweden. He finds that Stockholm, northern Norrland, and Jämtland constituted isolated rye markets in the late 1700s and that Jämtland remained isolated well into the 1850s. Moreover, Lagerlöf (2015) finds that the correlation between harvest shocks and local grain prices is higher in Jämtland than in rest of Sweden and concludes that Jämtland was not well integrated.

As to foreign influences, Copenhagen, Danzig, and Königsberg are never parts of the Swedish markets discerned in the 18th century. Despite its proximity to Königsberg, Danzig is most often grouped together with Copenhagen. This might be explained by the fact that I have not converted the Danish, Polish, and Prussian prices to Swedish currency. Very different inflation rates in Sweden and Denmark could then make the two price series to be less correlated then would two price series that have been deflated.

Table 7: Summary of PCA.

	Percentage explained by the first component				Number of principal components with eigenvalue>0.7			
	1732–1772	1772–1800	1800–1860	1860–1914	1732–1772	1772–1800	1800–1860	1860–1914
Barley	53	52	70	68	8	7	5	4
Oats	39	82	68	69	9	3	5	4
Rye	58	68	71	76	7	6	4	3
Wheat	–	–	–	–	–	–	–	3

5.3.3 Regional CVs

To corroborate the findings above, that Sweden integrated stepwise through the convergence of geographically clustered regions, CVs[32] have been calculated for three regions that were distinguished by the PCA: south, or Scania, (Ängelholm, Kristianstad, Simrishamn, and Malmöhus), west (Göteborg Bohus, Älvsborg, Skaraborg, and Värmland), and middle (Stockholm, Uppsala, Södermanland, and Västmanland). The results are shown in Figure 10. For data reasons the CVs have been calculated for the period 1732–1868 and wheat has been omitted. As expected, each one of these regions was more integrated than Sweden as a whole. Indeed, the middle region seems to have been very well integrated already in the 1730s, as little progress is being made thereafter. As already mentioned, Stockholm had a major grain deficit and it is probable that its demand for grains thus levelled the prices with nearby provinces.

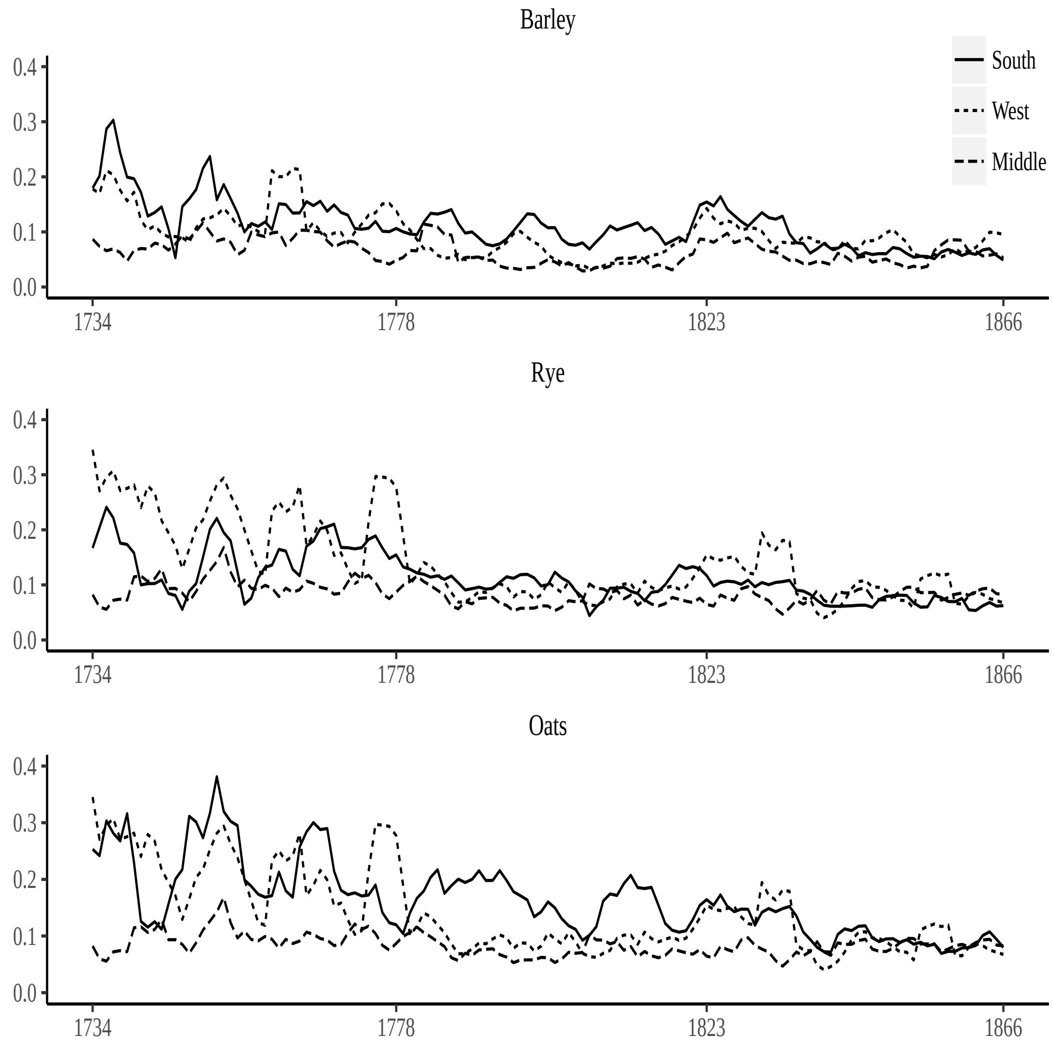

Figure 10: Regional 5 years rolling coefficients of variation.

[32]To smooth out the graphs but still allow for detection of potential sudden changes 5 years moving averages have been calculated.

6 Conclusion

In this thesis I have applied a variety of statistical techniques on historical grain prices in order to elucidate the questions of when and how Sweden integrated economically. There can be no definitive answer to the first question, but it seems to be the case that Sweden was well integrated by the middle of the 19th century. To the question of how, the findings point toward a gradual process that spanned centuries and that was free of any longer period of disintegration.

There is clear evidence that the Swedish regions began integrating already in the 1700s. This means that the development toward a national market was well under way long before the industrialization, the telegraph, and the arrival of the canals and the railway. As the Swedish provinces were at the same time clustered based on geographical distance, my findings seem to support Uebele (2011) in his claim that "non-revolutionary transport infrastructure improvements" fostered early market integration. Indeed, Kaukiainen (2001) found that the speed of information transmission decreased substantially already several decades before the introduction of the electric telegraph in the 1850s. In all, our measures of price volatility and price comovement suggest that Swedish grain markets had reached a high level of market efficiency already by the first half of the 19th century. Prices did, however, continue to converge also in the late 1800s, during a period in which Sweden was still very protectionist, implying that lower transportation costs were now the main driver of market integration.

Furthermore, foreign imports seem to have played a limited role in the Swedish market integration process. Neither Copenhagen nor Danzig were parts of Swedish regional markets and although foreign imports could explain why Stockholm was relatively isolated in the 1700s, its isolation shows that the foreign influence remained constrained to Stockholm. Uebele (2011) also shows that Sweden was among the least internationally integrated European countries in the 1800s. The relative importance of the domestic trade for Swedish market integration supports Schön who rejects the "globalization model" and instead stresses the importance of the domestic markets for industrialization in Sweden.

Judging from the very limited number of studies that trace national market integration as far back as the 1700s, it seems as if Sweden began integrating domestically relatively early, having lower coefficients of variation in the 1750s than France, Spain, Germany, and Italy but trailing Scotland, England, and the Netherlands (Federico 2011, Gibson and Smout 1995). It could thus be inferred that political unity (seeing as Spain was only beginning to centralize and Germany and Italy had not yet been unified[33]) and geographical distance both mattered for

[33] For example, in the states that were to become Germany, peasants did not have freedom of movement (Bengtsson and Jörberg 1975).

domestic market integration. How come, then, that Sweden was ahead of European countries of roughly the same size but with far better conditions for agriculture? One possibility could be that it is precisely the relatively harsh agricultural conditions that explain why domestic Swedish trade took off earlier. The quality of grains varied in the country (Åmark 1915), thereby creating incentives for specialization and grain trade. As an example, the strategically important iron mining districts in the middle of Sweden (*Bergslagen*) were exempted from grain trade restrictions since the middle of the 1600s (Jörberg and Bengtsson 1975). Federico (2011) establishes that the most important determinants of the level of integration in the 1800s was war and "political events." It is then plausible that Sweden's peaceful 19^{th} century and domestic free trade policies contributed to its early integration.

As to the "Smithian origin of the industrial revolution," the fact that Sweden was in the forefront of national market integration but still industrialized comparatively late supports the view of Keller and Shiue (2007b) and Bateman (2011, p. 465) that "markets alone are insufficient for a take-off to modern economic growth." As recent research hypothesizes that the industrial revolution happened first in England due to its unique combination of high real wages and low cost of energy (Allen 2009) it is conceivable that well integrated markets mattered the most only for the *first* country to industrialize, i.e. England. As other countries followed suit, market integration and industrialization might have been tightly connected. This seems to have been the case in e.g. Germany, where market integration developed parallelly to industrialization (Uebele 2010), and Japan, where Yao and Zheng (2016) find that "a well-integrated market is a cause as well as a result of economic growth."

Finally, as we can only reach so far with descriptive statistical measures, there is a need for data (on e.g. transport costs, trade flows, and weekly grain prices) that would allow us to use econometrics to disentangle causes and effects of Swedish market integration. The way forward for research on historical market integration thus lies in thorough scrutiny of historical archives and the compilation of ever better datasets.

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8 Appendix

Table 8: ADF-tests on CV.

	Barley	Oats	Rye	Wheat
L1.	-0.002	-0.003	-0.004	-0.003
	(-0.154)	(-0.290)	(-0.440)	(-0.262)
LD.	-0.480***	-0.295***	-0.322***	-0.457***
	(-7.274)	(-4.124)	(-4.539)	(-6.852)
ADF-statistic	-0.154	-0.290	-0.440	-2.044
N	181	181	181	181

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 9: ADF-test on CV – trend stationary.

	Barley	Oats	Rye	Wheat
Intercept	0.188***	0.238***	0.198***	0.052***
	(7.869)	(8.697)	(8.783)	(4.654)
L1.	-0.774***	-0.790***	-0.956***	-0.351***
	(-8.205)	(-9.014)	(-9.197)	(-5.403)
LD.	-0.048	0.126	-0.007	-0.065
	(-0.644)	(1.710)	(-.092)	(-0.864)
ADF-statistic	-8.205***	-9.014***	-9.197*	-2.044**
Time trend	0***	0***	0***	0**
	(-6.874)	(-7.857)	(-7.231)	(-5.403)
N	181	181	181	181

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 10: Fixed effect regression on pairwise differences.

	Rye	Barley	Oats	Wheat
1732–1751	0.0857***	0.178***	0.249***	0.0852***
	(25.21)	(71.80)	(72.76)	(29.23)
1752–1771	0.0866***	0.145***	0.184***	0.0692***
	(26.32)	(60.70)	(54.73)	(23.88)
1772–1791	0.122***	0.111***	0.139***	0.0275***
	(36.31)	(46.83)	(41.31)	(9.43)
1792–1811	0.0805***	0.0823***	0.107***	0.0185***
	(25.08)	(35.45)	(32.14)	(5.96)
1812–1821	0.0778***	0.0830***	0.106***	0.0342***
	(25.11)	(36.98)	(32.62)	(11.31)
1822–1841	0.0540***	0.0517***	0.0664***	0.0149***
	(17.57)	(23.19)	(20.98)	(6.05)
1842–1861	0.0303***	0.0202***	0.0224***	0.0189***
	(9.87)	(9.07)	(7.19)	(8.93)
1862–1881	0.0188***	0.00392	0.0121***	0.0114***
	(6.04)	(1.74)	(3.84)	(5.72)
1882–1914	0	0	0	0
	(.)	(.)	(.)	(.)
Constant	0.182***	0.108***	0.118***	0.0815***
	(80.68)	(66.18)	(50.06)	(54.25)
N	69212	69682	57028	25077

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 11: P-values for Moran's I, using longitude and latitude for biggest market town.

Year	Barley	Oats	Rye	Wheat
1732	0.000	0.311	0.000	0.495
1914	0.242	0.146	0.278	0.993

Table 12: CV breaks, fitted constant.

	Barley	Oats	Wheat	Rye
1732 - 1766	0.23	0.29	0.19	0.19
1767 - 1833	0.19	0.20	0.09	0.16
1834 - 1867	0.14	0.15	0.10	0.12
1868 - 1914	0.10	0.11	0.07	0.09

Table 13: Eigenvalues, Rye, 1732–1772.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	17.65	56.95	56.95
comp 2	2.52	8.12	65.07
comp 3	1.95	6.29	71.36
comp 4	1.62	5.23	76.59
comp 5	1.19	3.85	80.44
comp 6	0.91	2.93	83.37
comp 7	0.83	2.68	86.05
comp 8	0.80	2.58	88.63
comp 9	0.68	2.19	90.82
comp 10	0.50	1.60	92.43
comp 11	0.40	1.30	93.73
comp 12	0.34	1.11	94.83
comp 13	0.28	0.92	95.75
comp 14	0.22	0.70	96.45
comp 15	0.20	0.64	97.09
comp 16	0.16	0.53	97.62
comp 17	0.15	0.49	98.11
comp 18	0.12	0.37	98.48
comp 19	0.11	0.34	98.82
comp 20	0.09	0.30	99.12
comp 21	0.06	0.19	99.31
comp 22	0.05	0.18	99.48
comp 23	0.05	0.16	99.64
comp 24	0.03	0.11	99.75
comp 25	0.02	0.07	99.83
comp 26	0.02	0.06	99.89
comp 27	0.01	0.04	99.93
comp 28	0.01	0.03	99.96
comp 29	0.01	0.02	99.98
comp 30	0.00	0.01	99.99
comp 31	0.00	0.01	100.00

Table 14: Factor loadings, Rye, 1732–1772.

	RC1	RC3	RC2	RC6	RC7	RC4	RC8	RC5
1 Stockholm	0.90	0.18	0.19	0.06	0.18	0.02	0.09	-0.05
2 Uppsala	0.80	0.20	0.07	0.31	0.20	0.28	0.13	-0.06
3 Södermanland	0.75	0.34	0.11	0.12	0.25	0.19	0.25	0.06
4 Östergötland	0.67	0.21	-0.04	0.29	0.09	0.51	0.23	-0.04
5 Jönköping	0.50	0.56	0.20	0.03	-0.04	0.47	-0.13	0.15
6 Kronoberg	0.08	0.83	0.09	0.30	-0.06	0.14	-0.21	-0.09
7 Kalmar	0.39	0.75	0.11	0.33	0.17	0.15	0.09	0.03
8 Gotland	0.30	0.18	0.00	0.17	0.06	0.14	0.85	-0.04
9 Blekinge	0.50	0.60	-0.03	0.31	0.30	-0.07	0.03	0.12
10a Kristianstad	0.21	0.52	0.11	0.70	0.12	0.22	0.18	0.09
10b Ängelholm	0.46	0.52	0.19	0.49	0.08	0.11	0.13	0.15
10c Simrishamn	0.51	0.55	0.14	0.48	0.16	-0.17	0.03	0.10
11 Malmöhus	0.31	0.49	0.05	0.69	0.22	-0.06	0.18	-0.07
12 Halland	0.18	0.85	0.16	0.23	0.10	0.01	0.33	0.02
13 Göteborg Bohus	0.35	0.70	-0.03	0.26	0.24	0.12	0.34	0.00
14 Ästerborg	0.32	0.82	0.05	0.18	0.08	0.22	0.26	0.11
15 Skaraborg	0.32	0.44	0.04	0.03	-0.05	0.75	0.21	0.01
16 Värmland	0.43	0.78	0.13	-0.04	0.27	0.16	0.04	0.08
17a Närke	0.48	0.70	0.34	-0.04	0.20	0.06	0.02	-0.15
17b Nora/Linde/Karlskoga	0.68	0.51	0.19	0.14	0.31	0.14	0.05	0.08
18 Västmanland	0.70	0.43	0.17	0.31	0.22	0.18	0.12	0.17
19 Kopparberg	0.80	0.40	0.23	0.21	0.14	0.08	0.06	0.06
20a Gästrikland	0.72	0.38	0.14	0.29	0.23	0.04	0.20	0.09
20b Hälsingland	0.74	0.30	0.46	-0.04	0.03	0.02	0.14	0.07
21a Medelpad	0.40	0.15	0.80	0.11	0.11	-0.10	0.03	0.15
21b Ångermanland	0.48	0.34	0.68	0.02	-0.02	-0.30	-0.01	-0.04
22b Jämtland	0.01	-0.02	0.83	0.04	0.09	0.35	0.02	-0.12
23 Västerbotten	0.08	0.18	0.53	0.17	0.56	-0.14	-0.11	-0.36
Copenhagen	0.43	0.15	0.11	0.20	0.72	0.18	-0.01	0.18
Danzig	0.39	0.22	0.08	0.06	0.69	-0.13	0.24	0.24
Konigsberg	0.06	0.04	-0.05	0.05	0.14	0.00	-0.03	0.93

Table 15: Eigenvalues, Oats, 1732–1772.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	10.22	39.31	39.31
comp 2	2.99	11.51	50.82
comp 3	2.57	9.90	60.72
comp 4	1.55	5.95	66.67
comp 5	1.20	4.62	71.29
comp 6	1.10	4.21	75.51
comp 7	1.02	3.93	79.44
comp 8	0.93	3.56	83.00
comp 9	0.77	2.95	85.95
comp 10	0.67	2.58	88.53
comp 11	0.58	2.23	90.76
comp 12	0.45	1.75	92.51
comp 13	0.38	1.47	93.98
comp 14	0.31	1.18	95.16
comp 15	0.29	1.12	96.27
comp 16	0.21	0.83	97.10
comp 17	0.17	0.65	97.75
comp 18	0.15	0.59	98.33
comp 19	0.10	0.40	98.74
comp 20	0.09	0.34	99.07
comp 21	0.06	0.24	99.32
comp 22	0.06	0.22	99.54
comp 23	0.05	0.17	99.71
comp 24	0.04	0.14	99.85
comp 25	0.02	0.09	99.94
comp 26	0.02	0.06	100.00

Table 16: Factor loadings, Oats, 1732–1772.

	RC1	RC3	RC4	RC5	RC2
1 Stockholm	0.66	0.56	0.20	0.23	-0.10
2 Uppsala	0.53	0.59	0.15	0.15	0.14
3 Södermanland	0.83	0.34	0.01	0.07	0.19
4 Östergötland	0.81	-0.14	0.14	0.17	0.19
5 Jönköping	0.47	-0.05	0.49	0.25	0.18
6 Kronoberg	0.12	0.01	0.53	0.44	0.56
7 Kalmar	0.59	0.26	0.20	0.04	0.52
8 Gotland	-0.02	0.08	-0.04	0.13	0.64
10a Kristianstad	0.04	-0.01	0.31	0.25	0.65
10b Ängelholm	0.34	0.17	0.07	0.10	0.65
10c Simrishamn	-0.03	0.84	-0.07	0.09	0.18
11 Malmöhus	-0.03	0.80	-0.00	0.22	0.35
12 Halland	0.02	0.11	0.80	0.08	0.23
13 Göteborg Bohus	0.18	0.14	0.06	0.80	0.35
14 Ästerborg	0.12	0.19	0.15	0.79	0.45
15 Skaraborg	0.67	-0.25	0.29	-0.46	0.03
16 Värmland	0.28	-0.00	0.39	0.57	0.36
17a Närke	0.58	0.03	0.24	0.35	0.42
17b Nora/Linde/Karlskoga	0.21	0.17	0.40	0.57	-0.08
18 Västmanland	0.76	0.45	-0.07	0.27	-0.03
19 Kopparberg	0.57	0.42	0.48	0.31	0.17
20a Gästrikland	0.15	0.42	0.54	0.25	0.30
20b Hälsingland	0.43	0.42	0.59	0.12	-0.07
21a Medelpad	0.14	0.73	0.28	0.10	-0.23
21b Ångermanland	0.29	0.68	0.30	-0.14	0.06
Copenhagen	0.48	0.12	0.43	0.12	-0.23

Table 17: Eigenvalues, Barley, 1772–1800.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	15.61	53.84	53.84
comp 2	3.73	12.88	66.71
comp 3	1.92	6.61	73.32
comp 4	1.70	5.86	79.18
comp 5	1.41	4.85	84.03
comp 6	0.96	3.31	87.34
comp 7	0.67	2.32	89.66
comp 8	0.60	2.07	91.74
comp 9	0.47	1.61	93.35
comp 10	0.37	1.28	94.63
comp 11	0.32	1.10	95.73
comp 12	0.25	0.88	96.60
comp 13	0.25	0.86	97.46
comp 14	0.20	0.69	98.15
comp 15	0.13	0.44	98.59
comp 16	0.10	0.34	98.93
comp 17	0.09	0.32	99.26
comp 18	0.06	0.20	99.46
comp 19	0.05	0.16	99.62
comp 20	0.04	0.14	99.76
comp 21	0.03	0.09	99.85
comp 22	0.02	0.08	99.93
comp 23	0.01	0.04	99.97
comp 24	0.00	0.01	99.99
comp 25	0.00	0.01	99.99
comp 26	0.00	0.01	100.00
comp 27	0.00	0.00	100.00

Table 18: Factor loadings, Barley, 1772–1800.

	RC2	RC1	RC6	RC5	RC3	RC4	RC7
1 Stockholm	0.04	0.79	0.36	0.04	-0.06	0.25	-0.03
2 Uppsala	0.11	0.91	0.21	0.10	0.12	0.06	-0.12
3 Södermanland	0.21	0.84	0.26	0.16	0.18	0.17	0.03
4 Östergötland	0.41	0.74	0.32	0.26	0.18	0.09	0.07
5 Jönköping	0.65	0.50	0.29	0.22	0.19	0.14	0.24
6 Kronoberg	0.52	0.28	0.55	0.28	0.24	-0.11	0.26
7 Kalmar	0.60	0.38	0.53	-0.19	0.19	0.02	0.13
8 Gotland	-0.00	0.43	0.86	0.05	0.07	-0.01	-0.06
9 Blekinge	0.47	-0.18	0.08	-0.03	-0.25	-0.28	0.70
10a Kristianstad	0.87	0.35	-0.02	-0.04	-0.19	0.02	0.21
10b Ängelholm	0.88	0.26	-0.01	-0.02	-0.16	0.03	0.21
10c Simrishamn	0.77	0.53	0.04	0.06	-0.07	0.05	0.25
11 Malmöhus	0.59	0.62	0.37	0.09	0.14	-0.08	0.07
12 Halland	0.94	0.05	0.05	0.18	0.05	0.11	-0.04
13 Göteborg Bohus	0.91	0.20	0.16	0.18	0.14	0.05	0.06
14 Ästerborg	0.73	0.34	0.30	0.41	0.05	-0.04	-0.10
15 Skaraborg	0.58	0.43	0.23	0.40	0.08	0.24	-0.01
16 Värmland	0.47	0.18	0.07	0.70	0.28	-0.00	0.31
17 örebro	0.45	0.68	0.08	0.42	0.13	0.22	0.05
18 Västmanland	0.15	0.89	0.32	0.18	0.03	0.12	-0.06
19 Kopparberg	0.36	0.72	-0.05	0.19	-0.22	-0.23	0.24
20a Gästrikland	0.32	0.81	0.06	0.04	0.14	-0.06	0.01
20b Hälsingland	0.49	0.72	0.03	0.29	-0.24	0.06	-0.18
21 Västernorrland county	0.61	0.53	0.09	0.19	-0.30	-0.07	-0.28
22a Härjedalen	-0.04	0.12	0.15	0.08	0.89	0.15	-0.12
23 Västerbotten	0.06	0.46	0.03	0.77	-0.09	0.11	-0.20
Copenhagen	0.25	0.31	0.63	0.07	-0.02	0.52	0.02
Danzig	0.64	-0.03	0.26	0.19	-0.43	0.22	-0.33
Konigsberg	-0.08	-0.10	-0.02	-0.07	-0.12	-0.92	0.12

Table 19: Eigenvalues, Rye, 1772–1800.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	20.01	69.00	69.00
comp 2	2.20	7.58	76.58
comp 3	1.69	5.82	82.40
comp 4	1.08	3.74	86.14
comp 5	0.97	3.35	89.48
comp 6	0.76	2.62	92.11
comp 7	0.49	1.67	93.78
comp 8	0.38	1.30	95.08
comp 9	0.35	1.22	96.29
comp 10	0.24	0.82	97.11
comp 11	0.19	0.64	97.75
comp 12	0.15	0.51	98.26
comp 13	0.11	0.38	98.64
comp 14	0.09	0.30	98.93
comp 15	0.09	0.29	99.23
comp 16	0.05	0.18	99.41
comp 17	0.04	0.15	99.55
comp 18	0.04	0.13	99.68
comp 19	0.03	0.12	99.80
comp 20	0.02	0.08	99.88
comp 21	0.01	0.05	99.93
comp 22	0.01	0.03	99.96
comp 23	0.01	0.02	99.98
comp 24	0.00	0.01	99.99
comp 25	0.00	0.01	100.00
comp 26	0.00	0.00	100.00
comp 27	0.00	0.00	100.00

Table 20: Factor loadings, Rye, 1772–1800.

	RC1	RC3	RC2	RC5	RC6	RC4
1 Stockholm	0.81	0.36	0.28	0.29	0.09	-0.07
2 Uppsala	0.82	0.25	0.20	0.35	0.14	-0.00
3 Södermanland	0.73	0.57	0.23	0.19	0.16	0.04
4 Östergötland	0.60	0.68	0.29	0.17	0.14	0.01
5 Jönköping	0.61	0.64	0.29	0.10	0.08	-0.02
6 Kronoberg	0.23	0.90	0.14	0.02	0.11	0.07
7 Kalmar	0.26	0.74	0.45	0.26	-0.05	-0.02
8 Gotland	0.28	0.77	0.12	0.40	-0.16	0.07
9 Blekinge	0.21	0.17	0.91	0.15	0.12	-0.12
10a Kristianstad	0.31	0.54	0.57	0.35	0.35	0.04
10b Ängelholm	0.34	0.55	0.54	0.33	0.34	0.06
10c Simrishamn	0.45	0.51	0.54	0.28	0.18	0.01
11 Malmöhus	0.33	0.74	0.42	0.25	0.19	0.00
12 Halland	0.29	0.57	0.62	0.26	0.24	0.06
13 Göteborg Bohus	0.36	0.20	0.64	0.39	0.32	0.19
14 Ästerborg	0.59	0.58	0.30	0.12	0.40	0.10
15 Skaraborg	0.54	0.67	0.12	0.14	0.39	0.10
16 Värmland	0.63	0.53	0.29	-0.23	0.14	0.18
17a Närke	0.66	0.68	0.07	0.09	0.18	0.11
17b Nora/Linde/Karlskoga	0.81	0.34	0.35	0.06	0.08	0.17
18 Västmanland	0.83	0.38	0.27	0.19	0.12	0.06
19 Kopparberg	0.81	0.33	0.26	0.24	0.18	0.08
20a Gästrikland	0.66	0.05	0.44	0.35	0.40	-0.01
20b Hälsingland	0.61	0.36	0.31	0.48	0.36	0.01
21 Västernorrland county	0.54	0.14	0.15	0.10	0.68	-0.07
22a Härjedalen	0.08	0.09	-0.02	0.04	-0.02	0.97
Copenhagen	0.35	0.21	0.24	0.82	-0.02	0.09
Danzig	0.11	0.21	0.45	0.79	0.21	-0.06
Konigsberg	0.35	0.27	0.78	0.21	-0.14	0.02

Table 21: Eigenvalues, Oats, 1772–1800.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	20.38	81.54	81.54
comp 2	1.45	5.82	87.36
comp 3	0.92	3.67	91.02
comp 4	0.45	1.78	92.80
comp 5	0.36	1.46	94.26
comp 6	0.30	1.21	95.47
comp 7	0.25	1.00	96.47
comp 8	0.18	0.74	97.21
comp 9	0.16	0.62	97.84
comp 10	0.12	0.47	98.31
comp 11	0.10	0.39	98.69
comp 12	0.07	0.30	98.99
comp 13	0.06	0.26	99.25
comp 14	0.05	0.20	99.44
comp 15	0.04	0.17	99.61
comp 16	0.04	0.14	99.75
comp 17	0.02	0.07	99.82
comp 18	0.02	0.06	99.88
comp 19	0.01	0.04	99.92
comp 20	0.01	0.03	99.95
comp 21	0.00	0.02	99.97
comp 22	0.00	0.01	99.99
comp 23	0.00	0.01	99.99
comp 24	0.00	0.00	100.00
comp 25	0.00	0.00	100.00

Table 22: Factor loadings, Oats, 1772–1800.

	RC1	RC2	RC3
1 Stockholm	0.46	0.85	0.08
2 Uppsala	0.62	0.74	0.08
3 Södermanland	0.52	0.78	0.16
4 Östergötland	0.73	0.61	0.24
5 Jönköping	0.75	0.57	0.19
6 Kronoberg	0.79	0.45	0.25
7 Kalmar	0.75	0.58	0.19
8 Gotland	0.14	0.92	-0.01
10a Kristianstad	0.89	0.32	0.07
10b Ängelholm	0.90	0.36	0.16
10c Simrishamn	0.90	0.21	0.13
11 Malmöhus	0.77	0.47	-0.02
12 Halland	0.87	0.37	0.23
13 Göteborg Bohus	0.88	0.30	0.27
14 Ästerborg	0.83	0.34	0.18
15 Skaraborg	0.80	0.47	0.27
16 Värmland	0.85	0.40	0.19
17a Närke	0.73	0.61	0.11
17b Nora/Linde/Karlskoga	0.79	0.52	0.07
18 Västmanland	0.68	0.68	0.04
19 Kopparberg	0.83	0.42	-0.02
20a Gästrikland	0.90	0.35	0.10
20b Hälsingland	0.84	0.41	0.13
21 Västernorrland county	0.81	0.44	0.15
Copenhagen	-0.20	-0.05	-0.96

Table 23: Eigenvalues, Barley, 1800–1860.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	19.59	69.97	69.97
comp 2	1.97	7.04	77.00
comp 3	1.59	5.67	82.67
comp 4	0.79	2.82	85.49
comp 5	0.72	2.58	88.06
comp 6	0.46	1.64	89.71
comp 7	0.42	1.51	91.21
comp 8	0.36	1.28	92.49
comp 9	0.30	1.09	93.58
comp 10	0.26	0.93	94.51
comp 11	0.25	0.90	95.41
comp 12	0.21	0.76	96.17
comp 13	0.19	0.66	96.83
comp 14	0.16	0.57	97.40
comp 15	0.12	0.44	97.84
comp 16	0.11	0.41	98.25
comp 17	0.09	0.31	98.56
comp 18	0.08	0.30	98.86
comp 19	0.07	0.27	99.13
comp 20	0.07	0.25	99.37
comp 21	0.05	0.16	99.53
comp 22	0.04	0.15	99.68
comp 23	0.02	0.09	99.77
comp 24	0.02	0.07	99.84
comp 25	0.02	0.06	99.90
comp 26	0.01	0.04	99.94
comp 27	0.01	0.03	99.97
comp 28	0.01	0.03	100.00

Table 24: Factor loadings, Barley, 1800–1860.

	RC4	RC1	RC3	RC5	RC2
1 Stockholm	0.49	0.71	0.30	0.14	0.04
2 Uppsala	0.44	0.74	0.29	0.21	0.18
3 Södermanland	0.45	0.69	0.27	0.34	0.15
4 Östergötland	0.55	0.62	0.25	0.35	0.12
5 Jönköping	0.57	0.43	0.30	0.45	-0.00
6 Kronoberg	0.71	0.23	0.20	0.50	0.06
7 Kalmar	0.58	0.51	0.32	0.39	0.07
8 Gotland	0.36	0.73	0.24	0.22	0.03
9 Blekinge	0.75	0.33	0.14	0.32	0.14
10a Kristianstad	0.80	0.46	0.15	0.16	-0.05
10b Ängelholm	0.79	0.50	0.19	0.12	-0.05
10c Simrishamn	0.73	0.54	0.17	-0.04	0.02
11 Malmöhus	0.75	0.51	0.22	0.20	0.03
12 Halland	0.82	0.25	0.21	0.27	0.07
13 Göteborg Bohus	0.65	0.44	0.35	0.41	-0.05
14 Ästerborg	0.56	0.36	0.34	0.54	-0.19
15 Skaraborg	0.52	0.48	0.25	0.61	0.08
16 Värmland	0.36	0.49	0.35	0.64	-0.02
17 örebro	0.45	0.68	0.27	0.45	-0.06
18 Västmanland	0.54	0.72	0.26	0.27	0.05
19 Kopparberg	0.32	0.68	0.42	0.36	0.02
20a Gästrikland	0.55	0.68	0.36	0.17	0.04
20b Hälsingland	0.48	0.54	0.53	0.19	-0.05
21 Västernorrland county	0.35	0.22	0.85	0.13	0.05
22a Härjedalen	0.06	0.07	-0.32	-0.03	0.89
22b Jämtland	-0.01	0.05	0.24	0.03	0.92
23 Västerbotten	0.30	0.30	0.81	0.13	0.06
24 Norbotten	0.01	0.31	0.82	0.24	-0.13

Table 25: Eigenvalues, Rye, 1800–1860.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	20.72	71.45	71.45
comp 2	2.04	7.05	78.50
comp 3	1.32	4.57	83.07
comp 4	1.04	3.59	86.66
comp 5	0.64	2.21	88.87
comp 6	0.57	1.96	90.83
comp 7	0.42	1.44	92.27
comp 8	0.35	1.21	93.48
comp 9	0.29	0.99	94.47
comp 10	0.25	0.85	95.32
comp 11	0.22	0.75	96.07
comp 12	0.19	0.67	96.73
comp 13	0.17	0.58	97.31
comp 14	0.14	0.47	97.78
comp 15	0.11	0.39	98.17
comp 16	0.10	0.34	98.50
comp 17	0.08	0.27	98.77
comp 18	0.07	0.23	99.01
comp 19	0.06	0.22	99.22
comp 20	0.04	0.14	99.36
comp 21	0.04	0.14	99.50
comp 22	0.04	0.13	99.63
comp 23	0.03	0.11	99.73
comp 24	0.03	0.09	99.82
comp 25	0.02	0.07	99.89
comp 26	0.01	0.05	99.94
comp 27	0.01	0.03	99.97
comp 28	0.01	0.03	100.00
comp 29	0.00	0.00	100.00

Table 26: Factor loadings, Rye, 1800–1860.

	RC2	RC1	RC3	RC4
1 Stockholm	0.50	0.81	0.20	0.00
2 Uppsala	0.39	0.87	0.22	-0.03
3 Södermanland	0.50	0.77	0.27	0.01
4 Östergötland	0.63	0.64	0.21	0.07
5 Jönköping	0.74	0.38	0.35	0.05
6 Kronoberg	0.72	0.39	0.27	0.08
7 Kalmar	0.63	0.66	0.24	0.08
8 Gotland	0.42	0.78	0.14	0.11
9 Blekinge	0.77	0.49	0.03	0.08
10a Kristianstad	0.76	0.53	-0.11	0.06
10b Ängelholm	0.73	0.55	0.02	0.12
10c Simrishamn	0.81	0.52	0.01	0.00
11 Malmöhus	0.72	0.63	0.06	0.01
12 Halland	0.79	0.44	0.26	-0.03
13 Göteborg Bohus	0.79	0.43	0.30	-0.09
14 Ästerborg	0.82	0.38	0.22	-0.12
15 Skaraborg	0.76	0.49	0.23	-0.01
16 Värmland	0.73	0.38	0.35	-0.06
17a Närke	0.55	0.71	0.25	-0.12
17b Nora/Linde/Karlskoga	0.56	0.70	0.26	-0.12
18 Västmanland	0.41	0.85	0.23	-0.07
19 Kopparberg	0.43	0.61	0.47	-0.15
20a Gästrikland	0.41	0.85	0.24	-0.01
20b Hälsingland	0.46	0.71	0.38	-0.10
21 Västernorrland county	0.42	0.49	0.59	-0.18
22a Härjedalen	0.12	-0.04	-0.11	0.95
22b Jämtland	-0.33	0.24	0.75	0.33
23 Västerbotten	0.45	0.32	0.61	-0.09
24 Norbotten	0.31	0.07	0.76	-0.33

Table 27: Eigenvalues, Oats, 1800–1860.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	17.04	68.17	68.17
comp 2	1.64	6.55	74.72
comp 3	1.05	4.19	78.91
comp 4	0.82	3.27	82.18
comp 5	0.70	2.81	84.99
comp 6	0.64	2.54	87.53
comp 7	0.55	2.21	89.74
comp 8	0.49	1.96	91.70
comp 9	0.35	1.40	93.11
comp 10	0.31	1.25	94.36
comp 11	0.25	0.98	95.34
comp 12	0.21	0.85	96.20
comp 13	0.19	0.74	96.94
comp 14	0.18	0.72	97.66
comp 15	0.12	0.49	98.15
comp 16	0.10	0.39	98.55
comp 17	0.09	0.35	98.89
comp 18	0.06	0.26	99.15
comp 19	0.06	0.24	99.39
comp 20	0.05	0.21	99.59
comp 21	0.04	0.15	99.74
comp 22	0.03	0.12	99.86
comp 23	0.02	0.08	99.94
comp 24	0.01	0.06	100.00
comp 25	0.00	0.00	100.00

Table 28: Factor loadings, Oats, 1800–1860.

	RC1	RC3	RC4	RC5	RC2
1 Stockholm	0.62	0.60	0.36	0.10	0.15
2 Uppsala	0.55	0.52	0.37	0.27	0.14
3 Södermanland	0.59	0.67	0.23	0.19	0.10
4 Östergötland	0.58	0.62	0.29	0.20	0.02
5 Jönköping	0.68	0.31	0.40	0.21	-0.13
6 Kronoberg	0.51	0.57	0.30	0.31	-0.01
7 Kalmar	0.37	0.62	0.47	0.17	0.14
8 Gotland	0.18	0.29	0.07	0.79	0.27
10a Kristianstad	0.27	0.86	0.21	0.17	-0.18
10b Ängelholm	0.34	0.81	0.27	0.14	-0.19
10c Simrishamn	0.37	0.82	0.21	0.20	-0.18
11 Malmöhus	0.48	0.80	0.21	0.05	-0.00
12 Halland	0.49	0.62	0.31	0.20	0.09
13 Göteborg Bohus	0.69	0.18	0.30	0.43	0.05
14 Ästerborg	0.79	0.42	0.26	0.11	-0.05
15 Skaraborg	0.81	0.43	0.06	0.01	-0.12
16 Värmland	0.87	0.36	0.11	0.02	0.05
17a Närke	0.70	0.40	0.40	0.18	0.01
17b Nora/Linde/Karlskoga	0.70	0.39	0.41	0.16	0.01
18 Västmanland	0.70	0.55	0.31	0.17	0.12
19 Kopparberg	0.63	0.29	0.48	0.27	0.22
20a Gästrikland	0.54	0.37	0.63	0.19	0.05
20b Hälsingland	0.27	0.26	0.70	0.41	-0.17
21a Medelpad	0.23	0.34	0.72	-0.17	0.27
22b Jämtland	0.00	-0.17	0.08	0.18	0.88

Table 29: Eigenvalues, Barley, 1860–1914.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	18.48	68.43	68.43
comp 2	2.87	10.62	79.05
comp 3	0.95	3.51	82.56
comp 4	0.75	2.78	85.33
comp 5	0.60	2.23	87.56
comp 6	0.53	1.96	89.51
comp 7	0.43	1.60	91.11
comp 8	0.40	1.49	92.60
comp 9	0.33	1.22	93.82
comp 10	0.24	0.88	94.70
comp 11	0.22	0.81	95.51
comp 12	0.17	0.65	96.16
comp 13	0.17	0.64	96.80
comp 14	0.14	0.53	97.33
comp 15	0.13	0.47	97.80
comp 16	0.12	0.44	98.24
comp 17	0.09	0.33	98.58
comp 18	0.08	0.29	98.87
comp 19	0.08	0.29	99.16
comp 20	0.05	0.18	99.34
comp 21	0.05	0.17	99.51
comp 22	0.03	0.12	99.63
comp 23	0.03	0.11	99.74
comp 24	0.02	0.09	99.83
comp 25	0.02	0.07	99.90
comp 26	0.02	0.06	99.96
comp 27	0.01	0.04	100.00

Table 30: Factor loadings, Barley, 1860–1914.

	RC1	RC3	RC4	RC2
1 Stockholm	0.83	0.40	0.23	0.15
2 Uppsala	0.83	0.15	0.19	0.33
3 Södermanland	0.88	0.33	0.18	0.08
4 Östergötland	0.78	0.45	0.19	0.10
5 Jönköping	0.71	0.54	0.25	0.08
6 Kronoberg	0.32	0.79	0.28	0.25
7a öland	0.39	0.81	0.05	0.22
7 Kalmar	0.69	0.63	0.19	0.15
8 Gotland	0.74	0.34	0.15	0.30
9 Blekinge	0.64	0.60	0.26	0.04
10 Kristianstad	0.62	0.56	0.08	0.15
11 Malmöhus	0.67	0.53	0.06	0.05
12 Halland	0.58	0.58	0.33	0.21
13 Göteborg Bohus	0.64	0.68	0.22	0.05
14 Ästerborg	0.73	0.44	0.28	-0.11
15 Skaraborg	0.84	0.27	0.23	-0.01
16 Värmland	0.74	0.54	-0.11	0.16
17 örebro	0.76	0.42	0.35	0.03
18 Västmanland	0.85	0.29	0.36	0.10
19 Kopparberg	0.70	0.43	0.33	-0.23
20a Gästrikland	0.79	0.37	0.19	-0.21
20b Hälsingland	0.72	0.31	0.49	-0.08
21 Västernorrland county	0.71	0.27	0.43	-0.24
22a Härjedalen	0.10	0.12	-0.29	0.85
22b Jämtland	0.03	0.19	-0.06	0.90
23 Västerbotten	0.37	0.47	0.69	-0.14
24 Norbotten	0.28	0.05	0.87	-0.30

Table 31: Eigenvalues, Rye, 1860–1914.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	22.27	76.78	76.78
comp 2	2.10	7.25	84.03
comp 3	1.19	4.10	88.13
comp 4	0.66	2.27	90.40
comp 5	0.54	1.88	92.27
comp 6	0.42	1.44	93.71
comp 7	0.31	1.05	94.77
comp 8	0.28	0.97	95.74
comp 9	0.20	0.67	96.41
comp 10	0.17	0.58	96.99
comp 11	0.14	0.47	97.47
comp 12	0.12	0.40	97.87
comp 13	0.11	0.37	98.24
comp 14	0.09	0.31	98.55
comp 15	0.08	0.28	98.83
comp 16	0.06	0.22	99.05
comp 17	0.05	0.18	99.23
comp 18	0.04	0.15	99.38
comp 19	0.03	0.12	99.50
comp 20	0.03	0.10	99.61
comp 21	0.03	0.09	99.70
comp 22	0.03	0.09	99.79
comp 23	0.02	0.07	99.85
comp 24	0.02	0.06	99.91
comp 25	0.01	0.03	99.94
comp 26	0.01	0.03	99.96
comp 27	0.01	0.02	99.99
comp 28	0.00	0.01	100.00
comp 29	0.00	0.00	100.00

Table 32: Factor loadings, Rye, 1860–1914.

	RC1	RC3	RC2
1 Stockholm	0.72	0.65	0.11
2 Uppsala	0.68	0.60	0.31
3 Södermanland	0.75	0.59	0.14
4 Östergötland	0.76	0.57	0.21
5 Jönköping	0.76	0.52	0.13
6 Kronoberg	0.70	0.54	-0.02
7a öland	0.68	0.51	-0.07
7 Kalmar	0.82	0.50	0.08
8 Gotland	0.78	0.55	0.11
9 Blekinge	0.82	0.47	0.09
1Kristianstad	0.77	0.56	0.08
11 Malmöhus	0.69	0.61	-0.02
12 Halland	0.84	0.41	0.09
13 Göteborg Bohus	0.78	0.57	0.03
14 Ästerborg	0.74	0.62	-0.01
15 Skaraborg	0.65	0.68	-0.02
16 Värmland	0.50	0.79	0.14
17 örebro	0.66	0.65	0.22
17a Närke	0.31	0.89	-0.06
17b Nora/Linde/Karlskoga	0.32	0.89	-0.07
18 Västmanland	0.77	0.55	0.14
19 Kopparberg	0.72	0.60	-0.10
20a Gästrikland	0.83	0.43	0.13
20b Hälsingland	0.87	0.42	0.01
21 Västernorrland county	0.82	0.44	-0.10
22a Härjedalen	-0.16	0.12	0.91
22b Jämtland	0.15	-0.09	0.91
23 Västerbotten	0.81	0.19	-0.11
24 Norbotten	0.82	0.08	-0.33

Table 33: Eigenvalues, Oats, 1860–1914.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	17.94	68.99	68.99
comp 2	2.07	7.97	76.96
comp 3	1.69	6.50	83.46
comp 4	0.92	3.54	87.00
comp 5	0.53	2.05	89.04
comp 6	0.47	1.81	90.85
comp 7	0.38	1.45	92.31
comp 8	0.31	1.20	93.50
comp 9	0.26	1.02	94.52
comp 10	0.24	0.92	95.44
comp 11	0.20	0.76	96.20
comp 12	0.16	0.63	96.83
comp 13	0.14	0.53	97.35
comp 14	0.12	0.46	97.82
comp 15	0.10	0.40	98.22
comp 16	0.09	0.35	98.57
comp 17	0.08	0.30	98.87
comp 18	0.07	0.26	99.13
comp 19	0.05	0.18	99.31
comp 20	0.04	0.17	99.48
comp 21	0.04	0.15	99.63
comp 22	0.03	0.12	99.76
comp 23	0.03	0.11	99.87
comp 24	0.02	0.07	99.94
comp 25	0.01	0.05	99.98
comp 26	0.00	0.02	100.00

Table 34: Factor loadings, Oats, 1860–1914.

	RC1	RC4	RC3	RC2
1 Stockholm	0.85	0.17	0.34	0.18
2 Uppsala	0.86	0.31	0.22	0.14
3 Södermanland	0.84	0.34	0.29	0.07
4 Östergötland	0.84	0.33	0.30	0.09
5 Jönköping	0.83	0.32	0.29	-0.02
6 Kronoberg	0.64	0.27	0.52	0.19
7a öland	0.72	0.40	0.38	0.20
7 Kalmar	0.82	0.33	0.27	0.15
8 Gotland	0.76	0.27	0.19	0.24
10 Kristianstad	0.74	0.35	-0.06	0.17
11 Malmöhus	0.74	0.25	0.32	0.05
12 Halland	0.84	0.37	0.18	0.02
13 Göteborg Bohus	0.82	0.37	0.26	-0.00
14 Ästerborg	0.87	0.33	0.25	0.03
15 Skaraborg	0.88	0.18	0.30	-0.12
16 Värmland	0.70	-0.11	0.32	0.27
17 örebro	0.88	0.26	0.28	0.10
17a Närke	0.42	0.06	0.89	0.12
17b Nora/Linde/Karlskoga	0.39	0.13	0.88	0.10
18 Västmanland	0.85	0.31	0.29	0.13
19 Kopparberg	0.52	0.75	0.13	0.06
20a Gästrikland	0.52	0.72	-0.03	0.30
20b Hälsingland	0.60	0.67	0.09	0.21
21 Västernorrland county	0.19	0.90	0.17	0.16
22a Härjedalen	0.00	0.15	0.23	0.92
22b Jämtland	0.17	0.18	-0.02	0.93

Table 35: Eigenvalues, Wheat, 1860–1914.

	eigenvalue	percentage of variance	cumulative percentage of variance
comp 1	15.95	75.97	75.97
comp 2	1.35	6.41	82.38
comp 3	0.90	4.29	86.66
comp 4	0.57	2.70	89.36
comp 5	0.43	2.03	91.40
comp 6	0.38	1.82	93.22
comp 7	0.29	1.38	94.59
comp 8	0.21	0.98	95.57
comp 9	0.17	0.79	96.36
comp 10	0.14	0.67	97.03
comp 11	0.13	0.63	97.66
comp 12	0.12	0.58	98.24
comp 13	0.09	0.44	98.69
comp 14	0.08	0.38	99.06
comp 15	0.06	0.27	99.34
comp 16	0.05	0.22	99.56
comp 17	0.04	0.19	99.74
comp 18	0.03	0.13	99.88
comp 19	0.02	0.11	99.99
comp 20	0.00	0.01	100.00
comp 21	0.00	0.00	100.00

Table 36: Factor loadings, Wheat, 1860–1914.

	RC1	RC2	RC3
1 Stockholm	0.46	0.71	0.43
2 Uppsala	-0.01	0.90	0.17
3 Södermanland	0.60	0.59	0.38
4 Östergötland	0.58	0.67	0.36
7 Kalmar	0.50	0.65	0.50
8 Gotland	0.65	0.60	0.26
9 Blekinge	0.61	0.63	0.34
12 Halland	0.56	0.53	0.48
15 Skaraborg	0.67	0.44	0.52
16 Värmland	0.50	0.53	0.21
18 Västmanland	0.59	0.63	0.41
19 Kopparberg	0.77	0.35	0.43
20a Gästrikland	0.87	0.25	0.06
20b Hälsingland	0.87	0.08	0.26
5 Jönköping	0.68	0.37	0.44
7a öland	0.49	0.66	0.50
10 Kristianstad	0.52	0.67	0.39
14 Ästerborg	0.79	0.31	0.37
13 Göteborg Bohus	0.75	0.35	0.44
17a Närke	0.27	0.31	0.90
17b Nora/Linde/Karlskoga	0.28	0.32	0.89