

Harvests and grain prices in Sweden, 1665–1870

by Rodney Edvinsson

Abstract

This paper investigates the impact of harvests and international markets on Swedish grain prices, 1665–1870. The paper finds that harvests at a national level had a greater impact on domestic grain prices than international grain prices. However, at a regional level, grain prices tended to be affected more by harvests outside the region. Furthermore, in the long term, foreign prices became a more important determinant of national grain prices. The conclusion is that, under certain circumstances, grain prices can be used as an indicator of harvest fluctuations and to construct historical national accounts, at least at a sufficiently aggregated level. Such an endeavour needs to be combined with a careful analysis of the impact of prices in the surrounding area.

The benefit of price stability to consumption is a fundamental theme in pre-industrial political economy.¹ In agrarian society, it was largely the growth and fluctuations of harvests that determined the growth and fluctuations of real incomes and consumption. One important indicator of harvest fluctuations is the grain price. The traditional view, as for example argued by Fogel, is that there was a very strong negative correlation between harvests and grain prices, due to an extremely inelastic, although constant, demand for grain.² A similar relationship is assumed in the pioneering work of W. G. Hoskins. His study of harvest fluctuations in England, 1480–1759, completely depends on fluctuations in grain prices to assess the scale of the harvest. Hoskins wrote that to look at the annual fluctuations of grain prices was like looking at an electrocardiogram of a living organism.³

More recent historians have been more cautious about assuming a linear relationship between harvest quality and price. Bruce Campbell accepts that grain prices ‘have provided the starting point for most analyses of the historical incidence of bad harvests’, not least since prices ‘are typically the most widely recorded item of information about grain’. However, he points out that the relationship is more complex than appears on first sight, since grain prices reflected other conditions as well. It is, therefore, important to compare prices with other independent evidence of harvest outcomes.⁴

¹ K. G. Persson, *Grain markets in Europe, 1500–1900* (1999).

² R. W. Fogel, ‘Second thoughts on the European escape from hunger, famines, chronic malnutrition, and mortality rates’, in S. R. Osmani (ed.), *Nutrition and poverty* (1992), pp. 243–86.

³ W. G. Hoskins, ‘Harvest fluctuations and English economic history, 1480–1619’, *AgHR* 12 (1964), pp. 28–45;

id., ‘Harvest fluctuations and English economic history, 1620–1759’, *AgHR* 16 (1968), pp. 15–31.

⁴ B. M. S. Campbell, ‘Four famines and a pestilence: harvest, price, and wage variations in England, 13th to 19th centuries’, in B. Liljewall *et al.* (eds), *Agrarhistoria på många sätt: 28 studier om människan och jorden* (2009), pp. 23–8 and 44–5.

Karl Gunnar Persson argues that price volatility is the combination of supply shock (harvest failure) and poor market integration. Both trade and carry-over mitigated fluctuations in supply, and, therefore, in grain prices. According to Persson, the effect of storage was negligible, but the impact of trade was substantial.⁵ Because of slow information and the high costs of transportation, harvest fluctuations had a large impact on prices. In contrast, studies of English agriculture show that the autoregressive effects were strong;⁶ implying that grain storage could have a larger impact on prices than assumed by Persson.

For Sweden, several authors have explicitly advised against using grain prices as an indicator for harvest fluctuations, finding that the correlation between grain prices and harvest fluctuations is not strong.⁷ Two of the most familiar arguments are firstly that domestic prices were substantially affected by inflationary policies and secondly that foreign prices had more effect than domestic harvests on domestic prices.

Angus Maddison criticizes those who use real wages as an indicator for changes in living standards, maintaining that wages are not macroeconomic data.⁸ This reasoning could also be applied to grain prices, since most of the harvest was not directed towards the market. Price data often reflected conditions in the metropolitan areas, highly integrated with the international markets, rather than in the countryside.

In their investigation of the Nuremberg region 1339–1670, Bauernfeind and Woitek found that the correlation between detrended rye prices and tithe revenues was only -0.4 ,⁹ implying that only 16 per cent of the variance in tithes could be predicted by price. The cycles in rye prices were also more regular than for tithes, which they suggest may be due to the effect of granary stocks smoothing out annual price fluctuations. In his study of Swedish prices 1732–1913, Lennart Jörberg similarly concludes that ‘the uncomplicated conception of a strong correlation between price and estimated yield is not borne out by a closer analysis’.¹⁰ Mary Young finds a co-movement of yield ratios on a farm and grain prices in Scotland, 1673–1695,¹¹ but it does not seem to be very strong on a closer inspection. A common feature of these three studies displaying a low correlation between harvests and grain prices in the pre-industrial period seems to be that they are based on regional or local data and, therefore, do not reflect the relationship at a higher level of aggregation.

This paper investigates how domestic harvests and international grain prices affected domestic grain prices in Sweden between 1665 and 1870. The study utilizes data on harvest outcomes during the early modern period that is of better quality than is available for many other countries at the aggregated national level. Although this harvest series is based on sources

⁵ Persson, *Grain markets*, p. 54.

⁶ S. Scott, S. R. Duncan, and C. J. Duncan, ‘The origins, interactions and causes of cycles in grain prices in England, 1450–1812’, *AgHR* 46 (1998), pp. 1–14.

⁷ B. Å. Berg, ‘Volatility and integration: Swedish Rye Prices, 1600–1900’ (unpublished licentiate thesis, Stockholm School of Economics, 2003); L. Jörberg, *A history of prices in Sweden*, II, 1732–1914 (1972), p. 71; L. Leijonhufvud, *Grain tithes and manorial yields in early modern Sweden: Trends and patterns of production and productivity, c.1540–1680* (2001).

⁸ A. Maddison, *Contours of the world economy, 1–2030 AD: Essays in macro-economic history* (2007), p. 308.

⁹ W. Bauernfeind and U. Woitek, ‘Agrarian cycles in Germany, 1339–1670: A spectral analysis of grain prices and output in Nuremberg’, *Explorations in Economic History* 33 (1996), p. 470.

¹⁰ Jörberg, *Prices in Sweden*, II, p. 71.

¹¹ M. Young, ‘Scottish crop yields in the second half of the seventeenth century: evidence from the Mains of Castle Lyon in the Carse of Gowrie’, *AgHR* 55 (2007).

that also exist for other countries, such as tithes, it adjusts some of the biases of these sources by relating them to the more reliable data collected by government statistical offices. The series is also a truly national one, given that it is based on data from many different counties or regions. The investigation stops at 1870, since it was at this moment that the Swedish economy started to industrialize. It was also in the period 1870–1913 that a major decrease in disparities between grain prices in various locations took place internationally due to the falling cost of transport that occurred after mid-century.¹²

In this paper it is maintained that it took up to several years for the national price to fully adjust in response to a divergence between domestic and international prices. Under such circumstances, annual harvest fluctuations had a greater impact on national grain prices than international grain prices, despite the existence of a relatively strong integration of grain markets. For Sweden, this applies only for short-term fluctuations at a national level, since at a regional level, grain prices tended to be more affected by harvests outside of the region and in the long-term prices were mainly affected by other factors. To what extent this can be generalized depends on the pattern of market integration. The important point is that various levels of aggregation and different time scales must not be confused.

I

The per capita harvest index that is used in this study is based on various series for different periods, tithes for the period 1665–1737, subjective harvest estimates for 1737–1802 and official harvest data and estimated yield ratios by priests and county governors for 1802–70 (see Figure 1). A per capita quantity index is used, from which potatoes are excluded (although data exists for the potato harvests from 1802, as shown in Figure 1). The index is presented in kilograms of grain, and includes seed reserved for sowing and grain fed to animals. This quantity index does not take into account the different values of various grains, which a volume (constant price) index does (for example, of the Laspeyres or Paasche types), although the difference between a quantity and volume index is quite small for the period 1802–70, for which data on different grains exists.

In Sweden, official statistics on crops have been gathered at the county level since 1802.¹³ Annual data exists for 1802–20 and from 1865 onwards. After 1820, official data on crops stopped being reported annually, and were instead reported only every five years. Annual data is available again from 1865. Nevertheless, annual reports on the harvest by 24 Swedish country governors exist for the missing years, including statements on yield ratios of various grains. This material has been used to construct annual estimates of per capita production of crops for the period 1820–65 as well.¹⁴ At present, there is a general consensus that the official harvest estimates for the early nineteenth century must be increased by around 100 per cent,¹⁵ and by a

¹² K. O'Rourke, 'The European grain invasion, 1870–1913', *JECH* 57 (1997), pp. 775–801.

¹³ Statistics Sweden, *Historisk statistik för Sverige*, II, (Örebro, 1955).

¹⁴ Some of this material has been published in *Post-och Inrikes tidningar* (Stockholm). The primary

material can be found in The National Archives (Stockholm), Statskontoret, kansliet, E3N.

¹⁵ C.-J. Gadd, 'Swedish agricultural production, 1800–1910' <http://www.ekhistmotet09.ekhist.uu.se/file-download.php?id=114> (viewed 1 June, 2009).

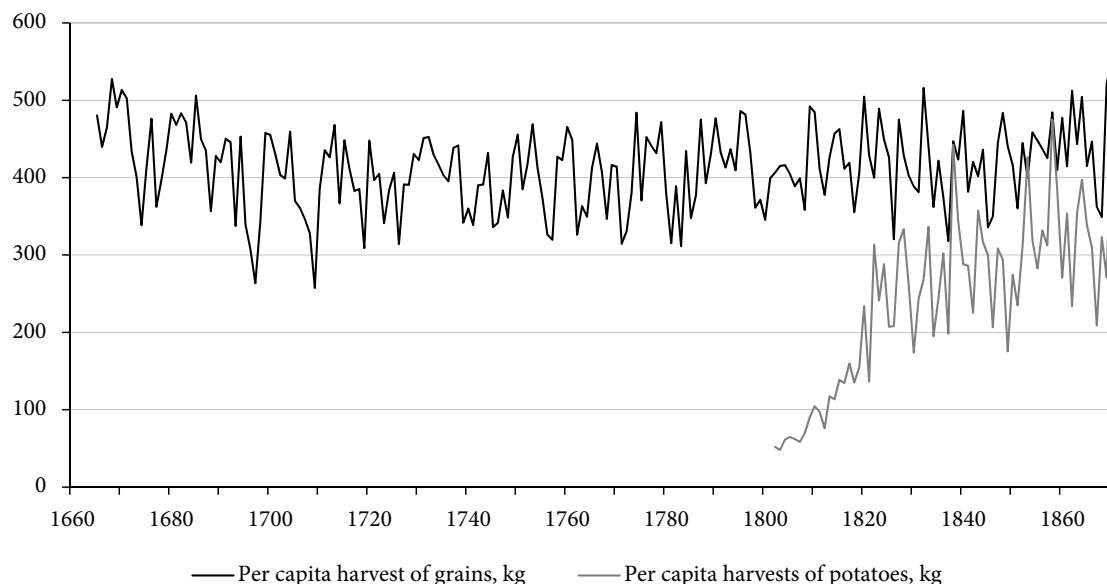


FIGURE 1. Per capita harvests of grains and potatoes in Sweden, 1665–1870
(in kilograms and including seeds and forage)

decreasing amount until around 1910 by which time official data is assumed to represent actual harvests accurately. However, the annual fluctuations of this series seem to be reliable. Previous studies on the underestimation of official statistics have been used to adjust the absolute levels in seeds and absolute harvests.¹⁶

There is also a difference in volatility of harvests when measured by weight (kilograms) and volume (barrels). Weight volatility was somewhat higher than volume volatility, since density of grains correlated positively with harvest fluctuations (according to official statistics after 1865). Since the harvest estimates in 1802–65 are based on volume values, the standard deviation of harvest fluctuations have been adjusted somewhat upwards by comparing the relation between weight and volume fluctuations in 1866–88.

Tithes probably constitute the most direct quantitative evidence concerning harvest fluctuations before the nineteenth century, and have been used with varying success in various international studies as an indicator for grain output.¹⁷ The tithe is traditionally a tax levied at 10 per cent of the harvest. In Sweden, after the Reformation, the Crown took two thirds of the tithe, while the remaining third was retained by the vicar. Thus Crown tithes were supposed to represent a fifteenth of the harvest (although in the counties previously belonging to Denmark and Norway tithes were supposed to represent a thirtieth of the harvest). While the tithes have

¹⁶ Ibid.

¹⁷ See, for example, E. Le Roy Ladurie and J. Goy, *Tithe and agrarian history from the fourteenth to the nineteenth centuries: an essay in comparative history* (1982); Bauernfeind and Woitek, 'Agrarian Cycles'; Leijonhuf-

vud, *Grain Tithes*; B. Dodds, *Peasants and production in the medieval north-east: the evidence from tithes, 1270–1536* (2007); B. Dodds, 'Demesne and tithe: peasant agriculture in the late middle ages', *AgHR* 56 (2008), pp. 123–41.

been shown to be unreliable concerning the absolute level of harvest, they seem to be more reliable when determining annual fluctuations.¹⁸

For the period 1665–1737 this paper uses a per capita tithe series that has been presented in an earlier study.¹⁹ For the period 1665–1680 this per capita harvest index is based on tithe data gathered by Lotta Leijonhufvud.²⁰

A problem when estimating volatility from tithes is that these were much more volatile than the national harvest, since the empirical data only covers the harvest in one or at most several regions. Furthermore, tithes tended to fluctuate more than the actual harvest, since the proportion of the harvest that was taxed decreased in years when harvests were lower (when various areas were hit by severe harvest failures the tithe tended to decrease towards zero).²¹ After the 1730s, the tithe data is less reliable. Instead, for the period 1737–1802, an index of subjective harvest estimates is used.²² The subjective harvest estimates for this period also exist for various counties.

When the data sets of the various sub-periods have been spliced together to form one series for the whole period 1665–1870, the standard deviations of annual changes in harvests according to the better data from 1803–1870 are assumed to have been the actual ones (which also corresponds well to later agricultural statistics). The standard deviations of earlier indicators are adjusted to this benchmark period, by looking into temporal overlaps between the three series. The splicing is made difficult since the three series are based on different sources, and there is no consistent individual series that is reliable for the whole period.

The ratio between the standard deviation of annual logarithmic changes in 1738–1802 and 1803–20 is assumed to be the same as the same ratio for the annual changes in the index of subjective harvest estimates. The latter shows a downturn in the standard deviation by 17 per cent between 1738–1802 and 1803–20. However, the better data for 1803–70 also shows an increase in the standard deviation by 34 per cent between 1803–20 and 1821–70.

The ratio between the standard deviation of annual changes in 1666–1737 and 1738–1802 is assumed to be the same as the ratio for the tithe index. The latter shows that harvest volatility was roughly the same in the two periods.

The difference between the estimated standard deviations in the three periods was quite small (see Table 1). A Levene's test yields a W-value of 0.263, which is insignificant ($p=0.769$). Henceforth, the null hypothesis of homogeneity of variances of the three periods cannot be rejected. As a comparison, the standard deviation of the annual changes in per capita grain

¹⁸ See R. Edvinsson, 'Swedish harvests 1665–1820: early modern growth in the periphery of European economy', *Scandinavian Economic History Rev.*, 57 (2009), pp. 2–25.

¹⁹ Ibid.

²⁰ Leijonhufvud, *Grain tithes*.

²¹ Dodds, *Peasants and production*, p. 143 proposes an opposite model for north-east England in the Middle Ages, i.e. that tithes as a proportion of output tended to increase with price, but that does not seem to be how tax collection functioned in Sweden during the early modern period.

²² Edvinsson, 'Swedish harvests'. The main secondary sources are J. Hellstenius, 'Skördarna i Sverige och deras verkningar', *Statistisk Tidskrift* 29 (1871), pp. 77–127; G. Utterström, *Jordbrukets arbetare: Levnadsvillkor och arbetsliv på landsbygden från frihetstiden till mitten av 1800-talet*, II, (1957), pp. 429–31; A. Imhof, *Aspekte der Bevölkerungsentwicklung in den nordischen Ländern, 1720–1750*, II (1976), pp. 715–54; G. Axelson, *Bidrag till kännedomen om Sveriges tillstånd på Karl XII:s tid* (1888). These authors use direct accounts of harvests, which should not be influenced indirectly by price notations.

TABLE 1. Multiple regressions for the period 1666–1870 and its sub-periods where the logarithmic change in the silver price of grain in Sweden is the dependent variable and the logarithmic changes in per capita harvest for three consecutive years the independent variables

	1666–1737	1738–1802	1803–70	1666–1870
R-value	0.779	0.862	0.766	0.787
Adjusted R-square	0.596	0.734	0.567	0.613
Degrees of freedom	69	62	64	201
Logarithmic change in per capita harvest, beta-coefficient	–0.829	–0.915	–0.845	–0.854
Logarithmic change in per capita harvest, one-year lag, beta-coefficient	–0.283	–0.360	–0.545	–0.397
Logarithmic change in per capita harvest, two-year lag, beta-coefficient	–	–	–0.217	–0.101
Logarithmic change in per capita harvest, <i>t</i> -value	–10.330	–13.347	–9.379	–17.950
Logarithmic change in per capita harvest, one-year lag, <i>t</i> -value	–3.531	–5.253	–5.521	–7.774
Logarithmic change in per capita harvest, two-year lag, <i>t</i> -value	–	–	–2.373	–2.117
Logarithmic change in per capita harvest, significance	0.000	0.000	0.000	0.000
Logarithmic change in per capita harvest, one-year lag, significance	0.001	0.000	0.000	0.000
Logarithmic change in per capita harvest, two-year lag, significance	–	–	0.020	0.036
Standard deviation (natural logarithms) of change in per capita harvest	0.153	0.152	0.160	0.154
Standard deviation (natural logarithms) of change in silver price	0.215	0.167	0.181	0.189

production in 1871–1955 was 0.156 natural logarithms, only slightly above the volatility in 1666–1870 (at 0.154 natural logarithms).

One question is whether there is some bias in the empirical sources concerning long-term changes in the volatility of harvests. Should we not expect a decline in the volatility of harvests during the early modern period? One way to make a reasonable judgement is to compare the few indicators we have for this period, and see if they point in the same direction. A problem arises, of course, if various indicators diverge. For example, in England, while the tithe series display a significantly lower volatility towards the end of 1275–1499, the volatility of yield ratio seemed to increase somewhat in that period.²³ Henceforth, since we deal with pre-industrial data, we must be cautious about drawing any definite conclusions.

²³ Campbell, 'Four famines and a pestilence', p. 29.

As discussed below (see Table 1), although the standard deviation of the logarithmic change in Swedish grain prices displays a decline between 1666–1737 and 1738–1802, it is likely that this decline can primarily be explained by improved market integration. There was an even larger decline in the volatility of grain prices after 1870, while harvest volatility did not change much. The price volatility was not much different in the periods 1737–1802 and 1803–70, respectively, which is in agreement with the spliced harvests series.

The somewhat higher volatility of harvests in 1821–70 is also visible in other data. For example, at a farm in Djäknebo, in Blekinge in the south of Sweden, the standard deviation of the logarithmic change in the average yield ratio increased by 18 per cent between 1762–1820 and 1821–61, while at a farm in Björnö, in Uppland, it increased by 12 per cent between 1803–20 and 1821–42.²⁴

There are some indications of a decline in harvest volatility in the pre-industrial period, but before 1665. A preliminary comparison of tithes and yield ratios of individual farms in the two periods 1539–1665 and 1666–1870 points in that direction.²⁵

II

For the period 1665–1732, the grain price index is largely based on estimates of rye and barley prices in various regions and counties, which is spliced together with the grain price from 1732 onwards.²⁶ The price is calculated as the average of the prices of rye and barley. For years when the price of only one of the grains is available, the price of grain is estimated based on the ratio of the relative prices of rye and barley in the adjacent time periods. One problem with the different price series is that it is not always clear which series refer to the harvest year and which refer to the calendar year. The Swedish harvest year runs roughly from mid-September in the current year to the mid-September in the following year. The grain prices in this period can be linked to the autumn harvest. Thus the price in the spring relates to the preceding year's harvest. How to treat the month of September can depend on various series; for example, if there is a small time lag, the September price of the current year becomes related to the harvest of the preceding year.

Many price notations, for example Jörberg's price scales, refer to the harvest year since they were gathered at the end of the year. However, much price data from before 1732 refers to the calendar year. These prices are mostly a reflection of the preceding year's harvest, especially if they were collected during the first half of the year. If the prices were gathered over the whole

²⁴ Utterström, *Jordbrukets arbetare*, I, pp. 201–02; L. Palm, *Gud bevare utsädet! Produktionen på en västsvensk ensädesgård: Djäknebo i Hallands skogsbygd, 1760–1865* (1997), pp. 159–60.

²⁵ For the period 1539–1665, tithes and yield ratios are from Leijonhufvud, *Grain tithes*.

²⁶ The main sources are O. Bjurling, *Skånes utrikessjöfart, 1660–1720: En studie i Skånes handelssjöfart* (1945); G. Hansson, *Såld spannmål av kyrkotonden: priser i Östergötland under Sveriges stormaktstid* (2006); B. Ericsson, *Bergsstadens Falun 1720–1769* (1970);

A. Hegardt, *Akademiens spannmål: Uppbörd, handel och priser vid Uppsala universitet, 1635–1719* (1975); A. Jansson and J. Söderberg, 'Priser och löner i Stockholm, 1600–1719', in L. Andersson Palm, A. Jansson, and J. Söderberg (eds), *Dagligt börd i onda tider: Priser och löner i Stockholm och Västsverige, 1500–1770* (1991); L. Andersson Palm, 'Priser i Västsverige 1551–1770', in Palm, Jansson, Söderberg (eds), *Dagligt börd*; S. Mårtensson, *Bryggerinäringen i Göteborg: Tiden från bryggaregillens tillkomst år 1661 intill 1800-talets början* (1961).

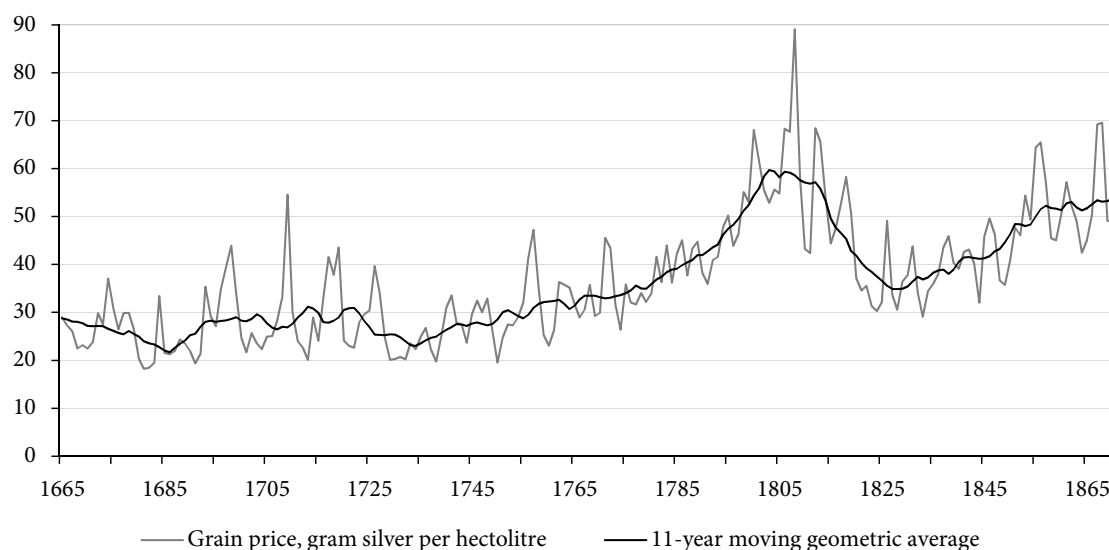


FIGURE 2. The estimated silver price of grain (gram silver per hectolitre) of this study for the period, 1665–1870

calendar year, the data becomes a mixture of two different harvest years. For price series in which it is not clear which harvest year is referred to, this study correlates the series with price series in other regions, international prices and the annual harvests to determine the harvest year.

For the period 1732–1870 the nominal price of the present study is calculated as a weighted geometric average of the prices of wheat, rye, barley, oats, peas and malt based on Lennart Jörberg's collection of price scales in various counties.²⁷ Malt has been given the weight 0.05, while the weights for the other grains are based on the value shares of these grains in total cereal production in 1802 and 1820. The composition of grains changed during the course of the studied period. However, since the prices of various grains are highly correlated with each other, price indices constructed in differing ways will not greatly differ from each other.

While the monetary conditions after the 1820s were quite stable, the period 1665–1820 experienced several inflationary episodes. To counter this effect, the nominal price of grain is converted into a silver price, i.e. the price of grain is expressed in grams of silver. The exchange rates of the Swedish *riksdaler specie* in *mark kopparmynt* up to 1776, the Swedish *riksdaler banco* in *riksdaler riksgälds*, 1789–1808, and Hamburger *reichstaler banco* in *riksdaler riksgälds* from 1790 onwards are used for this purpose.²⁸

Figure 2 presents the price of grain in grams of silver per hectolitre for Sweden in the period 1665–1870. The annual fluctuations were sharp, but up to around the 1770s the long-term trend was quite stable. During the late eighteenth and the nineteenth centuries some significant

²⁷ Jörberg, *Prices in Sweden*, I.

²⁸ Based on the data of the Riksbank project 'Historical monetary statistics for Sweden 1668–2008',

<http://www.riksbank.com/templates/Page.aspx?id=27394> (viewed 1 May, 2009).

medium term fluctuations occurred. In the long term, the purchasing power of silver declined. The sharp rise around 1800 also led to a corresponding decline in real wages. However, official Swedish harvest data shows that the dip in per capita grain production around 1800 was not as sharp as the increase in grain prices (compare Figures 1 and 2). Medium and long-term movements in grain prices are, therefore, not a good indicator of per capita production.

Table 1 shows that there were some differences in the standard deviation of the annual changes in grain price between the periods 1666–1737, 1738–1802 and 1803–70. However, Levene's test yields a W-value of 0.747, which is insignificant ($p=0.475$). The null hypothesis of no difference between the variances of the three periods cannot be rejected.

III

To avoid the impact of autoregression, the relation between per capita harvests and grain prices is analysed by taking the first difference to produce a stationary process of the two series, which are first transformed into logarithmic values. However, the Dickey–Fuller test yields $DF_{\tau} = -4.15$ for the original logarithmic price series and $DF_{\tau} = -10$ for the original logarithmic per capita harvests series, implying that the null hypothesis of a unit root can be rejected for the original series as well, i.e. without taking the first difference (the critical value is -2.59 for $p = 0.01$). For the first differences, the Dickey–Fuller test yields $DF_{\tau} = -14.9$ for the price series and $DF_{\tau} = -20.7$ for the harvest series.

As noted above, there is some uncertainty concerning the homogeneity of variances of the harvest series for various sub-periods. The price series also display a certain heteroscedasticity, although it could not be shown to be significant. Since the possible heteroscedasticity is quite small, the effect on the analysis of the relation between grain prices and harvests is only minor. Even econometricians studying modern conditions emphasize that we should not overreact to the problem of heteroscedasticity. For example, John Fox in his *Applied regression analysis* writes that 'unequal error variance is worth correcting only when the problem is severe'.²⁹

A simple analysis shows that, in Sweden, the domestic harvests had a great impact on grain prices. In 1666–1870 the correlation between annual logarithmic changes in the silver price of grains and per capita harvests, the first differences of the original series, was -0.71 , although it was somewhat weaker towards the end of the period. The correlation between the second differences of the two series was even stronger, at -0.73 , which suggests that the relation is not spuriously generated by autoregression. These correlations are very robust to alternative assumptions of volatilities in various sub-periods. For example, assuming the very unlikely case that the standard deviation of the annual logarithmic change in the per capita harvest series was 50 per cent higher in 1666–1737 than according to the present study, the first correlation would be about the same (-0.71). Assuming a 100 per cent higher standard deviation (an even more unlikely scenario) implies that the first correlation is only slightly reduced (to -0.70).

A correlation between the prices and harvests of the current year does not fully take into account the effects of harvests on prices. The effect of the previous year's harvest needs to be considered as well. Storage dampens the impact of current harvests on prices. If a bad

²⁹ J. Fox, *Applied regression analysis, linear models, and related methods* (1997), p. 306.

harvest occurs, the price will tend to be lower if the harvest had been better than normal in the preceding year. Vice versa, if a good harvest occurs, the price will tend to be higher if the harvest had been worse than normal in the preceding year. The monthly increase in the price of grain over the harvest year partly reflects the cost of storage.³⁰

Table 1 presents a multiple regression of the effect of three consecutive harvests on the current year's grain price. For the whole period 1666–1870 the model explains 61 per cent of the variance in the annual change in the silver price of grains. The beta-coefficient for the change in the current year's per capita harvest is about the same for all three sub-periods, 1666–1737, 1738–1802 and 1802–70, which clearly shows how stable the impact of domestic harvests was on grain prices through time.

Nevertheless, the effect of the previous year's harvests on the current year's grain price changed through time. The effects of the previous year's harvests seem to be strongest in 1802–70, and weakest in 1666–1737. The beta-coefficient of the logarithmic change in per capita harvest lagged by one year is almost twice the magnitude in 1802–70 than in 1666–1737, while the beta-coefficient for the change in per capita harvest in the current year is almost unchanged. The coefficient of the change in per capita harvest lagged by two years is insignificant for the periods 1666–1737 and 1738–1802 (and, therefore, excluded from the model for those two periods), while it is highly significant for 1802–70.

This may suggest that storage became more important through time, and, therefore that the influence of the previous year's harvests on the current year's prices became stronger. If, for example, no storage occurs from one year to another, then only the current year's harvest would have an effect on the current year's price (not considering that part of the harvests could be 'stored' by expanding the animal stock). In 1666–1737 and 1738–1802 the only substantial storage was from one year to the next, while in 1802–70 a more prolonged storage capacity must have been established. In his study on the establishment of Swedish local grain banks, so-called 'Parish Magasins', Bengt-Åke Berg also shows that it was in the second half of the eighteenth century that storage capacity expanded.³¹

IV

Markets are sometimes considered to be integrated when the price moves within the 'commodity points', i.e. the difference between the prices in two locations does not move beyond the transaction costs of moving goods from the one location to the other.³² In his study of Swedish grain prices Bengt-Åke Berg points out that, due to the availability of imports, the domestic price should not be used as an indicator for domestic harvests.³³ In his view, there is a maximum price, which is the international price plus the transaction margin. Import is

³⁰ J. L. van Zanden, 'On the efficiency of markets for agricultural products: rice prices and capital markets in Java, 1823–1853', *JECH* 64 (2004), pp. 1029.

³¹ B.-Å. Berg, *Volatility, integration and grain banks: Studies in harvests, rye prices and institutional development of the parish magasins in Sweden in the 18th and*

19th centuries (2007).

³² G. Federico, 'Market integration and market efficiency: the case of nineteenth-century Italy', *Explorations in Economic History* 44 (2007), pp. 293–316.

³³ Berg, 'Volatility and integration', pp. 44 and 91.

the marginal quantity, and whenever there is an opportunity for imports they will have a fundamental impact on domestic prices.

In practice it has been very difficult to estimate the so-called 'commodity points'. A temporary deviation could occur from 'equilibrium', and adjustments could take time. According to Karl Gunnar Persson the more markets are integrated, the faster local prices return to such 'equilibrium'.³⁴

In the short-term, the probability that transaction costs increased with increased imports must be taken into account. In a study on freight rates in the 1850s, Klovland showed that the increased import of grains was accompanied by increased freight rates, and vice versa.³⁵ An average price for freights, insurance, trade marginal, etc, cannot in itself be used. It is the marginal transaction costs that are interesting. Assuming increasing marginal transaction costs, the increase in imports was dampened during bad harvests. The number of ships was limited in the short term. Profits could also be highly variable. A higher rate of profit in one market did not immediately induce a movement towards that market, since there was an expectation that the increase might turn out to be temporary. This implies that it could take up to several years for the domestic price to adjust fully in response to the international price. Under such circumstances annual harvest fluctuations retained a great impact on annual movements in prices.

Furthermore, it must be considered that part of the correlation between domestic and foreign prices can be explained by the correlation between domestic and foreign harvests. Harvests in northern and western Europe were affected by similar conditions, although there were also differences in climatic and other factors. For example, in the period 1820–42, the correlation between annual changes in per capita harvests in Sweden and of the average yield of wheat, oats, barley, potatoes, hay and flax in Ireland, respectively, was as high as +0.57.³⁶ The correlation between annual changes in wheat yields in Ireland and England, respectively, was for the same period +0.68.³⁷ The decline in per capita harvests that can be observed for Sweden in the 1690s (see Figure 1) is also reflected in the yield ratios in Scotland³⁸ and grain prices in England.³⁹ During the nineteenth century, the Swedish yield ratio of potatoes reached its lowest level in 1846–51 (when looking at six-year periods), which almost exactly coincided with the Great Famine in Ireland.

The impact of foreign prices and domestic harvests on domestic prices can be analysed by relating rye prices in Gdańsk to domestic (Swedish) grain prices and harvests. The Gdańsk price is converted into a silver price by using the exchange rate of the Polish *grosz* against the *thaler*. The logarithmic change in the silver price of rye in Gdańsk is measured from the last quarter in year $t-1$ to the last quarter in year t .⁴⁰ In this way the Gdańsk price is connected to the current harvest year.

³⁴ Persson, *Grain markets*, p. 93.

³⁵ J. T. Klovland, 'New evidence on the fluctuations in ocean freight rates in the 1850s', *Explorations in Economic History* 46 (2009), pp. 266–84.

³⁶ P. Solar, 'Harvest fluctuations in pre-Famine Ireland: Evidence from Belfast and Waterford newspapers', *AgHR* 37 (1989), pp. 160–61. An average of south-eastern and north-eastern Ireland is estimated.

³⁷ For England based on B. R. Mitchell, *British historical statistics* (1988), p. 195.

³⁸ Young, 'Scottish crop yields', p. 67.

³⁹ Hoskins, 'Harvest fluctuations, 1620–1759', p. 22.

⁴⁰ Based on T. Furtak, *Ceny w Gdańsku w latach 1701–1815* (1935); J. Pelc, *Ceny w Gdańsku w XVI i XVII wieku* (1937).

Up to around 1800, the Swedish grain market was strongly integrated with the Polish one, not least since imports to Sweden mainly came through the Baltic. The annual change in the Swedish grain price was much more strongly correlated with prices in Gdańsk than, for example, prices in London and Amsterdam. In the eighteenth century, the transport cost between Stockholm and Gdańsk was around a third to a quarter of that between Stockholm and London, and around half or a third of that between Stockholm and Amsterdam.⁴¹ Unfortunately the Polish price series stops in 1815. The integration of the Swedish and Polish grain markets ceased to be important in the early nineteenth century because Sweden became self-sufficient in grains and Poland declined as an important grain exporter to Sweden.

The correlation between the absolute price and harvest is weaker than the correlation between the changes in price and harvests. For example, in 1665–1802, while the correlation between the absolute grain price in grams of silver and the national per capita harvest index was -0.48 , the correlation between the annual logarithmic changes of the two series was -0.75 . The opposite is true of the relation between domestic and foreign price. While the correlation between the absolute foreign and domestic price was $+0.8$ in the same period, the correlation between the annual logarithmic changes in the two series was only $+0.58$. Henceforth, while, in the long run, the price of grain was to a larger extent determined by the foreign price level, in the short run it was to a larger extent determined by domestic harvests. This also explains why the grain price is a better indicator of annual fluctuations in harvests than of long-term trends, as discussed above.

In comparison, the correlation between logarithmic changes in the silver price of barley in England and silver price of grain in Sweden, respectively, in the period 1666–1802 was only $+0.29$, and barely significant.⁴² There is no indication of higher integration of English and Swedish prices in the nineteenth century. In fact, the correlation between harvests in Sweden and England seems to be stronger than the correlation between grain prices of the two areas.

Another issue is whether there was a true Swedish market, and if not, whether the Stockholm–Gdańsk axis was more integrated than Stockholm and other areas of Sweden. An investigation of the correlations between the annual logarithmic changes in the silver prices of rye in various Swedish counties and those of Gdańsk in 1733–1815 shows a stronger positive correlation between these Swedish counties and Stockholm than the same Swedish counties and Gdańsk.⁴³ This is a clear indication that a distinct Swedish grain market had been formed.

Figure 3 presents the ratio of the rye price in Stockholm to the one in Gdańsk 1543–1815 (based on silver prices). For the period before 1732 the Stockholm rye price is based on the grain price, which has been spliced together with the series from 1732 onwards. The figure shows that the ratio fluctuated sharply on an annual basis. There was no stable transaction margin if rye was shipped from Gdańsk to Stockholm, and for some years must have been completely outside of the ‘commodity points’ despite the relatively high market integration of the two ports. There was no indication of a maximum price. In the medium and long term, there was a clearly visible trend line. Most notable is the difference between the periods 1543–1662 and 1663–1815.

⁴¹ Based on freight rates in *Stockholms stads priscourant* (Stockholm)

(2006), Microsoft Excel file, [http://gpih.ucdavis.edu/files/England_1209-1914_\(Clark\).xls](http://gpih.ucdavis.edu/files/England_1209-1914_(Clark).xls) (viewed 21 Feb. 2009).

⁴² G. Clark, ‘English prices and wages, 1209–1914’

⁴³ Based on Jörberg, *Prices in Sweden*, I.

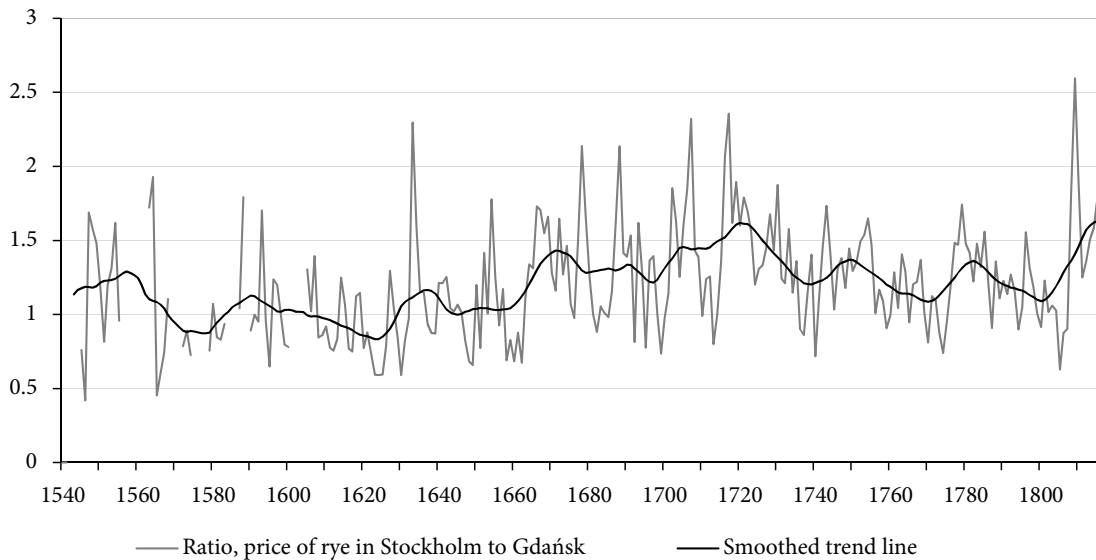


FIGURE 3. The ratio of the rye price in Stockholm to the rye price in Gdańsk, 1543–1815

Up to 1662, rye prices in Stockholm and Gdańsk were roughly the same, while in 1663–1815 the Stockholm rye price was, on average, 32 per cent above the rye price in Gdańsk. It was also during the course of the 1650s and 1660s that Sweden was transformed from a net exporter of grains to a net importer.⁴⁴

Table 2 presents a multiple regression model for 1666–1802 where the dependent variable is the logarithmic change in the domestic grain price. The independent variables are the logarithmic changes in per capita domestic harvests in the current and previous years and in the silver price of rye in Gdańsk. The model explains almost 75 per cent of the variance of the dependent variable, and confirms that the price of grain was affected by the foreign price as well as domestic harvests. However, fluctuations in domestic harvests clearly had a larger impact than fluctuations of foreign grain prices. The relation between the variables was quite stable during the whole time span of 1665–1802. There was no tendency for improved international market integration during the course of the period. The impact of foreign prices even decreased somewhat relative domestic harvests.

Table 3 presents a regression model for the period 1666–1802 where the change in the per capita harvest is the dependent variable and changes in the grain price in Sweden in the current and previous years and rye price in Gdańsk in the current year are the independent variables. It is a model of how well harvest fluctuations could be predicted from price fluctuations.

Table 3 shows that the beta-coefficients of the changes in the silver price of the preceding and current year are of different signs. If a weak harvest occurred, the price tended to be lower if the price was lower than normal the preceding year. Vice versa, if good harvest occurred, the price tended to be higher if the price was higher than normal the preceding year. There also

⁴⁴ J. Myrdal, *Jordbruket under feodalismen, 1000–1700* (1999), pp. 243–44.

TABLE 2. Multiple regression for the period 1666–1802 where the logarithmic change in the silver price of grain in Sweden is the dependent variable

<i>Variable</i>	<i>Beta-coefficient</i>	<i>t-value</i>	<i>Significance</i>
Constant		0.226	0.821
Logarithmic change in the per capita harvests	−0.723	−14.105	0.000
Logarithmic change in the per capita harvests lagged by one year	−0.211	−4.277	0.000
Logarithmic change in the silver price of rye in Gdańsk	0.328	6.717	0.000

Model summary: $R = 0,859$; $R^2 = 0.738$; adjusted $R^2 = 0,732$; degrees of freedom: 133; significance: 0.000.

TABLE 3. Multiple regression for the period 1666–1802 where the logarithmic change in the per capita harvest is the dependent variable

<i>Variable</i>	<i>Beta-coefficient</i>	<i>t-value</i>	<i>Significance</i>
Constant		0.017	0.986
Logarithmic change in the silver price of grain in Sweden	−0.820	−13.318	0.000
Logarithmic change in the silver price of grain in Sweden lagged by one year	0.292	5.828	0.000
Logarithmic change in the silver price of rye in Gdańsk	0.150	2.441	0.016

Model summary: $R = 0.821$; $R^2 = 0.674$; adjusted $R^2 = 0.666$; degrees of freedom: 133; significance: 0.000.

seems to be a direct positive correlation between the change in price lagged by one year and the change in per capita harvest the following year. This is the effect of the negative autocorrelation between two consecutive changes in per capita harvest production. Per capita production was stagnant in the long term (i.e. extreme harvests tended to bounce back to more normal levels the next year). Both these effects imply that the partial correlation between the change in grain price lagged by one year (from year $t-2$ to $t-1$) and the change in per capita harvest the current year (from year $t-1$ to t) is positive, holding constant for the change in the grain price of the current year (from year $t-1$ to t).

Table 3 also shows that the beta-coefficient of the change in the silver price of rye in Gdańsk is slightly positive (0.15), instead of being negative. This implies that, when harvests are to be predicted from the movements of prices, the change in foreign price counteracts somewhat the change in domestic price the current year provided that the two are of the same sign. However, if the changes in domestic and foreign prices are of different signs, the estimated change in the per capita harvest index is strengthened.

Henceforth, even if the existence of foreign markets makes the relation between domestic price and domestic production more complicated, at least for Sweden, the usefulness of grain price as an indicator of harvests should not be discarded. The model in Table 3 predicts more than two thirds of the variance in the annual logarithmic change of per capita harvests. The existence of foreign markets weakens the relation, but it is very strong, and would be even stronger in a closed economy.

V

Trade led to more uniform prices between regions.⁴⁵ Since transportation and other transaction costs increased with distance, the correlation between price and harvest should be better the larger the area under study. This is borne out by an empirical analysis of Swedish counties.

In Sweden, the average correlation between grain prices and harvests is weaker at a county level than at a national level. For example, in 1818–70, the median correlation at county level between the annual changes in rye silver price and the yield ratio was only -0.46 , while the correlation between the same variables at a national level was -0.66 .

To exemplify how the regional price was affected by the combined effects of harvest in the region itself, in nearby regions and international prices, two areas are discussed: Uppland, 1666–1753 and Dalecarlia, 1667–1753. While Uppland was an exporter of grains to other regions, Dalecarlia was highly dependent on grain imports, but a major producer of iron and copper. Dalecarlia is also located in inland Sweden (bordering Norway), while Uppland (north of Stockholm) borders the Baltic Sea. Five independent variables are studied: annual logarithmic changes in Gdańsk rye silver price, annual logarithmic changes in the per capita harvests of the current and previous years in the studied region, and annual logarithmic changes in the per capita harvests of the current and previous years in nearby regions.⁴⁶

Table 4 presents a multiple regression where the logarithmic change in the silver price of grain in Uppsala County (part of Uppland) is the dependent variable. It shows that the grain price in this region was mainly affected by the harvests of the region itself and foreign price. Harvests in nearby regions also had an impact, although their effect was somewhat weaker. The two lagged independent variables were excluded from the model. The multicollinearity is very strong for two of the independent variables. The correlation between the logarithmic changes in per capita harvests in Uppland and in nearby regions was as high as $+0.77$, which implies that it is very difficult to separate the effects of the two as is done in the multiple regression. The three independent variables together, however, have a very high predictive power, explaining almost 75 per cent of the variance.

Table 5 presents the multiple regression for the Dalecarlia region, which gives a very different picture from that for Uppland. Most notable is that the change in per capita harvests of the region in the current year is excluded from the model. Although there was a very weak, but significant, negative zero-order correlation between changes in grain price and per capita harvests of Dalecarlia, when holding constant for the annual change in per capita harvests of nearby regions, the partial correlation becomes slightly positive, although not significant. However, the multiple regression includes the annual change in per capita harvests of Dalecarlia lagged by one year. In other words, harvests of the current year in Dalecarlia did not by themselves have any impact on the grain prices of Dalecarlia, but previous harvests

⁴⁵ Jörberg, *Prices in Sweden*, II.

⁴⁶ The sources are provided in Edvinsson, 'Swedish harvests'. The tithes from Uppland are based on Hegardt, *Akademiens spannmål*; H. Lindgren, *Spannmålshandel och priser vid Uppsala akademi, 1720–1789: En prövning av markegångstaxornas källvärde* (1971). The tithes

from Dalecarlia are based on M. Isacson, *Ekonomisk tillväxt och social differentiering, 1680–1860: Bondeklassen i Bysocken, Kopparbergs län* (1979); J. Söderberg, 'Åkerbruk och boskapsskötsel', in J.-E. Pettersson, and O. Karlsson (eds), *Mora, Sollerö, Venjans och Våmhus socknars historia*, III (1999).

TABLE 4. Multiple regression for the period 1666–1753 where the annual logarithmic change in the silver price of grain in Uppsala County (Uppland) is the dependent variable

<i>Variable</i>	<i>Beta-coefficient</i>	<i>t-value</i>	<i>Significance</i>
Constant		–0.168	0.867
Logarithmic change in the per capita tithe of Uppland	–0.462	–5.332	0.000
Logarithmic change in the per capita tithe of nearby counties	–0.304	–3.493	0.001
Logarithmic change in the silver price of rye in Gdańsk	0.349	6.154	0.000

Model summary: $R = 0.863$; $R^2 = 0.745$; adjusted $R^2 = 0.736$; degrees of freedom: 83; significance: 0.000.

TABLE 5. Multiple regression for the period 1667–1753 where the annual logarithmic change in the silver price of grain in Dalecarlia is the dependent variable

<i>Variable</i>	<i>Beta-coefficient</i>	<i>t-value</i>	<i>Significance</i>
Constant		0.027	0.979
Logarithmic change in the per capita tithe of Dalecarlia lagged by one year	–0.294	–4.920	0.000
Logarithmic change in the per capita tithe of nearby counties	–0.661	–10.815	0.000
Logarithmic change in the silver price of rye in Gdańsk	0.421	7.073	0.000

Model summary: $R = 0.848$; $R^2 = 0.719$; adjusted $R^2 = 0.709$; degrees of freedom: 84; significance: 0.000.

did. The impact on the grain prices was, however, dominated by the harvests of the nearby regions, reflecting the dependency of Dalecarlia on grain imports. Interestingly international prices had a somewhat stronger impact on Dalecarlian grain prices, although this region does not border the Baltic.

The two multiple regressions for Uppland and Dalecarlia show that the impact of harvests outside the region (either in other parts of Sweden or abroad) probably had a greater impact on the grain price of the region than the harvest of the region itself. This is a clear indication of market integration. Whether the impact from the region's harvest or nearby regions' harvests was greatest could vary, depending on whether the region was an importer or exporter of grains. Dalecarlian grain prices were almost completely determined by harvests outside of the region. However, a common result of the two multiple regressions was that the impact on grain prices was greater from the harvests in the region and nearby regions taken together than from international grain prices. This is a similar result to the determinants of national grain prices. The impact of foreign prices was about the same in the two counties. This underlines why the area under study is of crucial importance when studying the relation between harvests and grain prices.

VI

This paper investigates the relationship between harvests and grain prices in Sweden, 1665–1870 to study the long-term integration of grain markets. Although it focuses on Sweden, it has a wider relevance for the early modern period in general. To investigate market integration we need sources on grain prices as well as harvests. Prices are readily available for a number of countries, but reliable sources on harvest fluctuations at aggregated national levels are scarce. Tithe data exists for a number of countries and regions, but this source is highly biased and needs to be corrected for underassessment.

In a pre-industrial society, it was largely the growth and fluctuations of harvests that determined the growth and fluctuations of the overall economy. The traditional view, as held by Fogel and Hoskins, is that there was a very strong negative correlation between harvests and grain prices, since demand was extremely inelastic. A somewhat different view is that due to the integration of international grain markets, domestic prices were weakly correlated with domestic harvests.

This paper uses the rye price of Gdańsk as an indicator for international prices. Swedish grain markets were relatively integrated with the Polish ones. In contrast, the grain prices of London, for example, were only weakly correlated with Swedish prices. There was probably a higher correlation between Swedish and British harvests; the similarities in the conditions of cultivation were greater than the economic ties of the two areas.

In this paper it is argued that it might take several years for the domestic price to fully adjust in response to a divergence between domestic and international prices. Under such circumstances, annual harvest fluctuations had a greater impact on domestic national grain prices than international grain prices, despite the existence of a relatively strong integration of grain markets. In Sweden, this applies only at the national level, since at a county level, grain prices tended to be more affected by harvests external to the region, especially in regions that were heavily dependent on the outside supply of grains. Medium- and long-term changes in grain prices, as well as real wages, were probably also more affected by factors other than per capita harvests.

The existence of import and storage smoothed out demand. Although grain import was responsive to harvests and prices, this paper concludes that changes in quantity of grain held in store and internal trade were probably more important than imports in smoothing demand and consumption over time. Karl Gunnar Persson's hypothesis that granaries had a negligible effect may be questioned, and this paper finds supporting evidence for Bauernfeind's and Woitek's view that stocks were important for price fluctuations.⁴⁷ However, up to the eighteenth century, storage only smoothed demand from one harvest year to another, and it was not until the nineteenth century that more long-term storage capacity was developed. The early-modern economy could handle individual years of severe harvest failures, while two or more such years in a row tended to have catastrophic consequences, especially if the availability of grains through imports was reduced.

⁴⁷ Bauernfeind and Woitek, 'Agrarian Cycles'.

This paper suggests that grain prices can be used both as an indicator of harvest fluctuations, and to construct historical national accounts. The method of identifying harvest failures through the study of grain prices should not be completely discarded. Nevertheless, there are a number of risks involved in such a project. For example, improved market integration caused price volatility to decrease, without that necessarily implying a corresponding decline in harvest volatility.

The area under study is crucial when investigating the relation between harvests and prices. Confusing levels of aggregation may lead us to draw the wrong conclusions concerning the relationship between grain prices and harvests in the pre-industrial period. If we choose to study a smaller area, then we will find no strong relationship between harvests and grain prices. Grain prices in regions and countries that were well integrated with other markets may reflect harvests in the surrounding area rather than the investigated region or country itself, which would be similar to the Dalecarlia region in Sweden as discussed in this paper or the Nuremberg region as studied by Bauernfeind and Woitek. However, if we choose to study a larger area, then the relationship between harvests and grain prices tends to become much stronger, since transport costs increased with distance.

If grain prices are to be used as indicator of harvest fluctuations, a careful analysis of the impact of the surrounding area as well as inventory effects must be conducted. The best option would, as suggested by Campbell, probably be to combine grain prices with other indicators, or to use grain prices as a cross-check when other more direct indicators, such as tithes or yield ratios, are reliable.⁴⁸ Even if it were shown that grain price is not a good indicator for harvest fluctuations for countries such as England, Poland, France or Holland, because of the high integration between those markets, it may turn out to be a much better indicator of harvest fluctuation in Europe as a whole.

While the construction of historical national accounts for a number of countries has made substantial progress in measuring growth and interpreting its causes after the industrial revolution, the pre-industrial period is much more neglected, and there are substantial disagreements concerning the growth performance before the nineteenth century.⁴⁹ Improving the quantification of pre-industrial economic growth is one of the greatest challenges facing economic historians in the next decades. Short-term fluctuations must not be neglected in favour of long-term trends, the preoccupation of modern society. In the pre-industrial society, minimizing the risks of severe harvest failures was far more important than maximizing production and profits. More in-depth studies of the relation between grain prices and harvests at an aggregated level for a number of countries, not only in Europe but also in other parts of the world, are indispensable for a better understanding of pre-industrial economic dynamics. This will also have ramifications for adjacent fields, such as environmental and demographic history.

⁴⁸ Le Roy Ladurie and Goy, *Tithe*, pp. 25 and 37.

⁴⁹ Maddison, *Contours*, p. 295.