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COMPARING THE CORRELATION LENGTH OF GRAIN MARKETS IN CHINA AND FRANCE

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In economics, comparative analysis plays the same role as experimental research in physics. In this paper, we closely examine several methodological problems related to comparative analysis by investigating the specific example of grain markets in China and France respectively. This enables us to answer a question in economic history which has so far remained pending, namely whether or not market integration progressed in the 18th century. In economics as in physics, before any new result being accepted, it has to be checked and re-checked by different researchers. This is what we call the replication and comparison procedures. We show how these procedures should (and can) be implemented.

Keywords: Correlation Length; Comparative Analysis; Grain Markets; France; China.

1. Introduction: Replication and Comparison

> "Having gathered these facts, Watson, I smoked several pipes over them, trying to separate those which were crucial from others which were merely incidental. Conan Doyle, The adventure of the crooked man (1975)[1]"

Experimental research has a dual role in physics (i) For new phenomena (for which there is no established theory), it permits to separate factors which are of major importance from those which are not. In that kind of investigation, comparative analysis plays a prominent role; (ii) For those phenomena for which a theory exists, it permits to check its predictions. In both cases, the cornerstone of the investigation is the replication of crucial experiments under different conditions. For most physicists (we exclude astrophysics from our discussion), double role of experiments would probably seem self-evident.

In economics, the analog of the operation of repeating an experiment consists in carrying out consistent comparative observations. Unfortunately, economists have given very little attention to the methodology of comparative analysis.[a] Even in the "Journal of Comparative Economics" there are few truly comparative studies. The lack of rigorous guidelines for comparative investigation has detrimental consequences which are far-reaching as illustrated by the following examples.

1.1. *Physics versus economics: Examples*

In physics, after a new phenomenon has been observed by a researcher, other groups around the world try to repeat, the same experiment. If it cannot be repeated, it will be attributed (possibly after a period of controversy) to some spurious or factitious effect and will be quickly forgotten; such was for instance the case of the "discovery" of cold fusion in 1989 by S. Pons and M. Fleischmann. On the other hand, if the experiment can be repeated and confirmed, the phenomenon in question will become widely accepted as a new building block of physics; fairly often this will open a new avenue of research. One can mention the following historic examples: (i) the Foucault pendulum (1851); (ii) the discovery of superconductivity by Kamerlingh Onnes (1911); (iii) the discovery of the properties of spin glasses (mid-1970s). As an example of a major discovery that has still to be confirmed, one can mention the observation of a plasma of free quarks at the European Center for Nuclear Research (announcement made in February 2000). A first confirmation (or refutation) will come within one or two years from the experiments currently under way at Brookhaven National Laboratory (located on Long Island, New York State). A further check will be obtained in about five years by using the Large Hadron Collider currently under construction at CERN. To sum up, it may take some time, but, within a few years, the question of the possible existence of a plasma of free quarks will probably be settled in a satisfactory way.

In economics, in contrast, controversies often drag on for years without leading to any specific conclusion. A disenchanted but lucid assessment of this state of affairs has for instance been made in a review article by A. Zellner (1988).[3] As an illustration, one can mention the discussion around the so-called Prebisch–Singer conjecture (1950).[4,5] Basically, it posits a secular decrease in the price of primary commodities relative to the price of manufactured goods. In the last 50 years, it has fostered numerous statistical tests but its validity still remains controversial.[6,7]

What are the reasons of such an unsatisfactory situation? Broadly speaking, they gravitate around the two problems of *replication* and *comparison*. It is the purpose of this paper to examine these questions more closely by carrying out a specific comparative study namely the comparison of geographically separated grain markets in China and Europe. For the 19th century, due to major advances in transportation technology, it is fairly obvious that there was a strong increase in market integration, but, is that also true for the 18th century? To our best

[a]Some social sciences do not share that neglect: for instance, in sociology, the methodology of comparative analysis is a key issue which has been extensively discussed (see for instance Ref. 2).

knowledge that question has not been clearly settled so far. In the present paper, the approach that we use is almost as important as the answer that we arrive at. In the course of the investigation, we will set forth a number of rules that more generally can apply to the analysis of other comparative issues as well.

1.2. *Replication in physics and in economics*

At first sight, it could seem that the parallel with physics that we hinted to above is questionable. The obvious objection would be that in physics, one can repeat an experiment while in economics one cannot. However, a little reflection shows that such an objection does not hold. As a matter of fact, the central problems of replication and comparison present themselves very similarly in both fields. Let us briefly see why. In physics, these problems are often condensed into the single question: "Can a researcher B repeat the experiment carried out by a researcher A?" For definiteness, let us consider the example of the Foucault pendulum. Replication would then mean: "Knowing that Foucault has carried out his experiment at the Panthéon in Paris, can I repeat it at the same location and with the same pendulum?" On the other hand, comparability would mean that the same observation can also be made in Brazil with a different pendulum. By stating these questions, one immediately understands why they are usually considered together; indeed nobody would try to perform *exactly* the same observation as Foucault did. In the years after 1851, there were a number of experiments with the Foucault pendulum in England, Germany and indeed in Brazil. Not only were the locations different but the technical characteristics of the pendulum (weight, length, nature and diameter of the wire) were not the same either. By doing so, one implicitly assumes that these characteristics are not crucial; that is possible because the principles on which the phenomenon relies are fairly well understood. As one knows, the outcome of the experiment is of course *not* the same in Brazil and in Paris but, knowing the theory, it is possible to take into account the effect of a different latitude.[b]

On the contrary, in economics, one does *not* know in advance which factors are essential and which ones are of little importance. Suppose (for instance) one wants to examine if it is true that the distribution of income follows a Pareto law with an exponent of 1.4. For such a problem, the replication and comparison issues are clearly distinct one from another. Replication means that if researcher A claims that result to be true for France in 2000, he (she) must publish his (her) results in such a way that researcher B can perform the same fit on the same data and check if the same results obtain. This implies in particular that the data are made available to researcher B, a condition which is only rarely fulfilled in practice. That obstacle to

[b]Furthermore, a spurious factor called the Puiseux effect had to be discounted. It states that if a pendulum describes an ellipse (and all Foucault pendulums, whatever their technical characteristics, do in fact describe an ellipse), its major axis will turn at a rate which is proportional to the area of the ellipse. It took some time to experimenters to realize which correction had to be performed in order to discard that perturbation.

replication has been deplored by several lucid economists as for instance in the paper by Dewald *et al.* (1986).[8] Comparability, on the other hand, would mean that if a researcher performs a similar study for the distribution of revenue in Germany (for instance), he (she) will also find a Pareto exponent of 1.4. In general, this will not be true of course, but, in contrast to what happened with the Foucault pendulum, one does not know if the discrepancy should be attributed to the measurement process (other kind of sources had to be used in Germany than in France) or to the phenomenon itself. As a result (in contrast to the experiment performed in Brazil), one is unable to apply to the German data whatever correction factor which would be required in order to make them truly comparable to the French data.

To our best knowledge,[c] few (if any) revenue investigations for different countries are truly comparable; in Atkinson's words,[9] "professor X will take the household as the unit of measurement while professor Y will take the nuclear family and professor Z will take the revenue per head". That would not be a problem if one had at one's disposal a reliable correction formula in order to adjust for family size; unfortunately this is not the case.

As an illustrative example, one can mention the "comparative" study of income distribution edited by Brenner *et al.* (1991)[10]: six countries are examined by six different authors, but, almost none of the data are comparable. The data for Britain are based on wages (which excludes capital gain), those for Germany are based on data from tax authorities (which include capital gains); in some cases, a correction was performed which takes into account the distribution of age groups while in others, it was not, and so on.

Is the situation hopeless then? Certainly not. For one thing, one should consider a phenomenon which depends upon a few parameters only. That is why we selected the distribution of grain prices in this paper. Secondly, we will show that it is possible to consider data which make the comparison meaningful.

The paper proceeds as follows. In Sec. 2, we list the parameters which affect the phenomenon under consideration; this will help us to define data sets for which a meaningful comparison can be made. In Sec. 3, we describe the Chinese and French price data. In Sec. 4, we show that the prices have the same spatial structure in the two countries and we estimate the correlation length in each case. In Sec. 5, we examine whether or not market integration progressed in the 18th century. Finally, in the concluding section, we summarize our findings along with the precepts which in a general way can improve the reliability of comparative analysis.

2. Comparing Two Systems of Markets

For a cross national comparison to be valid, one must ensure that all factors (except of course the factor that one wants to study) are identical. This is undoubtedly a

[c]May be some truly comparative investigations have escaped our attention; we express in advance our gratitude to those of our readers who would bring such studies to our attention. As a matter of fact, we would be more than pleased to see comparative analysis become a key issue in economic research.

very strong constraint; it is due to the fact that we do not know how to discount the effect of factors which are different. A number of factors that can be expected to be relevant for the comparison of two systems of markets are listed in Table 1.

Needless to say, this list cannot be exhaustive; one has to posit all factors that are not explicitly considered, play a negligible role. It is only by performing numerous comparative studies for the same phenomenon that one can separate the factors which are important from those which play only a small role. In fact, the situation is the same in physics: when an experiment is carried out for the first time in a new field, one does not know which factors are crucial and which ones are not.

In Table 1, we made a distinction between factors (labeled by numbers) which are fairly well defined and can therefore be easily controlled, and more complex factors (labeled by capitals). A few words are required to explain the phenomena to which these entries refer. What do we mean by "propensity for trade"? Propensity for trade will for instance be low for fragile goods such as eggs or fresh figs, or for goods which cannot be stored for a long time, or in a general way for all products for which transportation costs are too large compared to their value. Thus, one would expect the propensity for trade to be larger for caviar than for wheat. Another (less exotic) example is wheat versus potatoes. In 19th century Germany, one kilogram of wheat was worth at least three times as much as one kilogram of potatoes.[d]

Table 1. Factors which affect the analysis of the spatial distribution of prices.

Well-defined parameters	1	Unit of currency
	2	Unit of weight or volume
	3	Type and quality of grains
	4	Type of prices (market/contract prices)
	5	Frequency of prices
	6	Size of the region
	7	Topography of the region (plain/mountain/sea-coast)
Broad factors	A	Propensity for trade
	B	Means of transportation
	C	Business situation

Notes: For a comparative study to be meaningful, all factors must be identical (or at least controlled in the sense that a reliable correction can be performed) except the one under study. That is why this table will subsequently be referred to as the "ceteris paribus" (i.e., everything else being identical) table.

[d]The calculation which leads to that estimate goes as follows. In the decade 1891–1900, the average price of wheat in Berlin was 164 mark/ton[11] while the average price of potatoes was 2.19 mark/50 kg that is to say 43.8 mark/ton, i.e., 3.7 times less than the price of wheat. Needless to say, since the prices of wheat and potatoes fluctuate in a fairly uncorrelated manner, this price ratio fluctuates as well: it was equal to 4.4 in the decade 1811–1820, and to 5.3 in 1925–1934. For the United States, in the second half of the 20th century that ratio seems to be much lower, of the order of 1.2 to 2.

Regarding entry B, a central question is whether a decrease in transport costs will lead to an increase in trade and hence to a xstronger market-interdependence. Although the answer could at first sight seem fairly obvious, it is not in fact. Indeed, a decrease in transport cost between two cities A and B leads to a decrease in the price differential $p_A - p_B$, and in the face of such a lower price differential, traders will have a lower incentive to trade (assuming that their profit rate is somehow determined by the price differential). To decide which of these opposing effects will prevail is not obvious. In the framework of the stochastic spatial arbitrage model,[12,13] it is found that a decrease in transport cost leads to a trade increase, a prediction which seems to be confirmed by empirical evidence.[e,12,14]

The business situation (that is to say whether or not one is in a phase of recession, whether interest rates are low or high, and so on) undoubtedly plays a role, but, in a way which is difficult to specify. Usually, one expects that by considering a sufficiently large span of time (e.g., 50 years or more), these effects can be averaged out.

Note that the previous factors could be replaced by a single variable which is the trader's profit margin. Unfortunately, that kind of information is rarely (if ever) made public and cannot be controlled therefore; this is why one must contend oneself with the indirect criteria listed above.

The previous discussion could well lead to a pessimistic view. In the previous section, we claimed that the present problem has been selected on account of its relative simplicity, and yet the above discussion seems to show that it has in fact numerous facets. To get a more realistic perception, let us once again consider the example of the Foucault pendulum. Even if the experiment is repeated on two successive days, at the same place and with the same device, one could well *argue* that the conditions have changed. Indeed the position of the Moon (which undoubtedly exercises a gravitational attraction on the pendulum) has changed as well as (though to a smaller extent) the position of the main planets. Furthermore, vibrations transmitted to the pendulum from the outside world are not the same on two successive days. The physicist would answer that the gravitational attraction of the Moon is negligible (it is about 10^6 times smaller than the attraction of the earth) while outside vibrations will be averaged out. Well and good, but the fact that the precision of the measurement does not exceed 5% in the best experiments and is more often of the order of 10% clearly shows that there are indeed a number of perturbations which are not well understood and hence cannot be controlled. In spite of such defects, the experiment is nevertheless highly successful in demonstrating the rotation of the earth. Similarly, for the economic problem under consideration, one can hope that in spite of the fact that there are some poorly controlled factors, one will nevertheless get a reliable comparison.

[e]Once again it is because of the ceteris paribus requirement that the question is not easy to settle empirically.

3. Grain Prices

In contrast to many aggregated macro-variables, commodity prices are well defined and can be accurately measured. This of course does not mean that comparisons of price data are ipso facto reliable. As an illustration, one can mention the monthly share prices published by the Organization for Economic Cooperation and Development[15]: prices for the Milan stock exchange are averages of daily quotations, figures for Oslo give the quotation on the 15th of each month, the data for Stockholm are quotations at the end of each month. Clearly, such figures are *not* comparable.[f] Such a lack of comparability in an official publication is all the more surprising when one considers that daily share price statistics are easily available; if anything, it proves that data-comparability is not of major concern for international statistical organizations.

For 18th century grain prices, there are usually two main sources: (i) Prices recorded by government officers on each grain market of some importance; (ii) Prices at which grains are bought by various institutions such as hospitals, monasteries, and so on. Prices from the second source usually display a smaller volatility (i.e., standard deviation) than prices from the first, but, this difference is sizeable only when one considers monthly or weekly prices. For the annual prices that we use in this paper, the two kinds of prices would be fairly comparable. However, since we need a comprehensive geographical coverage, the prices recorded by government officers will be more homogeneous. The prices that we use subsequently are of that kind; let us describe them in more detail.

3.1. *China*

At least from the 17th century, a systematic reports of the prices of the major grains was required from every county (*xian*) magistrate. Prices were recorded at a minimum interval of once per month. The local government of the county was charged with the task of investigating the markets within or serving the main city of the county and recording the selling price of different grains. These reports were subsequently sent to the prefectural city (*fu*). The county reports were then summarized by two prices for each grain, the highest and lowest price among all the counties. The county reports and the summary were then sent on to the provincial capital where the provincial governor then used the summaries to prepare monthly price reports to the Emperor. While the county level reports have been largely destroyed, copies of the monthly price report summaries at the prefectural level have survived and it is these price reports, the Grain Price Lists in the Agricultural Section of the Vermillion Rescripts in the Palace Archives [*Gongzhong shupi souze, nonye lei, liangjia qingdan*], currently kept in the Number One National Archives of Beijing which are used in this paper.

[f]Assuming independent random price fluctuations, the standard deviation of the Milan prices will be five times (i.e., $\sqrt{30}$) times smaller than that of the two other markets.

There were two main reasons why the government collected price data along with local weather reports and local harvest reports. First, to deal with problems of mass riots resulting from food shortages, the government maintained a sophisticated system grain management. Disaster relief institutions included tax relief or tax postponement, cash and grain transfers to local governments, seed loans, and grain disbursal from public granaries. Price data was used to help monitor the market conditions, the local grain supply availability, and the harvest outcomes in local areas. The information was used to preempt potential crises resulting from grain shortage and to assess the severity of food shortage and thus the validity of applications for food relief from local officials. Second, the government had to purchase grain for the consumption of its soldiers and the approximately one million bureaucrats residing in Beijing. Price reports allowed government officials to identify which market to purchase from. The fact that the government utilized the price data for comparative purposes strongly suggests that not only is the accuracy of the prices relatively high, but that the prices have been converted into units of silver *tael* which are comparable in value.[g] The reports could not have served their purposes if they were not in comparable units of currency across regions.

3.2. *France*

In France, the recording of grain prices goes back to a royal ordinance of 1539. One may wonder why the government monitored so closely grain prices: (i) Grains constituted the main component in the diet of the population, any sudden price increase could lead to riots; (ii) When troops were marched through the country, the government had to know at which price grains were available. In short, grain prices were as important in that age as oil or stock prices are nowadays.

The 18th century price series that we use were built for the information of the National Convention (1792). They were subsequently re-published in 1837 (Archives Statistiques)[17] and 1933 (Labrousse).[18] The series give average annual prices for each of the 32 regions composing France at that time. We do not really know how the averages were computed, that is to say which markets were used in each region to define the region-average; however, some tests performed by Labrousse[18] show that the data are consistent with control-averages performed using four or five markets (which means that with five terms, the convergence towards the expectation is already good enough).

An important point concerns units of measurement. As one knows, back in the 18th century, there was a great diversity as to units of measurement. Yet, in the source of 1792, all prices are expressed in livres per "setier de Paris". How were the conversions performed? In 1755–1756, a systematic survey was carried out from which the required conversion factors could be drawn.[18]

[g]Prices of grain would have been postedq locally in terms of a copper cash price whereas the standard government unit of price accounting converted all copper prices to units of silver *tael*.[16]

4. Measuring the Correlation Length

As in statistical mechanics, the correlation length L of a set of markets characterizes the range of the interaction. It is defined through the formula: $\rho(d) = e^{-d/L}$ which expresses the correlation ρ between prices on two markets as a function of the inter-market distance d. The operational definition of the correlation length is recalled in Fig. 1. Note that for the sake of convenience, we will rather use a smaller correlation length l defined by: $l = L/100$. It should be emphasized that the correlation length is in many respects ideally suited to the structural comparison of two systems of markets. Because the correlation between two price series is independent of the respective magnitude of the prices, conditions 1, 2 and 3 in Table 1 are automatically satisfied and since the correlation length characterizes the behavior of the correlation as a function of distance, the overall size of the region under consideration (condition 6) does not matter.

In order to ensure that one compares two territories characterized by a similar topography (condition 7), one must restrict the analysis to regions of limited extent. As a result, a global comparison of China [Fig. 2(a)] and France [Fig. 2(b)] would be questionable; indeed, as each country has plains as well as mountains, the result would be an ill-defined average whose interpretation would be open to debate.

A last remark is in order. In the same way as one expects price correlations to decrease with intermarket distance, one would expect price differentials to increase with distance. Why then did we not also study price differentials; in fact we did, but that dependence turns out to be very noisy and chaotic. An obvious reason for the

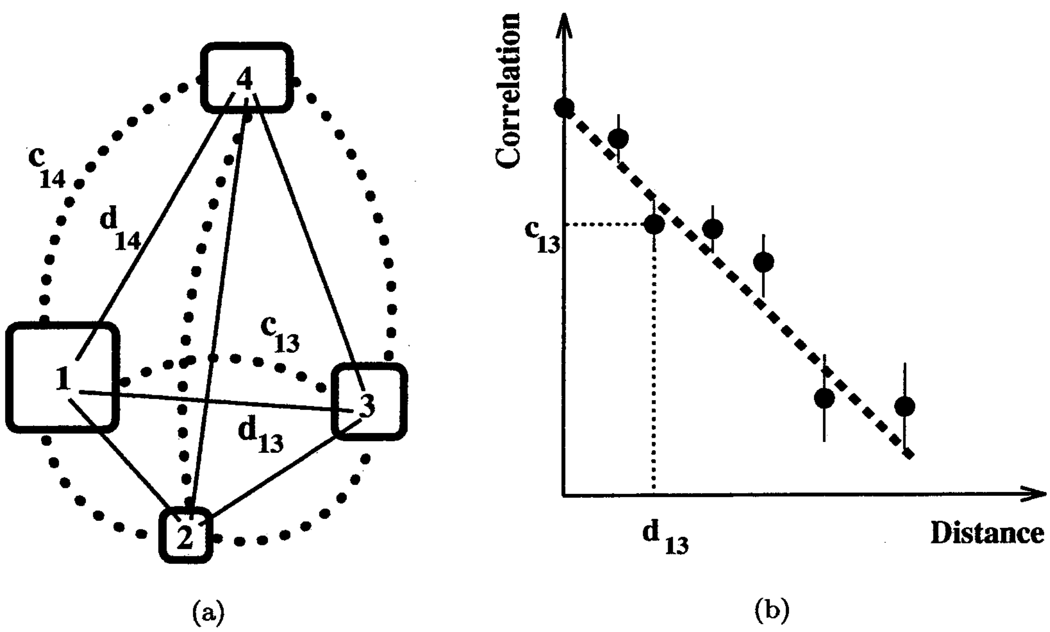
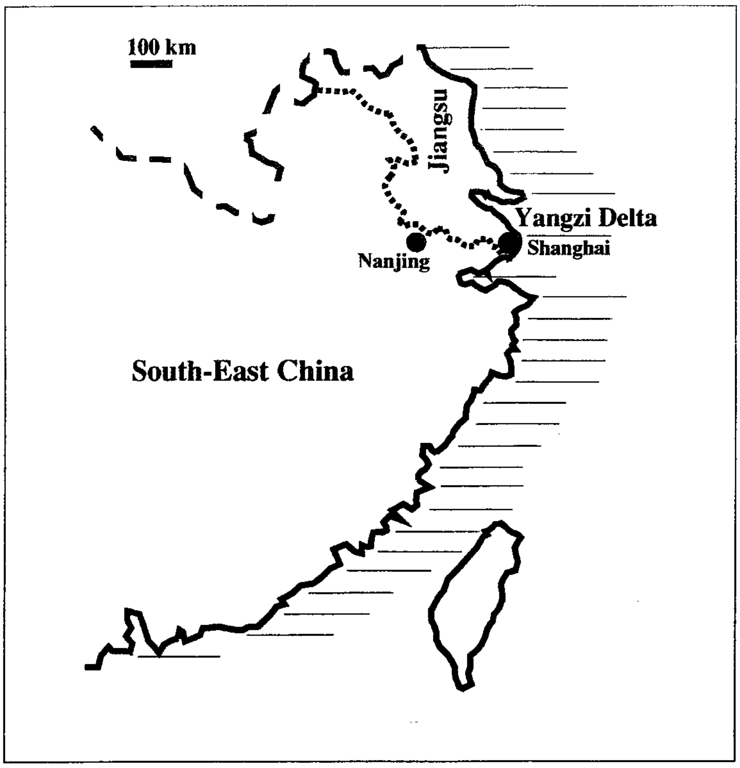
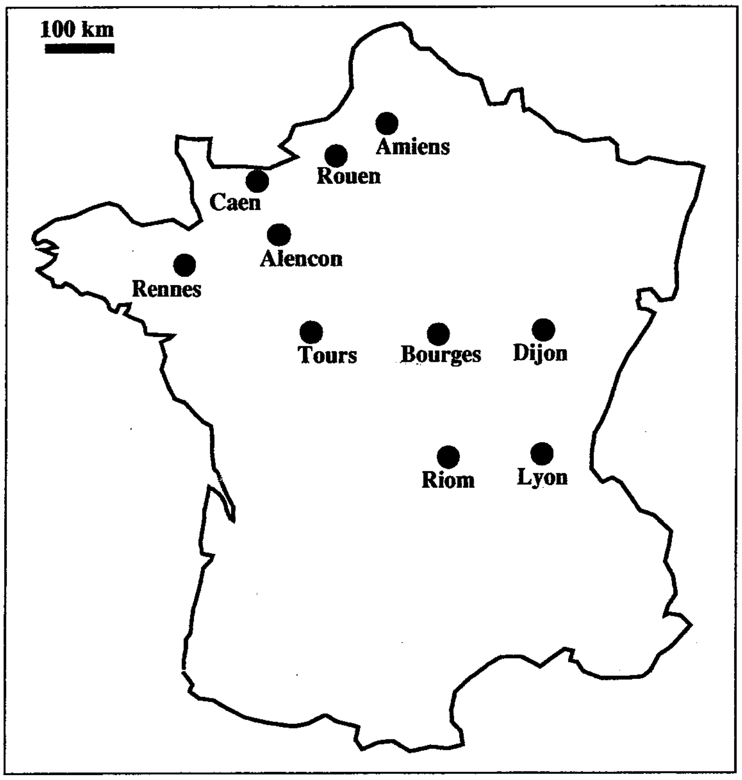


Fig. 1. (a) Operational definition of the correlation length. The rectangles schematize grain markets; the interactions between them is represented by the dots; the level of price series they give rise to correlations $c_{12}, c_{13}, c_{14}, \ldots$. (b) Once these correlations are plotted (on a logarithmic scale) as a function of distance, the correlation length δ can be read from the slope m of the regression line as: $\delta = -1/m$.



(a)



(b)

Fig. 2. (a) Map of South-East China. Within South-East China, the provinces of Jiangsu and Yangzi Delta are the main plain regions. (b) Map of France with location of markets.

smoother behavior of correlations is the fact that the latter implicitly involve a built-in time average. If adequate time-averaging is performed, the differential-distance relationship becomes meaningful as well.[12]

4.1. *China (Jiangsu)*

The most developed economic region of China is generally regarded to be in the Yangzi Delta, a plains area on the eastern coast in the provinces of Jiangsu and Zhejiang and situated at the center of the most important long-distance water routes of the 18th century: the mouth of the Yangzi River, the Grand Canal, and a sea port. The province of Jiangsu is significant because all three of the major water routes and many tributaries pass through the province giving it a natural advantage in transport costs. Table 2(a) shows the correlation length for two samples. Sample 1 consists of all ten prefectures of Jiangsu province for the series 1742–1795. Inter-market distances are measured from the capital cities of each of the prefectures. For every 4.8 kilometer increase in distance between markets in Jiangsu, the correlation declines by 1%. Figure 3 graphs the relationship between the log of correlations and distance in kilometers.

4.2. *France*

Figure 3 shows the decrease of the correlation as a function of distance for a sample of 10 regions. Subsequently, this sample will be referred to as the long-term sample because the data for these regions can be extended to the 19th century. Note the very fact that there is a well-defined relationship between correlations and inter-market distances is a nontrivial property of the system of markets. It is this structural property which allows a correlation length to be defined. For the long-term sample, the correlation length is $l = 16.5 \pm 3.3$ km. One must of course examine to what extent that result is modified when one considers another sample. Table 2(b) provides the result for three different samples.

Table 2(a). Correlation length for Chinese grain markets 1742–1795.

	Sample	Regions (Prefectures)	Correlation Length [km]
1	Jiangsu	Changzhou, Haizhou, Huaian, Jiangning, Sungjiang Suzhou, Taicang, Tongzhou, Yangzhou, Zhenjiang	4.8 ± 2.3
2	Yangzi Delta	Changzhou, Hangzhou, Huzhou, Jianxing Ningbo, Shaoxing, Sungjiang, Suzhou	4.3 ± 5.9

Notes: In each region, the geographical center has been identified with the capital city. The results in this table refer to rice prices. It turns out that wheat and rice prices (data for both cereals are available for Hunan) per unit of volume or per unit of weight (one liter of rice weights approximately 81 kg[19]) were fairly comparable which means that wheat and rice have almost the same propensity for trade. The error bounds were not obtained in the same way as in the case of France and may be somewhat over-estimated.

Table 2(b). Correlation length for French grain markets 1756–1790.

	Sample	Regions	Correlation Length [km]
1	Long-term sample	Alençon, Amiens, Bourges, Bourgogne, Bretagne, Caen, Lyon, Riom, Rouen, Tours	16.5 ± 3.3
2	Sample 2	Alsace, Bordeaux, Champagne, Franche-Comté, La Rochelle, Limoges, Metz, Poitiers, Soissons	16.1 ± 4.1
3	Sample 3	Auch, Bordeaux, Champagne, Franche-Comté, Languedoc, La Rochelle, Limoges, Montauban, Poitiers	12.8 ± 2.3

Notes: For the sake of homogeneity, we have used French spellings even when the English spelling was different (as for instance for Lyons). The first two samples are restricted to the northern part of France while the third also includes locations from the south (e.g., Auch, Languedoc, Montauban). The fact that the third estimate of the correlation length is somewhat different is hardly surprising since it does not correspond to the same region; it gives a measure of the variability of the correlation length as one shifts from northern to southern France. The geographical center of each region has been defined as the localization of the capital region; for instance for Alsace, it is Strasbourg, for Franche-Comté, it is Besançon, and so on. The error bars correspond to the confidence intervals at probability level 0.95.

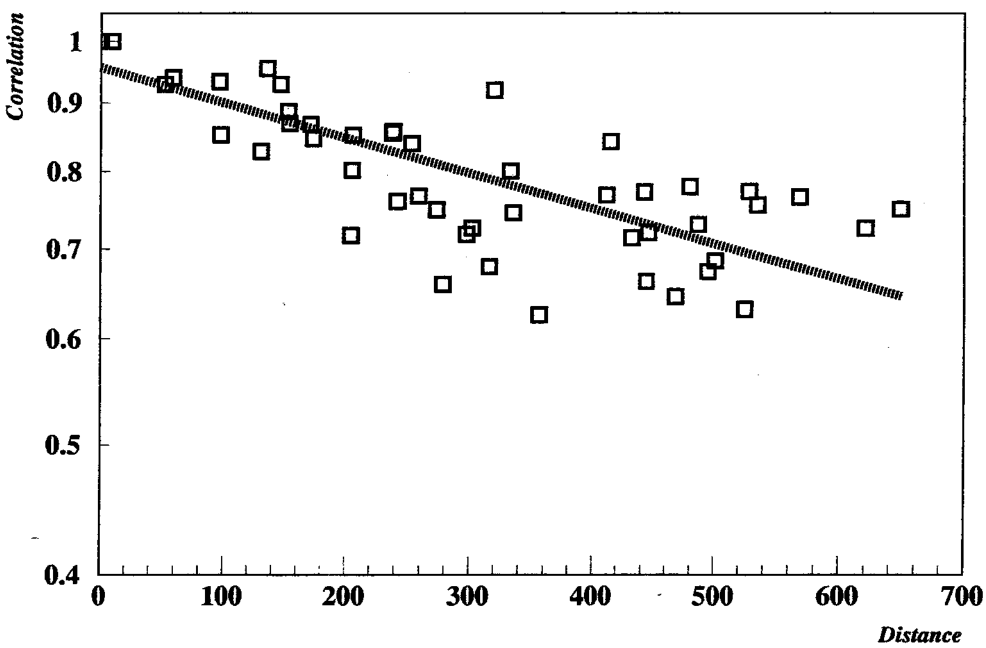


Fig. 3. Correlation as a function of distance in France 1756–1790. The corresponding graph for China would be very similar in shape and has therefore been omitted.

Sample 2 which is made up of nonmountainous regions located in the northern part of France leads to a correlation length which is almost identical to the previous one. Sample 3 consists also of nonmountainous regions but they are located in the northern as well as southern part of France; in this case, the correlation length is somewhat lower which suggests that southern France had a lower degree of market integration than northern France.

The correlation length estimates obtained in this section provide a static overall picture of market integration for the second half of the 18th century, but what about the evolution of market integration? To analyze changes in the correlation length between 1750 and 1790, one would have to use a narrower time-window; yet, in order to estimate the correlation with acceptable precision, the time-window must contain at least 40–50 prices. Thus, to get a dynamical picture, one would need monthly or weekly prices. As no high frequency data are available, one must use a different approach. This is discussed in the next section.

5. Did Market Integration Progress in the 18th Century?

In order to estimate the degree of market integration for a system of n markets in a given year t, we propose three different measures.

- The difference between the logarithm of the maximum and minimum prices within the set of n markets; if the prices on the n markets are denoted by $p_i(t)$, this variable reads,

$$a(t) = \max_{1 \leq i \leq n} [\ln(p_i(t))] - \min_{1 \leq i \leq n} [\ln(p_i(t))] \,.$$

  In statistics, this difference (without the logarithms) is called the range of the sample.
- The (spatial) standard deviation of the logarithms of the prices on the n markets,

$$b(t) = \sigma[\ln p_1(t), \ln p_2(t), \ldots, \ln p_n(t)] \,.$$

- The (spatial) coefficient of variation,

$$c(t) = \frac{\sigma[p_1(t), p_2(t), \ldots, p_n(t)]}{m[p_1(t), p_2(t), \ldots, p_n(t)]} \,,$$

  where $m[p_1(t), p_2(t), \ldots, p_n(t)]$ denotes the average price on the n markets.

Let us briefly explain what motivated the choice of these variables. Firstly, it must be noted that a, b, and c are scale invariant in the sense that they do not change when all prices are multiplied by the same constant. As a result, these variables are independent of the choice of the units of volume and currency which makes them well suited for cross-national comparisons. Note that the correlation was "naturally" scale invariant, one has to use log-prices in order to achieve that invariance (at least for a and b). Regarding the definition of a, its main advantage is the fact that it can be computed very easily (almost by mere inspection of the price series); on the other hand, it does not use the price data very efficiently since it takes into account only two prices. Moreover, the confidence interval of the range a is known to be fairly large: for large samples, it decreases as $1/\sqrt{\ln n}$ instead of the usual $1/\sqrt{n}$.[20]

In what follows, we want to study the evolution of the above variables in the course of time, in particular, we examine whether or not there is a downward trend.

However, it must be noted that if there is a downward trend, it cannot be linear because a, b, and c are necessarily positive. As a result, a linear regression will not give a good fit. A remedy is to fit instead: $A = \ln a, B = \ln b$, and $C = \ln c$; since A, B, and C are not bounded, they can have have a linear downward trend in the course of time. More specifically, the regressions performed in the following paragraphs correspond to the determination of the coefficient α defined as (similar expressions for B, C),

$$A = -\alpha t + \beta \Longrightarrow a = Be^{-\alpha t},$$

by their form, these regressions parallel in the time domain the regressions previously performed in the spatial domain.

5.1. *China (Jiangsu)*

Table 3(a) gives the results for the regressions with respect to time. For the Jiangsu province, the regression coefficients are not significantly different from zero (except perhaps the third); this is confirmed by the fact that the different criteria lead to conflicting signs. On the other hand, for the Yangzi Delta, the regression coefficients are significantly different from zero; this is confirmed by the fact that the three criteria lead to consistent signs.

Table 3(a) does not make full use of all data that are available for China. Indeed (see Sec. 3.1), for each prefecture (i), the archives give the lowest ($p_{i,\text{lo}}$) and highest ($p_{i,\text{hi}}$) price among all the counties composing prefecture i. So far, for each prefecture, we used the average price $p_{i,\text{m}} = (p_{i,\text{lo}} + p_{i,\text{hi}})/2$ (that we simply denoted p_i). However, the $p_{i,\text{lo}}$ and $p_{i,\text{hi}}$ prices can give us some information about the distribution of prices at a within (or infra) prefecture scale. To this end, we tentatively introduce the following variables.

(i) The difference between the logarithm of the highest and lowest price within prefecture (i) averaged over all n prefectures in a given region,

$$\alpha_{\text{wp}} = \frac{1}{n}\sum_{i=1}^{n}(\ln p_{i,\text{hi}} - \ln p_{i,\text{lo}}).$$

(ii) The standard deviation of the logarithms of the lowest/highest price averaged over all n prefectures in a given region,

$$\beta_{\text{wp}} = \frac{1}{n}\sum_{i=1}^{n}\sigma(\ln p_{i,\text{lo}}, \ln p_{i,\text{hi}}).$$

(iii) The ratio of the standard deviation of the lowest/highest price to the average price averaged over all n prefectures in a given region,

$$\gamma_{\text{wp}} = \frac{1}{n}\sum_{i=1}^{n}\sigma(\ln p_{i,\text{lo}}, \ln p_{i,\text{hi}})/p_{i,\text{m}}.$$

Table 3(a). Trend α for market integration in China: 1742–1795.

	Sample	Regression for A [century^{-1}]	Regression for B [century^{-1}]	Regression for C [century^{-1}]
1	Jiangsu	0.04 ± 0.1	0.012 ± 0.02	-0.16 ± 0.08
2	Yangzi Delta	-0.18 ± 0.1	-0.04 ± 0.02	-0.22 ± 0.06

Notes: The samples are the same as in Table 2(a). A, B and C respectively denote the Max-Min, standard deviation of log-prices and the coefficient of variation (see text).

Table 3(a)$'$. Trend α for market integration in Jiangsu within prefectures: 1742–1795.

Sample	Regression (i) [century^{-1}]	Regression for (ii) [century^{-1}]	Regression for (iii) [century^{-1}]
Jiangsu	-0.0071 ± 0.002	-0.006 ± 0.003	-0.026 ± 0.008

Remark. The analog of the variable $a(t)$ for this data set would have been,

$$a'(t) = \underset{1\leq i\leq n}{\text{Max}}\,[\ln(p_{i,\text{hi}}(t)] - \underset{1\leq i\leq n}{\text{Min}}\,[\ln(p_{i,\text{lo}}(t)]\,,$$

but, since this data set does not permit to compute the analogs of $b(t)$ and $c(t)$, we rather adopted the above definitions for the sake of homogeneity.

The regressions for $\alpha_{\text{wp}}, \beta_{\text{wp}}$, and γ_{wp} are given in Table 3(a)$'$; all coefficients are negative and significantly different from zero at 5% significance level which nonambiguously attests to a downward trend. In other words, progress of market integration seems more pronounced at smaller distances (of the order of 50 km) than at distances of several hundredths kilometers.

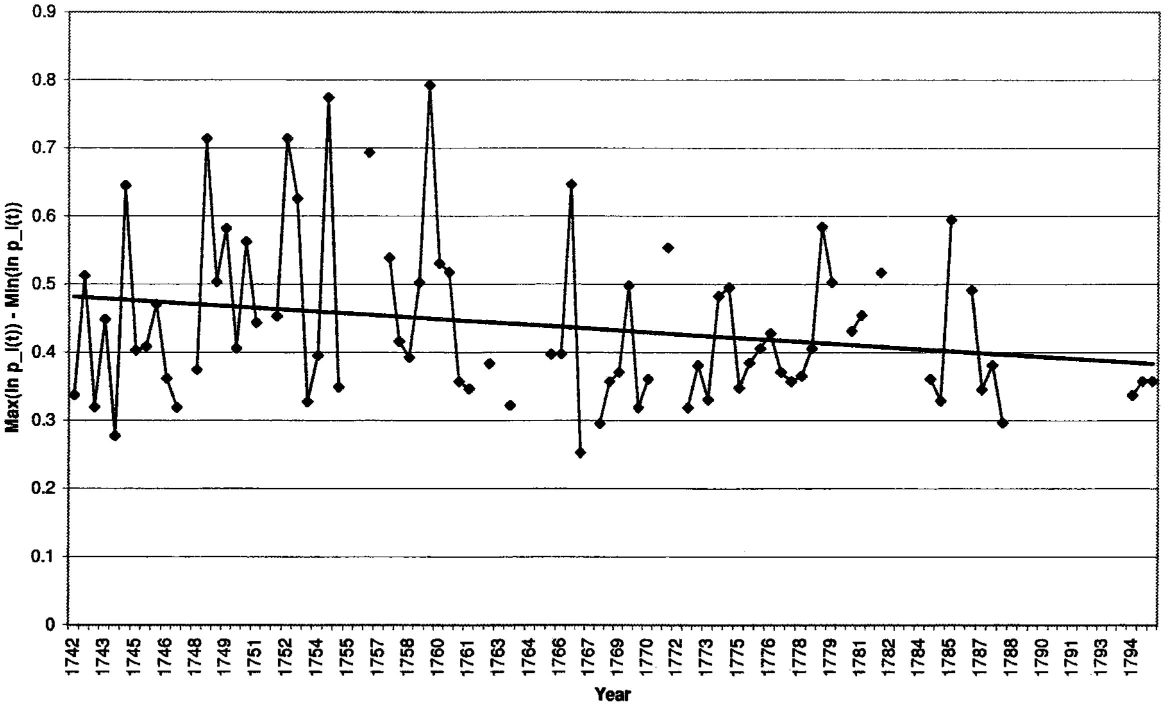
5.2. *France*

Table 3(b) gives the results for the regressions with respect to time. First, it can be noted that the variables A, B, and C lead to close results. Secondly, the width of

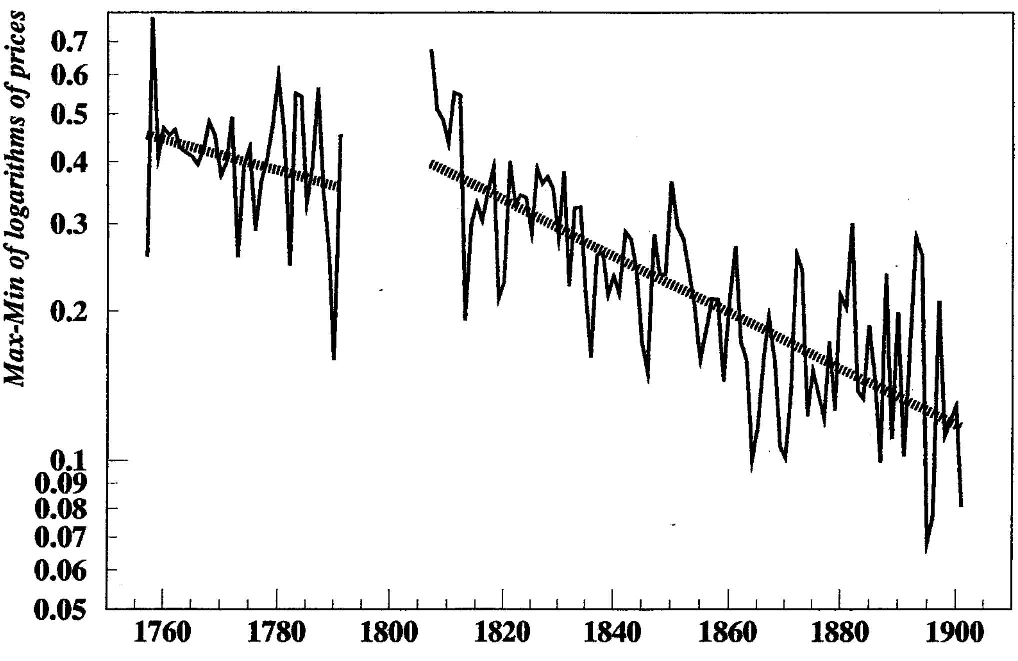
Table 3(b). Trend α for market integration in France: 1756–1790.

	Sample	Regression for A [century^{-1}]	Regression for B [century^{-1}]	Regression for C [century^{-1}]
1	Long-term sample	-0.72 ± 0.95	-0.87 ± 0.96	-0.89 ± 0.94
2	Sample 2	-0.39 ± 1.10	-0.39 ± 1.10	-0.31 ± 1.11
3	Sample 3	-1.25 ± 1.11	-0.94 ± 1.05	-1.11 ± 1.01

Notes: The samples are the same as in Table 2(b). A, B, and C respectively denote the Max-Min, standard deviation of log-prices and the coefficient of variation (see text). The figures give the slope of the regression lines with respect to time expressed in centuries. As shown by the width of the confidence interval, the three variables fluctuate markedly in the course of time.



(a)



(b)

Fig. 4. The vertical scale corresponds to the Max-Min variable to as a in the text. (a) Trend for market integration in Yangzi Delta 1742–1794. (b) Trend for market integration in France 1756–1900. There is an acceleration in the improvement of market integration between the 18th and 19th century.

the confidence interval shows that they are highly fluctuating in the course of time (this can also be seen on Fig. 4(b)). The fact that all samples lead to negative regression coefficients shows that the downward trend is a robust property. This leads us to the conclusion that both in northern and southern France market integration made notable progress in the forty years preceding the Revolution of 1789. The rate of the downward trend is between 3 to 8 times faster (according to which sample one considers) than the one observed in the Yangzi Delta region.

Naturally, because of the transportation revolution, one would expect that market integration has progressed even faster in the 19th century. This is indeed confirmed by Fig. 4(b). The decrease rate is almost twice as large in the 19th century than it was in the second half of the 18th century.

6. Conclusions

Two main results emerge from this comparative study: (i) In the 18th century, the level of market integration in France (expressed by the correlation length of grain prices) was about three times as large as in the plain region of Lower Yangzi on the eastern coast of China; (ii) Between 1750 and 1800, there was substantial progress of market integration in France, there was parallel progress in the Yangzi Delta and even in Jiangsu province if one takes into account the sub-prefecture distance scale.

Needless to say, it would be of great interest to complement these results with data pertaining to northern China and in particular to the prefectures around Beijing.

The study also lead to other findings such as for instance the fact that 18th century grain markets were less integrated in southern than in northern France, or the fact that for France, progress of market integration in the 19th century was about twice as fast as in the 18th century.

But, beyond these specific results, the main message of this paper was to advocate the definition and adoption of rigorous guidelines for comparative analysis. In particular, we emphasized that: (i) at an experimental level, the situation is not fundamentally different in physics and in economics; (ii) very little attention has been devoted by economists to the definition of methodological rules for comparative analysis. Hopefully, the present study can serve as a starting point for other cross-national comparisons.

Appendix

Price data

It is of crucial importance that other researchers can check our results and convince themselves that our conclusions do not depend on built-in artifacts at the level of data selection or statistical analysis. This is what we called the replication requirement. For that purpose, the present appendix provides the primary price data we have used. The Chinese data have never been published and are available only from

Table A.1. Rice prices in Jiangsu (Central–East China): 1756–1785.

Date	Jiangning	Suzhou	Sungjiang	Changzhou	Zhenjiang	Huaian	Yangzhou	Taicang	Haizhou	Tongzhou
1742.2	1.40	1.43	1.31	1.38	1.44	1.47	1.50	1.54	1.62	1.49
1742.7	1.49	1.76	1.73	1.70	1.60	2.03	1.70	1.95	1.73	1.77
1743.2	1.45	1.53	1.47	1.55	1.53	1.67	1.59	1.62	0.88	1.61
1743.7	1.40	1.49	1.47	1.40	1.46	1.35	1.25	1.60	2.05	1.46
1744.2	1.35	1.62	1.53	1.47	1.47	1.38	1.30	1.75	2.00	1.43
1744.7	1.30	1.38	1.52	1.40	1.40	1.32	1.24	1.65	1.87	1.28
1745.2	1.30	1.45	1.45	1.27	1.38	1.15	1.27	1.50	0.95	1.32
1745.7	1.22	1.42	1.48	1.31	1.32	1.33	1.24	1.50	1.94	1.30
1746.2	1.13	1.35	1.36	1.20	1.25	1.35	1.24	1.40	1.78	1.35
1746.7	1.12	1.40	1.52	1.33	1.25	1.30	1.30	1.47	0.80	1.30
1747.2	1.24	1.47	1.52	1.40	1.43	1.40	1.41	1.55	0.85	1.45
1747.7	1.55	1.83	1.67	1.57	1.60	1.55	1.36	1.88	1.70	1.58
1748.2	1.67	1.80	1.70	1.70	1.82	1.63	1.63	1.91	1.73	1.67
1748.7	1.68	2.12	1.83	1.70	1.78	1.77	1.50	1.94	1.75	1.51
1749.2	1.74	1.95	1.72	1.67	1.90	1.62	1.69	1.88	1.69	1.68
1749.7	1.33	1.58	1.40	1.45	1.43	1.43	1.33	1.67	1.47	1.64
1750.2	1.37	1.67	1.50	1.52	1.52	1.25	1.31	1.73	1.57	1.46
1750.7	1.33	1.70	1.77	1.48	1.45	1.42	1.17	1.70	1.67	1.37
1751.2	1.37	1.66	1.58	1.48	1.60	1.51	1.37	1.83	1.65	1.51
1751.7	1.72	2.51	1.83	1.95	1.98	1.57	0.00	2.55	2.05	1.88
1752.2	2.20	2.42	2.15	2.10	2.38	2.03	2.00	2.02	1.92	2.07
1752.7	1.87	2.33	2.25	2.10	2.12	2.06	1.90	2.44	1.78	1.88
1753.2	1.65	1.80	1.75	1.80	1.88	1.94	1.83	1.98	1.81	2.00
1753.7	1.60	1.80	1.73	1.65	1.70	1.85	1.77	1.95	1.00	1.75

Table A.1. (*Continued*)

Date	Jiangning	Suzhou	Sungjiang	Changzhou	Zhenjiang	Huaian	Yangzhou	Taicang	Haizhou	Tongzhou
1754.2	1.58	1.62	1.62	1.48	1.65	1.83	1.81	2.08	1.91	1.80
1754.7	1.42	1.60	1.58	1.45	1.55	1.65	1.59	1.98	1.91	1.75
1755.2	1.33	1.55	1.50	1.42	1.45	1.51	1.50	1.72	1.54	1.66
1755.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1756.2	2.38	3.05	2.68	2.72	2.78	2.63	2.55	2.93	2.09	2.39
1756.7	1.65	2.35	1.99	2.05	2.10	2.10	1.67	2.28	2.22	2.65
1757.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1757.7	1.43	1.62	1.52	1.48	1.48	1.75	1.46	1.77	2.22	1.64
1758.2	1.51	1.84	1.58	1.55	1.65	1.97	1.75	2.00	2.31	1.79
1758.7	1.33	1.65	1.62	1.55	1.55	1.38	1.32	1.90	2.09	1.53
1759.2	1.94	1.83	1.63	1.52	1.58	1.50	1.31	1.80	2.03	1.53
1759.7	1.44	2.22	1.80	1.75	1.62	1.43	1.40	2.07	1.71	1.59
1760.2	1.80	2.22	2.30	2.12	2.12	1.83	1.87	2.40	1.90	2.06
1760.7	1.62	2.12	2.15	2.03	1.90	1.82	1.98	2.14	1.85	2.23
1761.2	1.45	1.73	1.67	1.45	1.60	1.77	1.77	1.73	1.56	1.64
1761.7	1.43	1.92	1.85	1.62	1.62	1.71	1.62	1.84	1.59	1.75
1762.2	1.50	1.85	1.88	1.70	1.54	1.60	1.58	1.92	1.59	1.74
1762.7	1.58	1.94	1.92	1.82	1.76	1.63	1.63	1.92	1.63	1.73
1763.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1763.7	1.60	1.85	1.88	1.67	1.72	1.69	1.63	1.94	1.77	1.83
1764.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1764.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1765.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1765.7	1.67	2.05	1.93	1.83	1.76	1.72	1.67	2.03	2.00	2.05

Table A.1. *(Continued)*

Date	Jiangning	Suzhou	Sungjiang	Changzhou	Zhenjiang	Huaian	Yangzhou	Taicang	Haizhou	Tongzhou
1766.2	1.72	2.01	2.05	1.85	1.85	1.79	1.76	2.15	1.83	1.97
1766.7	1.65	1.99	2.05	2.30	1.77	1.81	1.62	2.06	1.99	1.98
1767.2	1.62	1.70	1.72	1.65	1.67	1.79	1.72	1.92	1.85	1.82
1767.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1768.2	1.50	1.65	1.55	1.45	1.57	1.75	1.42	1.70	1.83	1.60
1768.7	1.75	1.83	1.85	1.70	1.72	1.72	1.85	1.79	1.84	1.88
1769.2	1.77	1.82	1.80	1.90	1.85	1.95	2.03	1.97	1.96	2.10
1769.7	1.85	2.35	2.08	2.03	2.00	1.90	1.83	2.12	1.95	2.16
1770.2	1.88	1.99	1.95	1.83	1.80	1.82	1.75	2.15	1.95	1.84
1770.7	1.55	2.04	1.95	1.72	1.76	1.80	1.55	2.26	1.96	1.81
1771.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1771.7	1.27	1.59	1.77	1.45	1.50	1.74	1.41	1.83	1.88	1.68
1772.2	1.41	1.60	1.50	1.45	1.44	1.73	1.58	1.67	1.83	1.74
1772.7	1.30	1.58	1.50	1.38	1.35	1.61	1.33	1.63	1.84	1.65
1773.2	1.20	1.39	1.35	1.30	1.27	1.45	1.22	1.50	1.70	1.38
1773.7	1.22	1.37	1.42	1.25	1.20	1.50	1.15	1.58	1.72	1.25
1774.2	1.34	1.42	1.38	1.30	1.25	1.54	1.26	1.58	1.69	1.28
1774.7	1.55	1.75	1.50	1.80	1.67	1.58	1.66	2.03	1.71	1.61
1775.2	1.83	2.07	1.72	1.90	1.85	2.13	2.05	2.15	1.94	2.15
1775.7	2.25	2.12	1.90	2.00	2.08	2.11	2.40	2.28	1.94	2.37
1776.2	2.30	2.12	2.12	2.30	2.26	2.22	2.35	2.40	2.00	2.46
1776.7	1.65	2.10	2.08	1.80	1.80	1.90	1.83	2.18	1.96	2.10
1777.2	1.65	1.95	1.90	1.60	1.56	1.88	1.80	2.09	1.93	2.08
1777.7	1.58	1.88	1.95	1.62	1.63	1.65	1.53	2.07	1.95	2.00

Table A.1. (*Continued*)

Date	Jiangning	Suzhou	Sungjiang	Changzhou	Zhenjiang	Huaian	Yangzhou	Taicang	Haizhou	Tongzhou
1778.2	1.48	1.60	1.60	1.38	1.45	1.71	1.45	1.84	1.86	1.90
1778.7	1.90	1.78	1.85	1.90	1.78	1.70	1.70	2.03	1.92	2.12
1779.2	2.32	2.57	2.25	2.45	2.65	2.35	2.30	2.47	1.98	2.35
1779.7	2.15	2.34	2.22	2.15	2.00	2.15	2.00	2.17	2.10	2.15
1780.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1780.7	1.50	1.86	1.75	1.70	1.65	2.01	1.58	1.97	1.97	2.15
1781.2	1.55	1.60	1.73	1.65	1.50	1.96	1.70	1.85	1.91	2.15
1781.7	1.60	1.78	2.03	1.80	1.55	1.78	1.78	2.05	1.94	2.10
1782.2	1.73	2.03	1.60	1.99	1.70	2.05	1.88	2.08	2.02	2.15
1782.7	1.60	1.95	1.62	1.73	1.58	2.15	1.78	2.20	2.08	2.25
1783.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1783.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1784.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	2.20	2.20
1784.7	1.85	1.76	1.73	1.62	1.65	2.15	2.00	0.00	0.00	0.00
1785.2	1.85	1.77	1.65	1.60	1.60	2.24	2.05	2.00	2.24	2.25

Notes: The headings correspond to the names of the 10 prefectures composing Jiangsu province. The decimals 0.2 and 0.7 in the date respectively refer to the second and eighth month of the Chinese lunar calendar; a lunar month being shorter than 30 or 31 days, some years had 13 months. In the western calendar, those dates would approximately correspond to February and August. The prices are expressed in taels per shi (a shi is 103.5 liters). 0.00 means "missing figure"; between 1786 and 1792, there are many missing data which is why these years were omitted. Source: see text.

Table A.2. Wheat prices in France: 1756–1790.

Year	Alençon	Amiens	Bourge	Bourgogne	Bretagne	Caen	Lyon	Riom	Rouen	Tours
1756	1615	1380	1405	1720	1704	1670	1785	1455	1575	1410
1757	2400	2520	1330	2010	2020	2385	1804	1670	2905	1565
1758	1835	1485	1505	2230	1715	1854	1985	1760	1850	1505
1759	1750	1385	1590	2165	1800	1585	2210	1870	1890	1490
1760	1685	1520	1410	2145	1950	1555	2075	1670	1950	1365
1761	1555	1335	2075	1650	1935	1570	1690	1390	1580	1305
1762	1860	1615	1215	1570	1800	1854	1610	1310	1745	1445
1763	1415	1335	1005	1485	1525	1505	1335	1355	1430	1425
1764	1235	1320	1170	1679	1625	1115	1640	1420	1405	1305
1765	1595	1604	1335	1675	1650	1710	1979	1625	1675	1625
1766	1785	1635	1935	2485	2245	1925	2495	2210	2035	2130
1767	2190	2285	1940	2775	2180	2015	2655	2590	2400	1715
1768	2780	2920	1920	2505	2545	2510	2230	2065	3015	2190
1769	2960	2270	2035	2680	2480	2360	2355	2200	2730	2665
1770	3440	2355	3405	3505	3130	3230	3205	3480	2990	3015
1771	2865	2620	2795	3770	2630	2730	3655	3559	2850	2305
1772	2610	3375	2695	2655	2825	2710	3020	3120	2650	2770
1773	2695	2460	1950	2625	2710	2495	2885	2485	2850	2355
1774	2280	2095	1715	2330	2335	1950	2625	2255	2320	1954
1775	2785	2425	2350	2590	3145	2555	2630	2560	2765	2355
1776	2345	1845	1750	1904	2310	2000	2035	1875	2515	2105

Table A.2. (*Continued*)

Year	Alençon	Amiens	Bourge	Bourgogne	Bretagne	Caen	Lyon	Riom	Rouen	Tours
1777	2475	1950	1679	1765	2090	2165	2020	2135	2520	1979
1778	2140	1790	1665	2265	2305	2075	2630	2670	2215	1895
1779	2225	1590	1690	2595	2055	2405	2875	2410	2095	1650
1780	2180	1515	1640	2285	2095	2395	2375	2000	2080	1610
1781	2220	1750	1790	2120	2240	2195	2180	1925	2230	1910
1782	2180	1645	2475	2470	2850	2385	2555	2415	1960	2420
1783	2135	1725	2340	2745	2555	2205	2965	2540	1975	2305
1784	2720	2345	2070	2470	2570	2540	2525	2145	2875	2320
1785	2455	1860	1925	2285	2745	2605	2235	1865	2195	2485
1786	2305	1660	1915	1954	2915	2485	2190	1760	1920	2620
1787	2260	1735	2100	2210	2190	2060	2450	1960	2135	1979
1788	2390	2100	2310	2710	2240	2290	2735	2395	2495	2405
1789	3240	3375	3440	3370	3110	3215	3634	3340	3384	3100
1790	2790	2140	3270	3215	3060	2750	3365	3209	2750	2925

Notes: The prices are expressed in hundredth of livres per "setier de Paris" (a unit of volume equal to 156 liters and equivalent to a weight of about 120 kilogram of wheat). The city names refer to the "Généralités" (i.e., districts) of which the corresponding cities were the centers. Source: Labrousse 1933.

Table A.3. Wheat prices in France: 1806-1900.

Year	Alençon	Amiens	Bourges	Bourgogne	Bretagne	Caen	Lyon	Riom	Rouen	Tours
1806	1575	1606	1552	1731	1075	1560	2109	1648	1555	1364
1807	1750	1680	1603	1735	1226	1692	2040	1480	1682	1596
1808	1633	1459	1403	1486	1089	1573	1772	1428	1495	1370
1809	1474	1193	1283	1413	1112	1589	1571	1568	1396	1027
1810	1866	1614	1597	1915	1759	2176	2172	2140	1827	1253
1811	2126	2011	2317	2659	1725	2312	2974	2452	2242	1954
1812	3554	3299	3572	3228	3056	3558	3619	3152	3700	3238
1813	2231	2139	2254	2107	1895	2431	2325	1962	2465	1831
1814	1499	1366	1576	1560	1372	1577	1899	1503	1531	1389
1815	1612	1488	1634	1715	1595	1612	2016	1780	1636	1556
1816	2564	2714	2253	2795	2320	2685	2994	2619	2923	2111
1817	3257	3687	3075	4005	2778	3426	4099	3478	3697	2910
1818	2315	2091	2273	2198	2265	2311	2582	2102	2269	2265
1819	1862	1620	1656	1571	1945	1973	1890	1667	1860	1632
1820	2155	1850	1619	1725	1840	2416	2008	1824	2204	1709
1821	2023	1780	1558	1585	1749	2162	1834	1633	2109	1608
1822	1520	1418	1179	1362	1399	1660	1599	1403	1587	1259
1823	1696	1656	1337	1609	1473	1822	1875	1564	1734	1519
1824	1549	1348	1358	1556	1468	1719	1794	1495	1615	1424
1825	1686	1531	1274	1619	1548	1877	1828	1442	1681	1285
1826	1848	1528	1328	1577	1546	1906	1722	1412	1727	1432
1827	1756	1691	1737	2009	1513	1802	2197	1875	1891	1568
1828	2164	2207	1988	2277	1828	2198	2598	2325	2362	1883
1829	2646	2571	2118	2044	2144	2675	2275	2022	2550	2305

Table A.3. (*Continued*)

Year	Alençon	Amiens	Bourges	Bourgogne	Bretagne	Caen	Lyon	Riom	Rouen	Tours
1830	2217	2071	1978	2473	1866	2308	2734	2448	2098	2017
1831	2090	2191	1943	2128	2001	2209	2433	2237	2211	1999
1832	2120	2110	1689	2141	1942	2178	2332	2154	2092	1902
1833	1554	1466	1371	1742	1370	1550	1895	1636	1517	1381
1834	1502	1392	1292	1417	1404	1495	1603	1436	1485	1364
1835	1463	1395	1264	1402	1446	1458	1486	1393	1445	1390
1836	1516	1389	1510	1682	1639	1690	1800	1749	1520	1479
1837	1785	1486	1765	1785	1595	1932	1773	1679	1627	1739
1838	2095	2011	1880	1959	1716	2128	1964	1719	2029	1904
1839	2201	2260	2181	2345	1958	2245	2476	2099	2278	2146
1840	2387	2254	2119	2286	2055	2528	2450	2036	2362	2108
1841	1711	1656	1618	1945	1609	1839	2148	1892	1834	1624
1842	1784	1866	1714	2004	1643	1952	2172	1833	1975	1692
1843	2027	1834	1819	2048	1716	2102	2183	1999	2022	1876
1844	1942	1766	1852	1823	1717	2043	1981	2038	1959	1855
1845	1800	1684	1855	1843	1704	1888	1957	1950	1903	1801
1846	2219	2236	2310	2501	1953	2271	2597	2478	2457	2222
1847	3143	3001	3147	2873	2562	3174	2857	3247	3021	3123
1848	1608	1451	1425	1611	1556	1705	1805	1628	1582	1480
1849	1572	1498	1208	1459	1486	1739	1573	1396	1648	1407
1850	1412	1378	1119	1333	1358	1458	1502	1261	1450	1316
1851	1314	1439	1134	1363	1337	1362	1500	1218	1436	1302
1852	1654	1729	1428	1767	1605	1743	1816	1531	1755	1529
1853	2339	2318	2024	2291	2056	2413	2325	1967	2295	2194

Table A.3. (*Continued*)

Year	Alençon	Amiens	Bourges	Bourgogne	Bretagne	Caen	Lyon	Riom	Rouen	Tours
1854	3043	2828	2732	2721	2846	3154	2888	2690	2924	2770
1855	3156	3130	2775	2874	2804	3330	3068	2921	3242	2839
1856	2989	2920	3052	2918	2665	3070	3218	3294	3085	2931
1857	2271	2043	2333	2267	2188	2287	2470	2523	2260	2317
1858	1643	1488	1453	1578	1543	1679	1665	1635	1592	1477
1859	1614	1573	1379	1606	1614	1702	1677	1561	1663	1489
1860	2259	2091	1791	1979	2004	2345	2019	1849	2188	1936
1861	2684	2381	2312	2346	2299	2734	2337	2332	2534	2565
1862	2346	2155	2114	2123	2248	2479	2234	2455	2284	2178
1863	1855	1835	1771	1892	1789	1933	1956	1895	1885	1818
1864	1780	1622	1584	1681	1625	1759	1718	1640	1706	1613
1865	1674	1577	1447	1549	1516	1693	1638	1460	1688	1494
1866	2009	1887	1720	1902	1857	2059	1944	1786	2089	1882
1867	2742	2577	2519	2437	2548	2858	2614	2547	2736	2634
1868	2706	2432	2566	2441	2475	2682	2497	2592	2530	2704
1869	2020	1826	1908	1946	1850	2010	1982	1953	1964	1931
1870	2174	1894	1950	1990	1897	2137	2006	1935	2085	1997
1871	2847	2673	2678	2587	2262	2655	2443	2580	2674	2934
1872	2462	2435	2119	2401	2264	2698	2235	2355	2310	2277
1873	2749	2679	2508	2759	2492	2818	2573	2744	2633	2554
1874	2525	2493	2462	2521	2443	2702	2322	2693	2397	2543
1875	1899	1910	1780	1975	1743	1872	1844	1997	1888	1836
1876	2088	2093	1953	2195	1954	2168	1945	2051	2081	1976
1877	2507	2469	2267	2363	2443	2634	2215	2306	2428	2335

Table A.3. (*Continued*)

Year	Alençon	Amiens	Bourges	Bourgogne	Bretagne	Caen	Lyon	Riom	Rouen	Tours
1878	2321	2204	2260	2421	2152	2375	2172	2441	2174	2375
1879	2173	2096	2107	2445	2051	2260	1971	2378	2019	2216
1880	2304	2135	2279	2484	2200	2360	2368	2554	2085	2355
1881	2281	2224	2084	2356	1754	2308	2150	2368	2110	2266
1882	2205	2103	2035	2223	2015	2257	2161	2313	2136	2213
1883	1939	1790	1715	1940	1779	1936	1884	1959	1838	1897
1884	1826	1709	1594	1829	1559	1862	1759	1879	1719	1752
1885	1688	1643	1572	1739	1525	1766	1655	1718	1644	1633
1886	1692	1617	1580	1740	1576	1685	1712	1732	1667	1671
1887	1863	1693	1716	1838	1497	1836	1825	1898	1741	1817
1888	2029	1872	1825	1824	1817	2019	1817	1914	1893	1907
1889	1842	1681	1761	1861	1720	1945	1815	2050	1717	1826
1890	1967	1825	1869	1851	1847	2021	1854	2000	1870	1936
1891	2153	1989	2083	2098	1909	2150	2074	2246	2031	2218
1892	1750	1690	1782	1851	1549	1737	1796	2052	1712	1976
1893	1576	1553	1593	1675	1335	1599	1646	1720	1533	1728
1894	1502	1436	1455	1510	1522	1503	1500	1537	1455	1531
1895	1400	1391	1354	1430	1420	1439	1422	1385	1405	1333
1896	1439	1436	1422	1527	1258	1463	1493	1551	1399	1466
1897	1939	1860	1936	1953	1793	1914	1888	1894	1818	2005
1898	1975	1942	2047	2090	1906	2026	2016	2017	1856	2093
1899	1494	1470	1489	1533	1372	1487	1519	1560	1473	1521
1900	1504	1445	1456	1477	1406	1480	1443	1524	1455	1468

Notes: The prices are expressed in centimes per hectoliters (remember that a centime is one hundredth of a franc and that throughout the 19th century one franc was almost equal (in gold content) to one livre. The location names should be interpreted as the centers of the corresponding regions; the actual limits of the administrative divisions were redefined during the Revolution and are thus not exactly identical to those referred to in Table (A2). Source: 1806–1870: Labrousse (1970); 1871–1900: Drame *et al* (1991).

the archives in Beijing; the French data have been published in a French thesis[18] which may be difficult to obtain. In order to save space, we restricted the Chinese data to Jiangsu and the French data to the 18th century section of the long-term sample. The data for the other samples are available from the authors on request.

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