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Price shocks in disaster: the Great Kantō Earthquake in Japan,1923

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Abstract

This paper tests the operation of markets in the wake of a sudden exogenous shock in prewar Japan, the Great Kantō Earthquake of 1923. Using a unique monthly wholesale price dataset of provincial cities, we found that the earthquake had a positive impact on the price of rice and timber in the sample cities. Our results also indicate that the wholesale price of rice in cities in the northeast of Japan, which were more closely integrated with the affected region, experienced more significant price rises than those in western Japan. Nevertheless, although further research using retail as opposed to wholesale prices of goods is needed, these preliminary findings suggest that the diffusion of price instability outwards from the affected region was on a lesser scale than might have been expected.

Keywords: Great Kanto Earthquake; Natural disaster; Price shocks;

JEL Codes: N15; N35; N45; N95; Q5

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1. Introduction

The economic, social and political impact of natural disasters on developing economies is a recurrent theme in the contemporary world. While much attention has been paid to sustained and cumulative disasters, such as famines and flooding, the impact of one-off disasters, such as earthquakes and tsunami, has also attracted attention, particularly in developing economies in regions such as Southeast Asia, Latin America and the Caribbean. And yet, contrary to the mass of historical scholarship that has been undertaken on famines,[4] scholarly work on the economic impact of these one-off disasters in the past has, for whatever reason, remained relatively limited. Where there have been studies, the analysis has often been more focussed on the political economy, for example in the case of Pereira's study of the 1755 Lisbon earthquake.[5]

Is it, then, that such events are of limited significance in the longer term economic trajectory of a country or a region? Guidance on this point from social science theories appears to be of limited value. Such work as has been done makes clear that such shocks are likely to have a negative impact at least on short term growth, but at the same time has confirmed that little analysis has been undertaken of the mechanisms whereby this negative impact might be generated.[6] Over the longer term, the effects of these short term shocks have been evaluated as both contractionary and expansionary, and the issue remains somewhat open. Certainly wealthier economies have tended to withstand such shocks better than poorer ones.[7] Evaluations have in most cases looked at the macroeconomic picture in terms of GDP or incomes, but analysis of other indicators has been more limited, as have any attempts to disaggregate the macroeconomic indicators. How the stage of the business cycle might influence any measured impact, or how long it might last, also remain unknown. There is, moreover, the perennial problem of how to construct any appropriate counterfactual.

This paper seeks to contribute to the limited existing literature by focusing on

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[4] See eg. Amartya Sen, *Poverty and Famines: an Essay on Entitlement and Deprivation* (Oxford: Oxford University Press, 1983); Cormac O'Grada, *Famine: a Short History* (Princeton NJ: Princeton University Press, 2009).

[5] Alvaro S.Pereira, `The Opportunity of a Disaster: the Economic Impact of the 1755 Lisbon Earthquake', *Journal of Economic History* 69, 2, June 2009, pp.466-499.

[6] E.Cavallo & I.Noy, 'The Economics of Natural Disasters – a Survey', *International Review of Environmental and Resource Economics* 5, 1, 2011, pp.1-40.

[7] Hideki Tōya & Mark Skidmore, 'Economic Development and the Impacts of Natural Disasters', *Economics Letters* 94, 2007, pp.20-25.

the mechanisms whereby this kind of one-off exogenous shock impacts on economic transactions in the months and years immediately following the disaster. Our assumption is that these shorter-term effects are likely to be crucial in determining the longer-term impact of any such disaster on an economy. Our attention will be focussed on the extent to which the effects of a geographically confined exogenous physical shock, such as an earthquake, are diffused beyond the area that has been physically affected by that shock. The potential for such geographical diffusion has been well documented in the case of the damage inflicted on global supply chains by the Great East Japan disaster of March 2011.[8]

A number of economic mechanisms may be associated with this geographical diffusion. These mechanisms are in some ways distinct, but also to some extent overlap with each other. One is the nature and operation of markets for goods and services. Shortages of individual goods in the affected areas, for example, are likely to result in an inflow of those same goods from neighbouring areas, thus influencing the operation of markets over a much wider area. It seems likely that this influence will be greater in an integrated market economy than in an economy in which markets are less integrated and more fragmented, and in which fewer individuals participate in market transactions. A second diffusion mechanism is through physical and informational infrastructure. Limited communications between the area of destruction and other areas, for example, may influence transactions by reducing information flow and affecting decisions. Destruction of transport facilities, such as ports, stations or roads, will of necessity alter flows of goods and services, at least temporarily. Thirdly, this is clearly a case in which institutions matter. Governments, companies and business organisations, for example, will respond in diverse ways to any crisis of destruction and the need for relief, and are unlikely to do so in isolation, or in ways that are limited purely to the affected area. If revenue needs to be acquired for the purpose of rebuilding, for example, the burden is unlikely to fall exclusively on those impacted by the disaster, whose capacity to pay is in any case likely to be much reduced by the contingency.

Our focus in the present paper is on the first of these three mechanisms, namely the operation of markets in the wake of a sudden exogenous shock. Moving below the macroeconomic level, our intention is to try and assess the impact of a localised exogenous shock on the operation of wider markets for different goods

[8] Vasco M.Carvalho, Makoto Nirei & Yukiko Umeno Sato, 'Supply Chain Disruptions: Evidence from the Great East Japan Earthquake', RIETI Discussion Paper Series 14-E-035, June 2014, accessed at http://www.parisschoolofeconomics.eu/IMG/pdf/14e03 5.pdfon16/03/2014.

and services. We will explore this through an investigation of the price changes for a number of goods in the wake of that shock, and of the extent to which any price changes appear to have been diffused beyond the area immediately exposed to the shock. We seek to test two main assumptions. Firstly, it is apparent that a major shock of this kind will impact negatively on the availability of some goods in the immediate location, but it will also alter the demand schedule for certain goods, meaning that demand may increase or decrease, depending on the good in question. It follows that in the absence of price controls excess demand for some goods is likely to increase the prices of those goods, while a decrease in demand for others will have the opposite effect. Secondly, we hypothesize that price shocks of this kind will be communicated outwards from the affected area, through the mechanisms identified above, but that the scale of any price changes is likely to diminish with increased distance from the epicentre of the disaster. The findings of this paper support the accuracy of both these assumptions. They also suggest, however, that for some goods the price changes were far greater than for others; for some goods the changes appear to have been minimal. The extent of any changes, moreover, varied considerably, and the price instability was in most cases of relatively short duration.

2. The Great Kantō Earthquake of 1923 in Japan

We will seek to explore these hypotheses by using as a case study the Great Kantō Earthquake of 1923 in Japan. The history of market integration in Japan goes back a long way, and the country was by 1923 a relatively integrated market economy. The vast majority of citizens across the archipelago were engaged in market transactions on a day to day basis. A sophisticated national infrastructure, much of it centred in the Kantō region around Tokyo, supported market transactions. Traditionally market operations in the West of Japan had focussed more around the Osaka region (Kansai), while those in the east and northeast had focussed around the Tokyo region, but by the 1920s the increasing dominance of the capital area had become more apparent in some aspects of the economy, and the balance of power in the nation's economy had decisively shifted eastwards.[9] Nevertheless, it remained the case that when it came to daily transactions in a whole range of goods the north-eastern regions of Japan were still in 1923 significantly more integrated with the Kantō area than were regions towards the

[9] Carl Mosk, *Japanese Industrial History* (Armonk NY & London: M.E.Sharpe 2000).

west of the country.

What became known as the Great Kantō Earthquake occurred shortly before noon on 1st September, 1923. The epicentre of the 7.9 magnitude shock[10] that occurred was just south of Tokyo Bay. As shown in Figure 1, the size and location of the tremor meant that it impacted the whole of the Kantō plain, including both the capital city of Tokyo and the country's major port of Yokohama. Tokyo was at the time Japan's largest city, with over 2 million residing in the metropolitan area by 1920. Yokohama, less than 40 kilometers away, had close on half a million inhabitants. A further 4-5 million resided in the adjacent more rural jurisdictions across the rest of the Kantō plain, and the region accounted for a significant proportion of the country's total urban population.[11] The earthquake resulted not only in large scale physical destruction and collapse, but in a tsunami in many coastal areas, and huge conflagrations in both of the main cities. There are estimated to have been well over 100,000 deaths, and total casualties exceeded 140,000. The vast majority of the deaths and casualties were due to firestorms rather than the earthquake destruction or the tsunami.[12] Pictures taken in the immediate aftermath of the disaster suggest a scale of devastation comparable to that after the bombing of Dresden or Hiroshima.

A number of works have appeared in both English and Japanese relating to the Great Kantō Earthquake, but the majority of these works have focussed on the social and political consequences of the disaster, or its ideological or artistic construction. Schenking has explored in detail the politics of reconstruction after the earthquake, while Weisenfeld and Bates have looked at the imagery and the narrative associated with the event. We know something about its influence on education, urban planning, and seismology, and Gregory Smits has integrated some analysis of the event into his broader study of earthquakes in Japan's history.[13] Research on the economic impact of the disaster, however, has remained

[10] 7 Moment Magnitude scale.

[11] http://www.stat.go.jp/english/data/chouki/02.htm, Table 2-7 Population, Population Density, Population of Densely Inhabited Districts and Area by Prefecture, All Shi and All Gun (1898-2005), accessed 28/07/2016.

[12] For a general outline of the disaster see Naimushō Shakaikyoku, *The Great Earthquake of 1923 in Japan* (Tokyo: Sanshusha Press, 1926).

[13] Gregory Clancey, *Earthquake Nation: the Cultural Politics of Japanese Seismicity, 1868-1930* (Berkeley CA: University of California Press, 2006); Janet Borland, 'Capitalising on Catastrophe: Reinvigorating the Japanese State with Moral Values through Education following the 1923 Great Kantō Earthquake', *Modern Asian Studies* 40, 4, 2006, pp.875-907; Charles J.Schenking, *The Great Kantō Earthquake and the Chimera of National Reconstruction in Japan* (New York: Columbia University Press, 2013); Gennifer Weisenfeld, *Imaging Disaster: Tokyo and the Visual Culture of Japan's Great Earthquake of 1923* (Berkeley CA: University of California Press, 2012); Gregory Smits, *When the Earth Roars: Lessons from the History of Earthquakes in Japan* (Lanham MD: Rowman &

limited, perhaps because most economists and economic historians have taken the view that its influence on Japan's longer term growth and development was fairly minimal. Certainly it is acknowledged that the disaster was a key factor in the stop-go financial and monetary policy of Japan in the 1920s, that it also led to financial dislocation, and that it contributed to the occurrence of a major financial crisis in 1927. However, beyond the financial sphere there is less evidence of its being of fundamental importance for the economy. The country's key economic indicators had largely reverted to trend by 1928, or, in some cases, earlier. The longer-term impact of the disaster thus remains debateable, but there is at the same time no doubt that in the months after the disaster it was perceived by contemporaries to have had devastating economic consequences. It thus raises the issue of how we can reconcile these contrasting images of short-term and longer term impact.[14]

The acute economic problems perceived as having been caused by the disaster also suggest that it is an appropriate case study for exploring the nature of the short-term economic impact, something supported by the overall scale of what occurred and the key location in which the event took place. In line with the objectives indicated earlier, we therefore seek in this paper to ask three main questions. Firstly, we ask what the effect of the disaster was on the prices of different goods both in the devastated capital area and in cities in other parts of Japan. Where changes are identified, we also seek to establish how quickly the prices were stabilized. Secondly, we ask how far any changes in prices that occurred in the different cities were correlated with each other. The third question relates to geographical diffusion, namely the extent to which cities in regions closer to the devastated area may have been more affected than those that were further away, i.e. was the extent of any shock aligned with geographical distance from the capital area.

In line with our earlier assumptions and the context of Japanese market integration in the 1920s, we come to three more specific hypotheses that we

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Littlefield, 2014); Alex Bates, *The Culture of the Quake: the Great Kantō Earthquake and Taishō Japan* (Ann Arbor MI: University of Michigan Center for Japanese Studies, 2015).

[14] For some preliminary observations on this issue see Janet Hunter, "Extreme confusion and disorder"? The Japanese Economy in the Great Kantō Earthquake of 1923', *Journal of Asian Studies* 73, 3, pp.753-773. For the impact of the disaster on agglomeration see Asuka Imaizumi, 'Tōkyō-fu Kikai Kanren Kōgyō Shūseki ni okeru Kantō Daishinsai no Eikyō: Sangyō Shūseki to Ichijiteki Shokku', *Shakai Keizai Shigaku* 74, 4, 2008, pp.23-4; Tetsuji Okazaki, Kaori Itō & Asuka Imaizumi, 'Impact of Natural Disasters on Industrial Agglomeration: the Case of the 1923 Great Kanto Earthquake', *CIRJE Discussion Paper*, University of Tokyo, 2009, CIRJE-F-602. For the financial aspect see Nihon Ginkō Hyakunen Shi Hensan Iinkai, *Nihon Ginkō Hyakunen Shi* vol.3 (Tokyo: Nihon Ginkō, 1983).

propose to test empirically. Firstly, we expect any price changes in the Kantō region (in Tokyo or Yokohama) consequent upon the disaster to be reflected in price changes elsewhere in the Japanese islands. Secondly, we would expect cities further away from the area of devastation to witness smaller price changes than those occurring in cities nearer to the Kantō area. Finally, given the greater integration between northeast Japan and the capital area, it seems likely that any price changes in cities in the northeast would have been greater than those in cities towards the west and south of Japan (which were more integrated with the Osaka region).

3. Data and Methodology

3.1. Sample Characteristics

In order to explore our hypotheses we have assembled a monthly panel dataset of 11 provincial Japanese cities for the period May 1921 to December 1925. The cities used in the analysis are Niigata, Nagoya, Kanazawa, Sendai, Kyoto, Osaka, Kobe, Kōchi, Hiroshima, Otaru and Fukuoka. The location of these cities is shown in Figure 1. As shown in the second column of Table 1, the average population of the cities in our sample between 1921 and 1925 varied from 57,000 in Kōchi City to over 1.6 million in Osaka. Limitations on available sources of price data mean that we have not included in the sample a number of other cities with smaller populations, but despite this limitation we are able to include data for a significant part of Japan's city population, as the total population in our sample cities accounts for approximately 82% of the total population of all cities with more than 100,000 inhabitants in 1923, and approximately 58% of the population of all cities with 50,000 or more inhabitants. If we include all cities in Japan in 1923, the sample comprises approximately 47% of the city population.[15]

If we look at the geographical distribution of these cities shown in Figure 1, we see that the cities are well distributed throughout the country, and not concentrated in a specific district. The longitude and latitude of the southernmost city in the sample, Fukuoka, are 130.40° and 33.59°, while the equivalent locations for the northernmost city, Otaru, are 140.98° and 43.19°. The geospatial distance from Tokyo is 888 kilometers in the case of Fukuoka, and 839 kilometers in the

[15] Tokyo and Yokohama city are excluded in the calculation. The information on the city population is taken from Statistics Bureau of the Cabinet (1925a).

case of Otaru. This rich variation in geospatial location ensures heterogeneity of city characteristics, and enables us to capture the impact of the Great Kantō Earthquake across the Japanese archipelago. Tokyo and Yokohama, which were located near to the centre of the earthquake (the yellow-red circle in Figure 1), bore the brunt of the physical destruction, and served as the point of origin of any price changes, are excluded from the sample.

3.2. Wholesale Prices

The use of low frequency data, such as annual or quarterly data, is at higher risk of concealing any short run effects in the months immediately after the earthquake.[16] In order to estimate the impact of the earthquake on prices in the provincial cities, we have therefore compiled a unique dataset of monthly wholesale prices across various goods and categories in thirteen cities (including Tokyo and Yokohama). We focus on the analysis of prices rather than quantities, because the data on product availability are severely limited for the time period in question. The data are drawn from the statistics of wholesale prices (*Oroshiuri Bukka Tōkeihyō*)[17] compiled by the Statistics Division of the Japanese Ministry of Commerce and Industry in 1926. Since the Japanese government recognised these thirteen cities as 'main' cities under a ruling in June 1920,[18] in each case the local chamber of commerce was required to collect and report the wholesale prices of 84 different goods. As indicated in the introduction to this publication, its objective was to record the monthly wholesale prices for a range of goods in the thirteen cities for the convenience of general users.

We have selected a limited number of goods to represent different areas of purchase, notably foodstuffs, export manufactures, construction materials, fuel and agricultural inputs, each of which are likely to have different market characteristics. In the case of rice, the core foodstuff, data has been aggregated to include the prices of different grades of rice. Wheat has been selected as a grain of growing importance, but one where Japan's own production remained limited, and

[16] Alberto Cavallo, Eduardo Cavallo & Roberto Rigobon, 'Prices and Supply Disruptions during Natural Disasters', *Review of Income and Wealth* 2014, pp.1-2.

[17] This statistical report is held in the National Diet Library of Japan. The digitized archive is available on the *National Diet Library Digital Collections*; http://dl.ndl.go.jp/info:ndljp/pid/1710197.

[18] No.1319 of 10 June, 1920, entitled 'Shōgyō Kaigisho yori Chōsa Hōkoku subeki Bukka oyobi Chingin Tōkei Yōshiki'. The goods comprised 35 food items, 20 construction materials, 8 kinds of fertiliser and animal feed and 11 miscellaneous goods. See Ministry of Agriculture and Commerce 1904, p.218.

consumption was focussed on urban areas. In the case of reconstruction goods we selected data on wood products, since the majority of Japanese buildings were at the time constructed of wood, but due to incompleteness in the data for many wood products we have used pine boards (planks) as a proxy for wood products more broadly. In the case of fuel we have selected two products: coal, which was used largely in manufacturing, and charcoal, which was mostly for domestic use. The export good identified is cotton yarn, while fertilizer in the form of calcium superphosphate was chosen as an agricultural input. Japan remained a predominantly agricultural economy at this time, with agriculture accounting for the largest share of the occupied population, but the diffusion of best practice rice production techniques since the mid-nineteenth century had entailed massive growth in inputs of working capital, such as fertilizer. As indicated above, price data on these goods has been collected for Tokyo and Yokohama, and for eleven provincial cities: Otaru, Sendai and Niigata in the northeast regions, and Kanazawa, Nagoya, Kyōto, Osaka, Kōbe, Kōchi, Hiroshima and Fukuoka in the west and southwest. The data has been collected for a period of 56 months from May 1921 to December 1925, giving us 26 months following the disaster, and slightly more before it.

In selecting the goods we faced a number of data constraints, as indicated above. Having to use pine boards rather than putting these data together with that on other wood products means that we are reflecting only a small part of the reconstruction goods market. Separating different fuel products raises the issue of the extent to which one source of energy was substitutable for another. We are satisfied, however, that the markets for, and usage of, coal and charcoal were sufficiently separate to mean that aggregation would be likely to make little sense. By contrast, aggregation makes good sense in the case of something like rice, where consumers made choices depending on income and taste, but where it remained relatively easy to substitute one grade of rice for another. Our choice of goods is, of course, open to question, but we believe that, given the data constraints, it offers a range of marketed goods that can best reflect the kinds of price changes that might be expected for goods with different attributes. Potentially more problematic is our aggregation of the data for the different cities, as it has the potential to conceal outliers in the case of individual cities, outliers that may be generated by very particular local circumstances. This problem will be considered further below.

A further potential weakness in our data is the fact that it provides information only on wholesale prices. Wholesale prices were much more easy to control and regulate than were retail prices; wholesale prices tended to be set by the authorities and wholesale transactions mostly took place in official markets. Retail prices were set by individual retailers, both large and small, based on their desired profit margin. Retail in Japan in 1923 was overwhelmingly populated by individual retailers, small shops with maybe at the most just one or two employees, or making use of family members. A mass of contemporary anecdotal evidence suggests that retail prices for many goods rose far more in the weeks following the disaster than did wholesale prices. Obtaining systematic statistical evidence on retail prices is, however, very difficult. Monthly retail price data is lacking for many cities and many goods, and where it does exist it is often incomplete and potentially unreliable. Nevertheless, the potential for divergence between trends in wholesale and retail prices is considerable, and this risks limiting the validity of any findings based exclusively on wholesale price data. We will return to this problem when we consider the findings of our analysis of the wholesale price data, and seek to locate those findings in a broader historical context.

Figures 2a–2g show the prices of the selected goods in Tokyo and Yokohama before and after the disaster. The timing of the disaster is clearly marked on these figures. There are fluctuations in the wholesale prices of all the goods in the months both before and after the disaster. Depending on the product these fluctuations are likely to have been generated by cyclical, seasonal or other factors. If we compare the average prices in the months following the disaster with those in the months prior to it, we can see that with the exception of pine boards and coal the prices for all the other goods were on average higher in the months after the disaster than before. In the case of rice and wheat, prices were stable or rose only slowly in the first twelve months after the earthquake, which is commensurate with the existence of official attempts to requisition supplies, regulate wholesale rice prices, and encourage imports of essential goods through suspension of tariffs. The prices of cotton yarn, fertilizer and charcoal rose more rapidly. Particularly in the case of charcoal, the loss of housing and the onset of colder weather stimulated a jump in prices that only ended some twelve months after the disaster. While the price of pine boards rocketed after the earthquake, in the context of huge demand for reconstruction materials, the large scale provision of supplies from both domestic and foreign sources (mostly North America) had brought prices back to the pre-disaster level by the spring of 1924. Coal, too, experienced a sharp immediate price increase, lasting until the autumn of 1924.

The price data for the provincial cities for the period from May 1921 to December 1925 is provided in Figures 3a–3f. A similar comparison of the average prices in the eleven cities for each good in the months prior to and following the disaster suggests that any impact of the earthquake on the prices in provincial cities appears to have varied in timing and also depending on the product in question. As we can see from Figures 3a, 3b, 3c, and 3e, the average prices of rice, wheat, cotton yarn and calcium superphosphate tended to be higher in the period after September 1923 than in the period prior to it. The prices of these products began to increase a few months after the event, but the price of calcium superphosphate had declined again within the year. By contrast, the prices of rice, wheat and cotton yarn were still high a year after the disaster, and the price of rice was around 40 yen per 180 litres from October 1924 to October 1925, approximately 18% higher than the price in August 1923. The price of cotton yarn rose sharply towards the end of 1924 to a level approximately 60% higher than the level of August 1923. These findings are consistent with an expectation of rising prices for goods in short supply in the months after the disaster, including foodstuffs, clothing inputs and fertilizer, although the more prolonged increase in prices for foodstuffs and cotton yarn would appear to have been associated with other factors, including the level of the harvest in 1924 and some relaxation of the conservative exchange rate policy after the disaster.

By contrast we find that the average prices of pine boards, charcoal and coal after the earthquake were lower than before it, as shown in Figure 3d–3f. Pine boards and charcoal experienced short run positive price shocks, but prices had stopped increasing by the turn of the year, and had fallen to the pre-earthquake level by May 1924. The short duration of the price shock in the case of pine boards is again commensurate with the rapid increase in supply that occurred from early 1924, and that for charcoal with the peak demand winter period. The profile for coal prices in the sample cities, however, is very different from that of Tokyo and Yokohama; the average drop in coal prices following the disaster was significant, and did not mirror the initial price surge found in the case of the disaster region. While for almost all these products, therefore, there seems to have been some kind of positive price shock after September 1923, the duration of that shock varied considerably, and in some cases was outweighed by the significant declines in price that occurred thereafter. In order to capture the magnitude of the impact of the earthquake more precisely, therefore, we will also estimate the baseline specification using an alternative cut-off period, as described in Section 4.1 below.

3.3. Geospatial Distance between Tokyo and Provincial Cities

Our quantitative analysis relies on measures of geospatial distances between provincial cities and the affected city of Tokyo. To construct this variable, we calculated the minimum distances between each provincial city and Tokyo using the spheroid (GRS80) of the Geospatial Information Authority of Japan (GIAJ), based on the information on the longitude and latitude of each city. The data on longitude and latitude were obtained from the database of the GIAJ. Details of the data sources are described in Appendix B. For convenience of interpretation we use the reciprocal distance, i.e. the closeness to the devastated area, in our empirical analysis.

A summary of the geospatial information is provided in columns 3-6 of Table 1. The geospatial distances between the provincial cities and Tokyo vary from 255 kilometres in the case of Niigata up to 888 kilometres in the case of Fukuoka, meaning that the closeness to Tokyo varies from 0.39 (1/2.55) down to 0.11 (1/8.88). The mean value of the distance is 486 kilometres, and hence the mean value of the reciprocal number 0.25. Since our sample cities are scattered across the whole of Japan, there are significant differences in the intervals, and the distances do not concentrate on a specific value. Four of the cities, namely Niigata, Kanazawa, Sendai and Otaru, are located in the north-eastern region of Japan.[19] However, these four cities are also widely scattered, helping to confirm the geospatial distances listed in Table 1.

3.4 Covariates

We use covariates representing the demographic, industrial, trade-related and meteorological characteristics of the cities as baseline controls for our empirical analysis. Firstly, the size of population is included in the covariates to indicate the scale of demand for each commodity. Second, the number of factories per 100 population in the prefecture is used as prefectures with a larger number of factories were more likely to be affected by any shortages of raw materials and

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[19] Both the Hokuriku district, which includes the cities of Niigata and Kanazawa, and the Tōhoku district, which includes Sendai city, were more integrated with the Kantō region. Therefore, we have included both these districts as part of the north-eastern area of Japan. In fact, Hokuriku district is officially classified as part of Eastern Japan in terms of its meteorological conditions (see the classification of the Japan Meteorological Agency: http://www.jma.go.jp/jma/kishou/know/kisetsu_riyou/division/kubun.html).

fuels. Thirdly, the total tonnage of steam and sailing ships in the ports in each prefecture are used to control for the availability of marine transportation. This variable is included because sea routes are likely to have been used to transport one or more of the commodities between the centre of Japan and the provincial cities, notwithstanding a significant increase in marine freight costs following the earthquake. This variable also acts as a control for the quantity of imports, which is likely to have affected wholesale prices in the cities. Finally, for meteorological variables we use monthly average temperature and monthly average precipitation, which are drawn from the database of the Japan Meteorological Agency (JMA). These variables are included because it seems likely that meteorological conditions would have affected the availability of marine transport, especially in the case of sailing ships. Moreover, the prices of goods such as foodstuffs and charcoal are also likely to have been directly affected by weather conditions, through changes to both supply and demand. Details of the sources of the control variables are provided in Appendix B. Panel (C) of Table 2 gives summary statistics of the control variables.

4. Impact of the Earthquake on Wholesale Prices

4.1. Econometric Strategy and Results

As previously mentioned, the Great Kantō Earthquake struck in the centre of Japan on 1st September 1923. It was suggested in the historical overview in Section 2 that the disaster may well have increased the prices of some commodities and brought confusion to market transactions in provincial cities across the Japanese archipelago, even though these cities were not directly affected by the physical impact of the earthquake. Given the context it seems likely that wholesale prices in these cities would have been affected by the enormous physical losses in the central part of Japan and the subsequent disruption caused by the earthquake. In this section, we conduct quantitative analysis of our 11 provincial city–level monthly panel dataset to test whether or not the occurrence of the earthquake increased the wholesale prices of commodities in the provincial cities. As before, the data covers 28 months before and after the earthquake, i.e., from May 1921 to December 1925.[20]

[20] We confirmed the stationarity in our wholesale price panel dataset. For all wholesale prices of the products used in our analysis, several tests reject the null of unit-root nonstationary. Table A.1 in

Three questions regarding price changes in the commodities in the provincial cities are posed in order to test the hypothesis. First, to what extent were cities in regions closer to the devastated area more affected than those that were further away? In other words, was the extent of the shock aligned with geographical distance from the capital area? Second, was the impact on prices in north-eastern Japanese cities, which were more integrated with the devastated Kantō region, greater than the impact in the south-west? Third, how quickly was the impact of the earthquake on wholesale prices stabilised?

To answer these questions, we use the cross-sectional heterogeneity in the geospatial distance values to distinguish the impact of the earthquake. Our expectation is that cities located closer to Tokyo will be significantly affected by the physical devastation that has occurred in the centre of the country, whereas the cities located further away from the capital will be less affected by the physical devastation caused by the earthquake. For each city, therefore, we use the reciprocal number of geospatial distance from Tokyo as an indicator of the closeness to the center of the earthquake and thus, as an indicator of the magnitude of its influence. In order to test the extent to which the earthquake increased the market prices in provincial cities and identify how far the impact of the earthquake varied across these cities, we estimate the following model:

$$Price_{it} = \alpha + \rho Price_{it-1} + \delta Closeness_i \times Post_t + \mathrm{x}'_{it}\beta + \sum_{c=2}^{11} \gamma_c I_{ci} + \sum_{j=Jul\ 1921}^{Dec\ 1925} \theta_j I_{jt} + e_{it} \quad (1)$$

where i is the index of the cities from 1 to 11 and t the index of the months from May 1921 to December 1925, 56 months in total. The variable $Price_{it}$ is the price of a certain product, $Closeness_i$ is the reciprocal of geospatial distance from Tokyo, $Post_t$ is the indicator variable that equals one after September 1923, x_{it} is a vector of city characteristics, and e_{it} is a random error term. I_{ci} and I_{jt} are the indicator variables that equal one for the city c and month j, respectively. Thus, the variables $\sum_{c=2}^{11} I_{ci}$ and $\sum_{j=Jul\ 1921}^{Dec\ 1925} I_{jt}$ represent city and month fixed effects, respectively.

The coefficient δ is the focal point of our interest. We expect the estimate of $\hat{\delta}$ to be positive, which would indicate that the earthquake had a larger positive effect on prices in cities closer to Tokyo. For instance, in the case of rice being the dependent variable, a positive coefficient would indicate that cities located closer to

Appendix A shows the results of the unit-root tests.

Tokyo experienced a greater increase in the wholesale price of rice after September 1923 compared to before that date.

Regarding our identification, we assume that, after taking into account city observables, the variable of interest is exogenous. This assumption would appear to be basically plausible, as it is clear that both the timing of the earthquake and the geospatial distances of each city from Tokyo are exogenously determined. Although both demand- and supply- side institutions may also affect the level of prices, we are able to control for those factors using the covariates described in Section 3 and fixed effects. City fixed effects control for all time constant factors in each city. These factors include, for example, geographical features affecting transportation costs or productivity in relation to foodstuffs, market institutions such as the regulation of trade practices between producers and merchants, and citizens' preferences for different commodities. Other macroeconomic shocks affecting prices, including government intervention to stabilize markets, as well as any secular trends and seasonal effects on prices during the sample period are controlled for by monthly fixed effects. Finally, we also include a lagged dependent variable into the regressors in order to capture persistence in price. This lagged value of price can also be considered as potentially reflecting cross-city dynamics in price because it may reflect information on predetermined prices in other cities.[21] We employ cluster-robust standard errors in order to deal with heteroskedasticity and serial correlation in the idiosyncratic error term (see Stock and Watson 2008).[22]

Our estimates of the baseline model by product categories are reported in Table 3. As reported in column (1), the estimated coefficient on *Closeness* × *Post* is 1.829 for rice and statistically significant at the 5% level. This result implies that a 1 unit increase in the reciprocal of distance results in an increase of roughly 1.829 yen in the post-earthquake average wholesale price of rice relative to that before the earthquake. The maximum value of *Closeness* is 0.39 for Niigata and its minimum value is 0.11 for Fukuoka (see Table 1). Therefore, the impact of the

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[21] Note that the within estimator in a dynamic panel data model becomes consistent as T gets larger (see Hsiao 2014, pp.82–84). The number of sample periods in our baseline specification is 56-months in total and thus, can be considered large enough to bring our parameter of interest close to a true value (see Baltagi 2013, pp.155– 156).

[22] Throughout our empirical analysis, standard errors are clustered at the city level. Although Osaka and Kobe city are located close to each other (see Figure 1) and may be expected to have spatial correlations, our baseline estimates reported in Table 3 are robust to including these two cities in the same cluster. See Table A.2 in Appendix A for the results. In addition to this, we also employed the wild cluster bootstrap method proposed by Cameron et al. (2008) to deal with the issue of the small number of clusters. The main results could be confirmed as stable through using this procedure. Table A.3 in Appendix A shows the result.

earthquake on the average wholesale price of rice in Niigata is approximately 0.71 yen (0.39 × 1.829), whereas that in Fukuoka is approximately 0.2 yen (0.11 × 1.829). The impact in Kobe, which is located at a roughly intermediate point in terms of distance from Tokyo, is estimated to be 0.42 yen (0.23 × 1.829). The large disparity in the impact between Niigata and Fukuoka supports our hypothesis: that is, the cities closer to Tokyo were significantly affected by the consequence of the earthquake, whereas the cities further away were less affected by the earthquake. If we look at the figures for the other products reported in columns (2)–(7), we see that the estimated coefficients on *Closeness* × *Post* for wheat, cotton yarn, pine boards, calcium superphosphate, coal, and charcoal are 0.073, 2.735, 0.082, −0.064, −0.880, and −1.446 but those effects are not statistically significant. The above result suggests that if we look only at the impact of the earthquake on average prices in the 28 month period from September 1923, the wholesale prices of wheat, cotton yarn, fertilizer, and fuel were not affected by the earthquake.

To explore the magnitude of any effect in more detail, we then calculated the increase in the price of rice due to the earthquake as a proportion of the total increase in rice prices from the period from May 1921 to August 1923 to the period from September 1923 to December 1925. For example, in Kobe city, the estimated impact of the earthquake on the price of rice is 0.42 yen as shown above. The actual price of rice in Kobe increased by 5.05 yen, from 35.06 yen per 180 litres in the pre-earthquake period to 40.12 yen in the post-earthquake period. Thus, the effect of the earthquake, i.e., the proportion of the total increase in the wholesale rice price in Kobe due to the earthquake is estimated to be 8.3%. Figure 4 lists these percentage figures for each provincial city in order of distance.[23] It is clear that the impact of the earthquake on the price of rice increases the closer a city is to Tokyo. The impact of the disaster on the wholesale price of rice is highest in Kanazawa city, which is located at a distance of 295 km from Tokyo city. By contrast, it is lowest in Fukuoka city, which is 888 km from Tokyo. The average value of these magnitudes is calculated to be 8.4%.

The above analysis supports the available evidence that changes in prices in the Kantō region consequent upon the disaster are likely to be reflected in price changes elsewhere in Japanese islands. It also suggests that cities further away

[23] Table A.4 in Appendix A shows the details of the calculation of those magnitudes in each provincial city. The estimates suggest that the increase in the price of rice due to the earthquake was decreased by 0.08 yen per 180 litres for every additional 100 km of distance from Tokyo. Figure A.1 shows this relationship between the increase in rice price due to the earthquake and the geospatial distance from Tokyo.

from the area of devastation are likely to witness smaller price changes than those occurring in cities nearer the Kantō region. However, as discussed in Section 3, the scale and nature of the impact of the earthquake on prices is likely to vary not only according to the individual product but also in terms of timing, that is, in terms of the length of the period after the earthquake during which any changes might persist. We have therefore estimated our baseline specification using alternative cutoff periods. By means of this analysis, we can identify how quickly the impact of the earthquake on prices was stabilized, and in the process also address the last of our hypotheses, namely that changes in north-eastern Japanese cities are likely to have been greater than changes in the south-west.

4.2. Alternative Cutoff Period

In this section, we estimate the impact of the earthquake on wholesale prices using our baseline model in equation (1) for each 3-month segment after the earthquake. As discussed in Section 3, we expect the prices of rice, wheat, and cotton yarn to be impacted for a longer period, whereas the prices of pine boards, calcium superphosphate, and fuel appear to have been affected for a rather shorter period. Thus, as the treatment-period is increased, the effect on the latter group of products may become close to zero, while the effect on the former group of products may continue to be significantly different from zero.

The estimates for the alternative cutoff periods are reported in Table 4. The first to ninth rows of the table show the estimated impacts for each product using the panel datasets starting in May 1921, but setting the post-earthquake period as 3, 6, 9, 12, 15, 18, 21, 24, and 28 months, respectively. Thus, the total number of months in each sample is 31, 34, 37, 40, 43, 46, 49, 52, and 56 months, respectively. For all specifications, we include all control variables as well as city and month fixed effects.

As expected, persistent effects are observed in relation to the wholesale price of rice. For the shortest period of three months, the estimated coefficient on *Closeness* × *Post* is −0.065, and not significantly different from zero. By contrast, for the periods of 6 months or longer, the estimated coefficients are significantly positive, at 1.349, 1.601, 1.530, 1.528, 1.484, 1.528, 1.623, and 1.829, respectively. This result is consistent with our expectation that the impact of the earthquake on rice is relatively persistent in spite of the delayed increase in price after the shock.

The same calculation used earlier has been employed to illustrate the magnitude of the earthquake in each 3-month segment. For instance, for the case of Niigata city over the 12-month period after the earthquake, we see that the average wholesale price of rice increased by 2.5 yen, from 31.98 yen in the period between May 1921 and August 1923 to 34.48 yen in the period between September 1923 to August 1924. Since the increase in price due to the earthquake is estimated to be 0.6 yen (1.53 × 0.39), the proportion of the total price increase caused by the earthquake is calculated to be 23.9% (0.6/2.5). Applying the same calculation for all cities and for all cutoff periods, we aggregated the average magnitudes for three areas based on the distance from Tokyo, that is, cities located at from 255 to 302 km from Tokyo, those from 370 to 430 km from Tokyo, and those at a distance from 618 to 888 km. Figure 5 illustrates the proportion of the total price change before and after September 1923 accounted for by the earthquake.[24] There are two main findings regarding the price of rice.

First, the magnitude of the effect of the earthquake declined as the length of time following the event increased. On average, six months after the earthquake it was accounting for approximately 55% of total increase in prices. However, this proportion had sharply declined by nine months after the earthquake, by which time the proportion was approximately 24%. By twelve months after the earthquake, the proportion had declined to below 20%. In the case of rice, the effect of the earthquake on the wholesale price of rice eventually stabilised at around 8–9% some 21 months after the earthquake.

Second, the impact of the earthquake increased the closer a region was to Tokyo. The four cities located in the range from 255 km to 302 km were significantly impacted by the earthquake. The difference in the size of the effect between these cities and the three cities in the next distance band, from 370 km to 430 km, is roughly 5% for each cutoff period. Similarly, the size of the effect in these four cities is roughly 10% higher than that in the four most distant cities, those in the range from 618 km to 888 km away from Tokyo. The order of magnitude changes somewhat in the case of periods beyond six months. One possibility is that cities in the Kansai area, such as Kyoto, Osaka and Kobe, were less likely to be affected because they held larger stocks of rice than the other south-western provincial cities.

Regarding the hypothesis that changes in north-eastern Japanese cities are likely to have been greater than changes in the south-west, Figure 6 shows the proportion of increase in the rice price due to the incidence of the earthquake by

[24] The estimated magnitudes in each provincial city are also reported in Figure A.2 in Appendix A.

area categories, as described in column 7 of Table 1. Clearly, the effect of the earthquake is more significant in the four north-eastern cities than in the seven cities south west of Tokyo. The disparity is largest for the six month period after the earthquake, with the impact approximately 10% greater in the north-eastern cities. After nine months or longer, this disparity gradually converged to around 5%. We can therefore conclude that changes in the rice price due to the earthquake were more conspicuous in the north-eastern cities which were more integrated with markets in the devastated Kantō region than in the south-western cities which were more integrated with the physically unaffected Kansai region.

If we look at the impact of the shock son the wholesale price of pine boards, we see that the estimated coefficient is significantly positive for the three-month period after the earthquake, as shown in the 1st row in Table 4. This result is consistent with the overall trend in the time series showing that the increase in prices had been halted by the end of 1923, and that prices had begun to decrease around the turn of the year. This implies that in the case of wood the earthquake accounted for a significant proportion of the rise in price that occurred, and if we apply the same calculation used to estimate the average impact on rice, we can estimate that in the case of wood 73.6% of the total change in price in the months before and after September 1923 is accounted for by the earthquake.[25] In the case of our other products, such as wheat, cotton yarn, calcium superphosphate, coal, and charcoal, no statistically significant effects are observed. It seems possible, therefore, that the earthquake did not have a significant impact on the wholesale prices of these commodities.

4.3. Falsification Tests

In this section, we conduct a placebo test for the wholesale prices of rice and pine boards by using the period prior to the earthquake, in order to check the robustness of the main findings described in Sections 4.1 and 4.2. It is possible that for the period *before* the earthquake, given the existence of a relatively integrated economy, the wholesale price in cities nearer the Kantō area may not have been

[25] The magnitude of the effect in each provincial city is reported in Table A.5 in Appendix A. Kanazawa, Kyoto, Kobe, Kochi, and Otaru city are excluded from this calculation due to the negative value of the price change before and after the earthquake. Further testing would be necessary to see whether these findings are statistically significant, and there is no obvious historical explanation for the suggestion that prices in these cities may have been either stable or negative, in contrast to the other cities in the sample. These cities are, moreover, geographically widely spread, and extremely diverse in character.

significantly different from that in cities further away from the Kantō area. In other words, if the coefficient on the interaction term between $Closeness_i \times Post_t$ was estimated to be statistically significant using the pre-earthquake period, this key variable in our baseline specification may correlate with other factors that might have affected wholesale prices, such as unobserved time-varying transportation costs across the sample of cities.

The estimates are reported in Table 5. The placebo treatment periods in columns (1)–(2), (3)–(4), and (5)–(6) are the months from March 1922–August 1923, September 1922–August 1923, and March 1923–August 1923, respectively. These treatment periods have been chosen systematically as six months, twelve months and 18 months before the incidence of the earthquake. This means that, for example in column (1)–(2), we use the interaction term between the geospatial distances and an indicator variable that equals one for the months from March 1922 to August 1923. The same applies to the estimates listed in columns (3)–(4) and (5)–(6). The estimated coefficients do not differ significantly from zero for all specifications. In other words, when it comes to geospatial distance the differences in the prices of rice and pine boards appear only over the sample period after the earthquake. This result confirms that no unobserved factors have disturbed our main results.

5. The findings in context

In analysing the price changes for a number of goods in the wake of the Great Kantō Earthquake of 1923, this paper has sought to test two main assumptions. One is that in a market economy a localised exogenous shock such as that generated by a major natural disaster will alter demand and supply schedules, and in the absence of price controls the prices of some goods will rise, while those of other goods will fall. We also hypothesized that any price changes are likely to be communicated out from the affected area, but that the scale of any such changes will diminish with distance from the affected area.

The econometric exercises sought to address three questions: firstly, how far the extent of any price impact was aligned with geographical distance from the devastated area; secondly, was the impact more pronounced in northeastern Japan, whose economy was more integrated with the capital area than was the case with the southwest; and thirdly, how rapidly were prices stabilised after the shock.

These three questions were explored through an analysis of the price changes for particular products across eleven Japanese cities, including two in the devastated area, Tokyo and Yokohama. The findings were most pronounced in the price changes of rice, the core foodgrain. In the case of rice, our analysis showed that not only was the impact of the earthquake on prices relatively persistent (though declining over time), but also the impact of the disaster on the price of rice increased the nearer a provincial city was to Tokyo. It also showed that the impact was more significant in north eastern cities than in the southwest. In the case of the price of wood, a core reconstruction material, there was an immediate strong impact from the disaster, but it did not persist for very long, and in the case of the other products in our dataset the results were not statistically significant.

How, therefore, are we to interpret our findings? First of all, a caveat is in order. As noted earlier, it has only been possible to undertake the quantitative analysis using wholesale price data as there is no available systematic retail price data; at best there exists some retail price data for some cities for some commodities for some time periods. We know that wholesale prices were more easily regulated, and that most wholesale transactions took place in officially sanctioned markets. The retail sector was very different; retail transactions were largely unregulated and carried out by a myriad of small scale operators. It may well be that undertaking the same exercise using retail price data for the goods analysed here would have told a very different story. So, disparities between wholesale and retail price trends may help to explain the more limited changes that we identified in the case of a number of our selected goods. Such a possibility may be indicated either by the limited retail price data that are available or by anecdotal qualitative evidence.

If we turn briefly to the scant retail price data that are available these do not provide a clear message. As might be expected, the reported retail price for rice in Tokyo was marginally higher that the wholesale price, but the ratio of wholesale to retail prices remained relatively constant throughout the period from January 1923 to December 1925. A stable relationship between wholesale and retail prices was also true of charcoal, although during the three months from December 1923 to February 1924 the retail price for charcoal increased significantly more than the wholesale price, before settling down again. However, a similar phenomenon can be seen in the winter months of 1923 and 1925, suggesting that this may at least in part have been due to cyclical demand factors. In the case of cotton yarn Tokyo retail prices were consistently at least double the wholesale price from January

1923 through to June 1925, although the gap was considerably greater than 100% from October 1923 through to early in 1925, as retail prices shot up to new highs before declining again during 1925. The Tokyo retail price of cotton thread fell by a third between December 1924 and June 1925, a decline that is more likely to be associated with the increasing productivity in the industry and external market trends.[26] Statistics on retail prices compiled by the Tokyo Chamber of Commerce show that the average retail prices in 1924 of 47 'daily necessaries' in Tokyo were in most cases above the 1923 average retail price. In the case of rice, however, much of this higher average was accounted for by monthly rises in the second half of 1924, suggesting the importance of seasonal factors. A higher 1924 average retail price for charcoal is largely the consequence of unusually high prices in the early months of 1924, something that matches the findings indicated earlier. Data from the same series for cotton yarn also show a significantly higher retail price in 1924 than in 1923, reflecting the trends indicated above.[27] Further identification and analysis of suitable retail price data is needed if the relationship between retail and wholesale prices at this time is to be better understood.

If we consider contemporary accounts, such as official publications and newspaper and journal reports, however, we find a much starker story of price changes, at least in the early months after the disaster. Complaints regarding attempts by retailers to charge as much as they could for goods in short supply were on every page. Sympathy for the victims was often outweighed by the realisation that there were profits to be obtained, and it was in response to this situation that the authorities rapidly moved to issuing an anti-profiteering ordinance. Profiteering, according to this ordinance, was identified as the charging of a price increase of 30% or more over the pre-disaster price, and individuals found guilty of profiteering were liable to imprisonment or heavy fines. It is hard to judge how far such draconian regulations limited retail price increases, but they certainly did not stop them completely. Over the two months following the earthquake over 400 individuals were arrested for breaching the regulations,[28] although we have no way of knowing whether or not this was just the tip of the iceberg, and many hundreds more managed to evade the eyes of the police. Without doubt, though, the anti-profiteering measures demonstrate clearly that the

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[26] Tōkyō Shōgyō Kaigisho, *Tōkyō Shōgyō Kaigisho Tōkei Nenpō – Taishō Jūsannen* [Annual Statistical Report of Tokyo Chamber of Commerce, 1925 edition] (Tokyo, March 1927).

[27] Tōkyō Shōgyō Kaigisho, *Tōkyō Shōgyō Kaigisho Tōkei Nenpō – Taishō Jūsannen*, pp.47-52.

[28] Keishichō, *Taishō Daishinkasai Shi* (Tokyo: Keishichō, July 1925), pp.605, 622. See also Hunter, '"Extreme Confusion and Disorder"?'.

authorities thought that there was a problem. The 30% price increase criterion also suggests that they expected some retail prices to rise by a considerable margin in the wake of the disaster, and felt that they had no choice but to tolerate increases up to a certain level. The basic belief that anti-profiteering measures were necessary for price stability went well beyond government. One analysis of the economic impact of the disaster that appeared early in 1924, for example, noted the importance of the regulations to prevent excess profits, highlighting the existence of outrageous behaviour in Tokyo, such as an individual selling a sheet of zinc plate for 2 *yen* 70 *sen*, which was more than double the normal price. Nor were profiteering cases limited to Tokyo. Similar instances were cited from the provincial cities of Osaka, Kōbe and Nagoya.[29] Chambers of commerce across the country reported increases in the prices of lumber and other construction goods of up to 50%, while some regions reported significant price falls for key products for which demand had fallen, including raw silk and hemp.[30]

This kind of more anecdotal evidence does not necessarily call into question our findings, but it does confirm that at least for a limited period price instability, particularly in relation to retail prices, was a real issue of concern for many contemporaries. Our positive findings in relation to the impact of the disaster on the prices of rice and timber offer further support for what we know from descriptive statistics and qualitative evidence. The finding that, at least in the case of rice, prices in northeastern Japan were more strongly affected than those in the west of Japan, is in line with the concerns voiced by local business interests in the months following the disaster.[31] The significant, albeit short term, increase in the price of some wood products also resonates strongly with contemporary accounts of acute price instability in the market for timber.[32] Nevertheless, the findings for a number of the selected goods did not yield statistically significant results, and the scale and impact of the price changes in Tokyo and Yokohama, and their diffusion to other parts of the country, were somewhat less than suggested by the alarmist tone of contemporary reports. Both macroeconomic and price data

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[29] Jiji Shinpōsha Keizaibu, *Daishinsai Keizai Shi* (Tokyo: Jiji Shinpōsha & Nihon Hyōronsha, January 1924), pp.19-24.

[30] Nōshōmushō Shōmukyoku, *Kantō Chihō Shinsai no Keizaikai ni oyoboseru Eikyō* (Tokyo: Nōshōmushō, August 1924), pp.100, 109-10, 186, 200. The Commerce Bureau of the Ministry of Agriculture and Commerce asked local chambers of commerce to report on the effects of the earthquake on business within their jurisdictions, and this volume is the collected reports from across the country.

[31] See Nōshōmushō Shōmukyoku, *Kantō Chihō Shinsai no Keizaikai ni oyoboseru Eikyō*.

[32] See eg. Nōshōmushō Sanrinkyoku, *Kantō Daishinsai to Mokuzai oyobi Shintan* (Tokyo: Sanrinkyoku, October 1924).

suggest that the changes in most indicators were relatively short lived, and that the disaster had ceased to have any significant impact on Japan's economy by the late 1920s.

By contributing a new perspective from below the macro-level, and by offering a preliminary evidential study of prices for a range of different goods, this paper has contributed to our understanding of what was happening in markets in the aftermath of the Great Kantō Earthquake. The findings suggest that even at a relatively early stage prices were already stabilising, and that the diffusion of price instability outwards from the affected Kantō region was on a lesser scale than might have been expected. Much further research is needed, however, if we are to understand better the implications of these trends in prices. We need to analyse the factors that limited the spread and duration of price changes consequent on the earthquake in the face of a high degree of market integration. Following on from that a further question needs to be addressed, namely how far these factors may have been significant in determining the relatively confined impact of the disaster on Japan's economy over the longer term.

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Table 1: Characteristics of sample cities (1921-1925)

		Geographical location				
Name of cities (in order of distance)	Average population (hundred)	Distance from Tokyo (100 kilo meters)	Closeness (reciprocal)	Longitude (degrees)	Latitude (degrees)	Area classification
Niigata	1,051	2.55	0.39	139.04	37.92	North-east
Nagoya	6,923	2.65	0.38	136.91	35.18	South-west
Kanazawa	1,470	2.95	0.34	136.66	36.56	North-east
Sendai	1,337	3.02	0.33	140.87	38.27	North-east
Kyoto	6,692	3.70	0.27	135.77	35.01	South-west
Osaka	16,134	4.03	0.25	135.50	34.69	South-west
Kobe	6,865	4.30	0.23	135.20	34.69	South-west
Kochi	570	6.18	0.16	133.53	33.56	South-west
Hiroshima	1,773	6.81	0.15	132.46	34.39	South-west
Otaru	1,206	8.39	0.12	140.98	43.19	North-east
Fukuoka	1,306	8.88	0.11	130.40	33.59	South-west

Notes: The minimum distances between each city and Tokyo city are calculated using spheroid (GRS80) of the Geospatial Information Authority of Japan (GIAJ) based on the information on longitude and latitude of each city (Appendix B describes the details of the information of this Application Programming Interface of the GIAJ). Closeness is the reciprocal number of the distance. For instance, in the case of Niigata city, Closeness is calculated as 1/2.55. Sources: The data on latitude and longitude are from the database of the GIAJ (see Appendix B). The data on the number of population between 1921 and 1925 are from Statistics Bureau of the Cabinet (1924a–1926a).

Table 2: Summary statistics

	Entire period (May 1921–Dec 1925)			Before the earthquake (May 1921–Aug 1923)			After the earthquake (Sep 1923–Dec 1925)		
	Observation	Mean	Std.Dev.	Observation	Mean	Std.Dev.	Observation	Mean	Std.Dev.
Panel (A): Whole sale prices									
Rice, yen per 180 liters	616	36.11	5.10	308	33.38	4.72	308	38.84	3.87
Wheat, yen per 180 liters	608	19.32	3.40	307	17.98	2.17	301	20.70	3.85
Cotton yarn, yen per 60 kilograms	616	97.59	15.56	308	85.92	8.82	308	109.25	11.57
Pine board, yen per one piece	613	2.33	0.68	307	2.49	0.59	252	4.38	1.88
Calcium superphosphate, yen per 37.5 kilograms	609	1.73	0.29	302	1.71	0.31	307	1.76	0.27
Coal, yen per ton	616	20.50	4.33	308	21.53	4.34	308	19.47	4.08
Charcoal, yen per ton	616	90.27	17.33	308	92.70	17.39	308	87.84	16.95
Panel (B): Key variables									
Distance from Tokyo, 100 km	616	4.86	2.21	-	-	-	-	-	-
Reciprocal of distance	616	0.25	0.10	-	-	-	-	-	-
Post earthquake dummy	616	0.50	-	-	-	-	-	-	-
Panel (C): Control variables									
Population (annual), thousand	616	398.87	441.81	308	372.34	385.8	308	425.22	490.72
Tonnage (annual), thousand	616	8843.54	9633.86	308	8551.34	9597.05	308	9135.74	9677.31
Factories (annual), per 100 people	616	0.73	0.32	308	0.77	0.33	308	0.70	0.30
Monthly average temperature, Celsius	616	13.98	8.66	308	14.66	8.80	308	13.30	8.48
Monthly average precipitation, milimeters	616	141.19	114.56	308	153.37	125.91	308	129.02	100.69

Notes: The price of rice is the average value of the brown rice (1st, 2nd and 3rd grades) and white rice. The minimum distances between each city and Tokyo city are calculated using spheroid (GRS80) of the GIAJ based on the information on longitude and latitude of each city. Closeness is the reciprocal number of the distance. Post earthquake dummy is an indicator variable that equal one for the period after September 1923. Tonnage is the total volume of tonnage both of steamships and of sailing ships in the ports in each prefecture. Factories is the number of factories with more than five workman in each prefecture per 100 city population. Sources: Online database of the GIAJ and JMA; Statistics Bureau of the Cabinet (1924a–1926a); Statistics Bureau of the Cabinet (1924b–1927b); Statistical Division of the Minister's Secretariat of Commerce and Industry (1926); Statistical Division of Secretariat of Agriculture and Commerce (1923; 1925); Statistical Division of Secretariat of Commerce and Industry (1926; 1927). Appendix B describes the finer details of the data sources.

Table 3: Baseline estimates for May 1921 to December 1925, by product

	Dependent variable						
	(1)Rice	(2)Wheat	(3)Cotton yarn	(4)Pine board	(5)Calcium superphosphate	(6)Coal	(7)Charcoal
Closeness×*Post*	1.829**	0.073	2.735	0.082	-0.064	-0.880	-1.446
	(0.638)	(0.658)	(3.382)	(0.250)	(0.105)	(0.748)	(4.541)
Lagged dependent variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic p-value on joint significance of covariates	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
City- and month- fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.9741	0.9514	0.9819	0.9116	0.9452	0.9802	0.9400
Number of observations	605	594	605	600	594	605	605

Notes: Observations are at the city-month level. The unit of all wholesale prices are yen. *Closeness* is the reciprocal of the distance from Tokyo (100 km) described in Table 1. *Post* is an indicator variable that equals one for periods after September 1923. Control variables include the natural logarithm of the total population, the natural logarithm of annual tonnage, the number of factories per 100 people, monthly average of temperature, and monthly average of precipitation. Details of the data sources of each variable used in the regression are provided in Section Appendix B. ** represents statistical significance at the 5% level. Cluster-robust standard errors are in parentheses.

Table 4: Baseline estimates for alternative cutoff period

		Dependent variable													
		Rice		Wheat		Cotton yarn		Pine board		Calcium superphosphate		Coal		Charcoal	
Cutoff period	Post-earthquake period	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.	Coeff.	Std.Err.
May 1921–Nov 1923	3-month: Sep 1923–Nov 1923	−0.065	[1.589]	0.967	[1.205]	0.940	[1.963]	0.824*	[0.439]	0.283	[0.162]	0.071	[1.261]	−6.014	[15.131]
May 1921–Feb 1924	6-month: Sep 1923–Feb 1924	1.349*	[0.644]	−0.324	[1.096]	3.019	[3.424]	0.359	[0.217]	0.059	[0.157]	0.559	[0.742]	−2.363	[9.171]
May 1921–May 1924	9-month: Sep 1923–May 1924	1.601***	[0.453]	−1.123	[0.979]	0.481	[3.554]	0.274	[0.233]	0.011	[0.160]	0.414	[0.813]	−3.177	[6.119]
May 1921–Aug 1924	12-month: Sep 1923–Aug 1924	1.530**	[0.676]	−0.993	[0.780]	2.484	[3.298]	0.193	[0.201]	−0.003	[0.144]	−0.381	[0.841]	−2.004	[6.481]
May 1921–Nov 1924	15-month: Sep 1923–Nov 1924	1.528**	[0.655]	−0.374	[0.669]	3.644	[3.206]	0.204	[0.185]	0.005	[0.119]	−0.643	[0.853]	−0.039	[6.524]
May 1921–Feb 1925	18-month: Sep 1923–Feb 1925	1.484**	[0.592]	0.031	[0.516]	1.606	[2.894]	0.159	[0.238]	−0.016	[0.113]	−0.656	[0.788]	0.235	[5.277]
May 1921–May 1925	21-month: Sep 1923–May 1925	1.528**	[0.626]	−0.767	[0.540]	2.859	[3.256]	0.132	[0.256]	−0.043	[0.115]	−0.743	[0.774]	0.283	[4.707]
May 1921–Aug 1925	24-month: Sep 1923–Aug 1925	1.623**	[0.619]	−0.272	[0.731]	2.643	[3.107]	0.086	[0.254]	−0.054	[0.113]	−0.809	[0.797]	0.132	[4.504]
May 1921–Dec 1925	28-month: Sep 1923–Dec 1925	1.829**	[0.638]	0.073	[0.658]	2.735	[3.382]	0.082	[0.250]	−0.064	[0.105]	−0.880	[0.748]	−1.446	[4.541]
Lagged dependent variable		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City- and month- fixed effects		Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Observations are at the city-month level. The unit of all wholesale prices are yen. The number of observations for the periods from May 1921 to November 1923, to February 1924, to May 1924, to August 1924, to November 1924, to February 1925, to May 1925, to August 1925, and December 1925 are 330, 363, 396, 429, 462, 495, 528, 561, and 605, respectively. The estimates for the period from May 1921 to December 1925 are the same one that shown in Table 3. Control variables include the natural logarithm of the total population, the natural logarithm of annual tonnage, the number of factories per 100 people, monthly average of temperature, and monthly average of precipitation. Details of the data sources of each variable used in the regression are provided in Appendix B. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Cluster-robust standard errors are in parentheses.

Table 5: Baseline estimates for alternative cutoff period: falsification tests

	Placebo treatment periods					
	March 1922–August 1923		September 1922–August 1923		March 1923–August 1923	
	(1)Rice	(2)Pine board	(3)Rice	(4)Pine board	(5)Rice	(6)Pine board
Closeness×*Post*	-1.019	-0.076	1.097	-0.228	2.878	-0.026
	(1.498)	(0.287)	(0.847)	(0.187)	(1.751)	(0.270)
Lagged dependent variable	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic p-value on joint significance of covariates	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
City- and month- fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.9605	0.9369	0.9606	0.9372	0.9610	0.9369
Number of observations	297	295	297	295	297	295

Notes: Observations are at the city-month level. The unit of all wholesale prices are yen. *Closeness* is the reciprocal of the distance from Tokyo (100 km) described in Table 1. *Post* in the columns (1)–(2), (3)–(4), and (5)–(6) are an indicator variable that equals one for periods from March 1921–August 1923, from September 1922–August 1923, and March 1923–August 1923, respectively. Control variables include the natural logarithm of the total population, the natural logarithm of annual tonnage, the number of factories per 100 people, monthly average of temperature, and monthly average of precipitation. Details of the data sources of each variable used in the regression are provided in Appendix B. Cluster-robust standard errors are in parentheses.

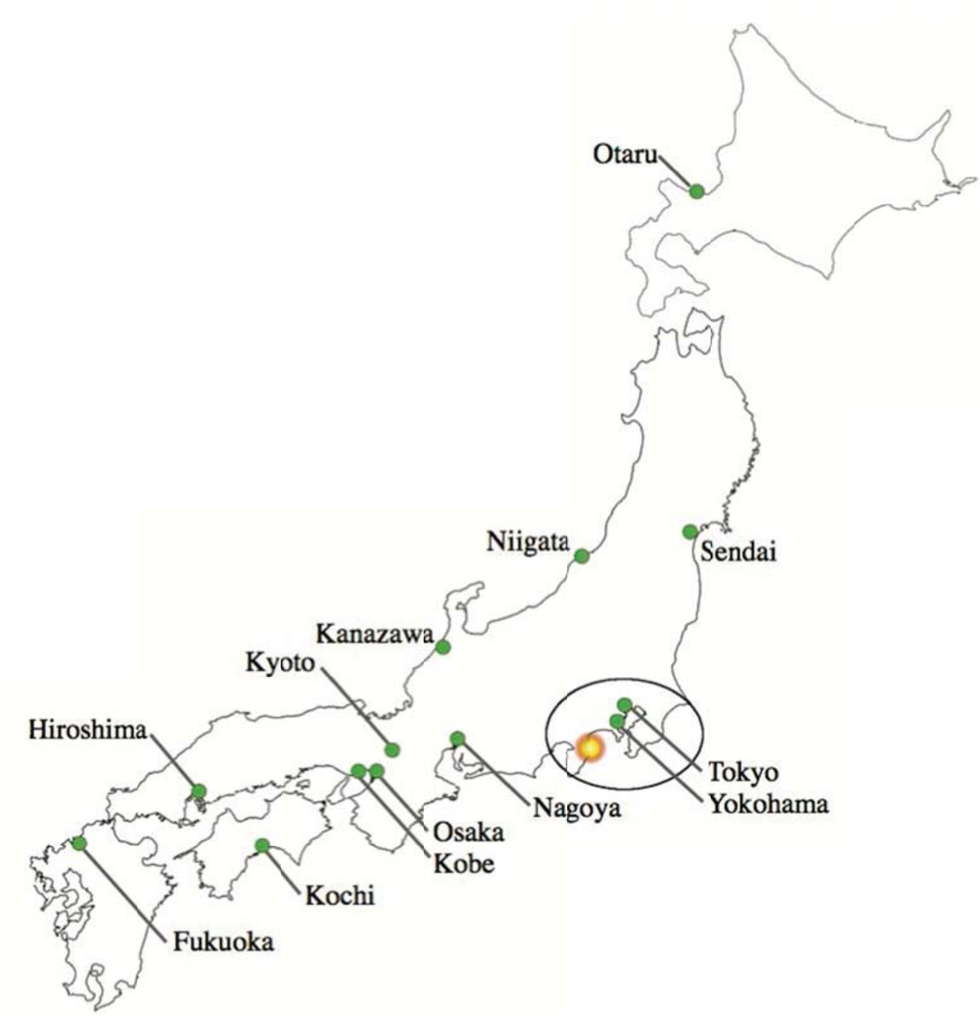
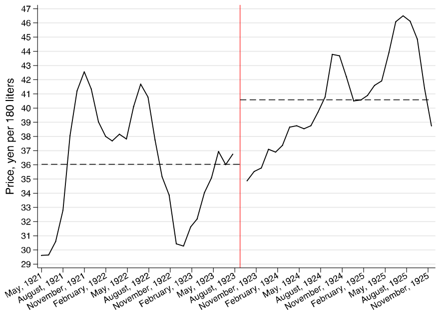
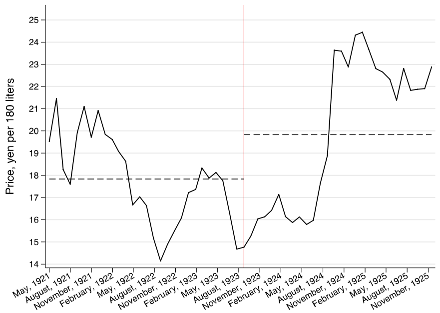


Figure 1: Spatial distribution of sample cities

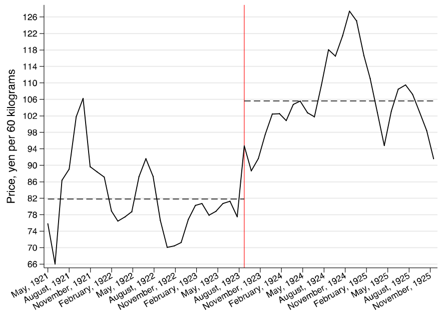
Notes: Each green circle represents the location of a sample city based on latitude and longitude information. The yellow-red circle shows the centre of the earthquake. The black circle shows the affected zone. Several islands including Okinawa prefecture are not shown in the figure. Sources: Data on latitude and longitude are from the database of the Geospatial Information Authority of Japan, as described in Appendix B. The information on the location of the center of the earthquake and the affected zone are from Department of Publications, Japan Union News Agency (1923, section 7) and Central Meteorological Observatory (1924, illustration no.1 and no.2).



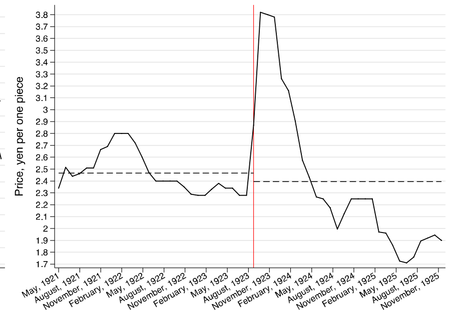
(a) Rice, yen per 180 liters



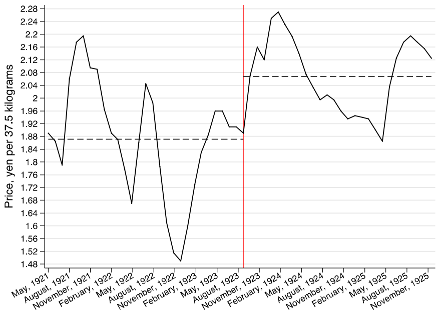
(b) Wheat, yen per 180 liters



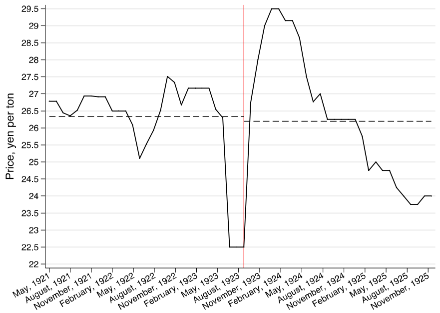
(c) Cotton yarn, yen per 60 kg



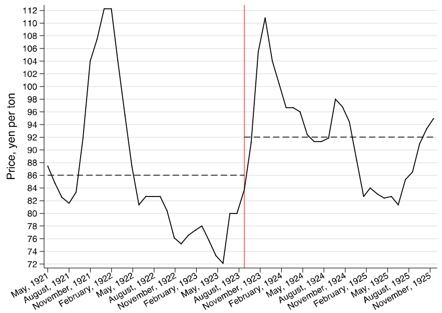
(d) Pine board, yen per one piece



(e) Calcium superphosphate, yen per 37.5 kg



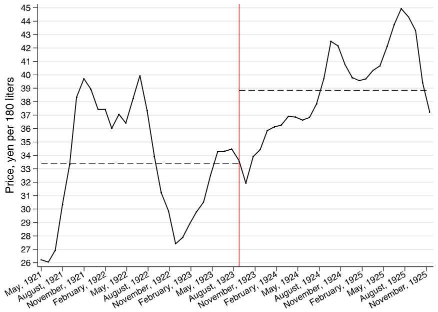
(f) Coal, yen per ton



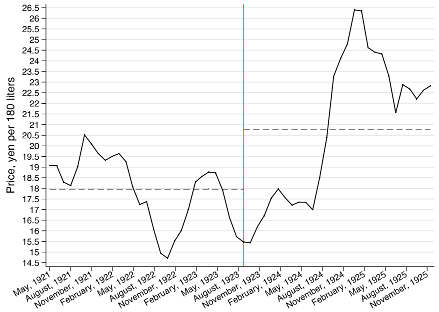
(g) Charcoal, yen per ton

Figure 2: Time series plots of average prices of products in Tokyo and Yokohama

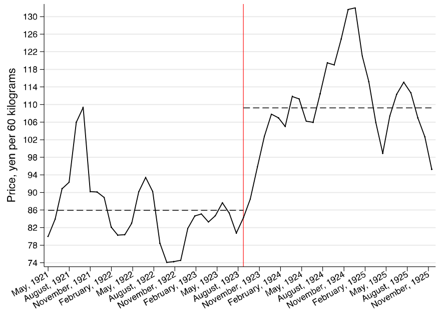
Notes: The average prices of products in Tokyo and Yokohama are described in the figures. For Tokyo city, the price of rice in September 1923 is not available. For Yokohama city, the price of rice from July 1923 to September 1923, the price of wheat, cotton yarn, pine board, and calcium superphosphate from July 1923 to February 1923, the price of coal from July 1923 to September 1923, and the price of charcoal from 1923 to October 1923 are not available. The red line shows September 1923. Dotted lines show the average prices of each product before and after the earthquake. Rice includes brown rice (1st, 2nd and 3rd grades) and white rice. Fuel includes coal and charcoal. Source: Statistical Division of the Minister's Secretariat of Commerce and Industry (1926).



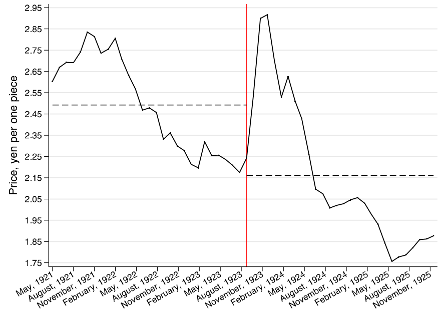
(a) Rice, yen per 180 liters



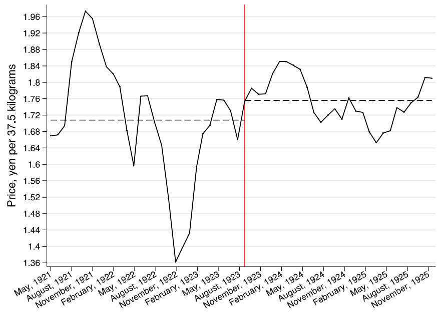
(b) Wheat, yen per 180 liters



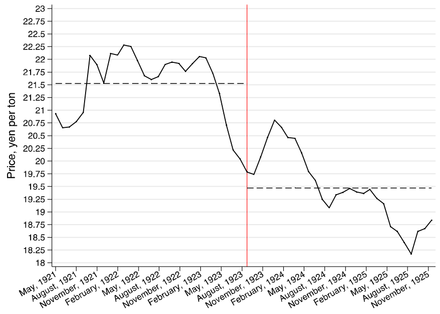
(c) Cotton yarn, yen per 60 kg



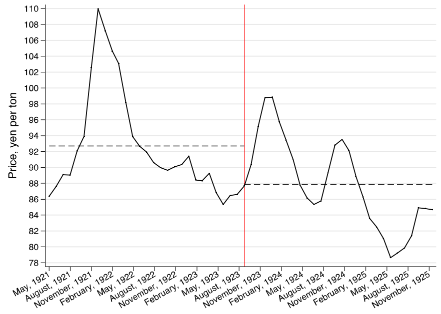
(d) Pine board, yen per one piece



(e) Calcium superphosphate, yen per 37.5 kg



(f) Coal, yen per ton



(g) Charcoal, yen per ton

Figure 3: Time series plots of average prices of products in provincial cities

Notes: The red line shows September 1923. Dotted lines show the average prices of each product before and after the earthquake. Rice includes brown rice (1st, 2nd and 3rd grades) and white rice. Fuel includes coal and charcoal. Source: Statistical Division of the Minister's Secretariat of Commerce and Industry (1926).

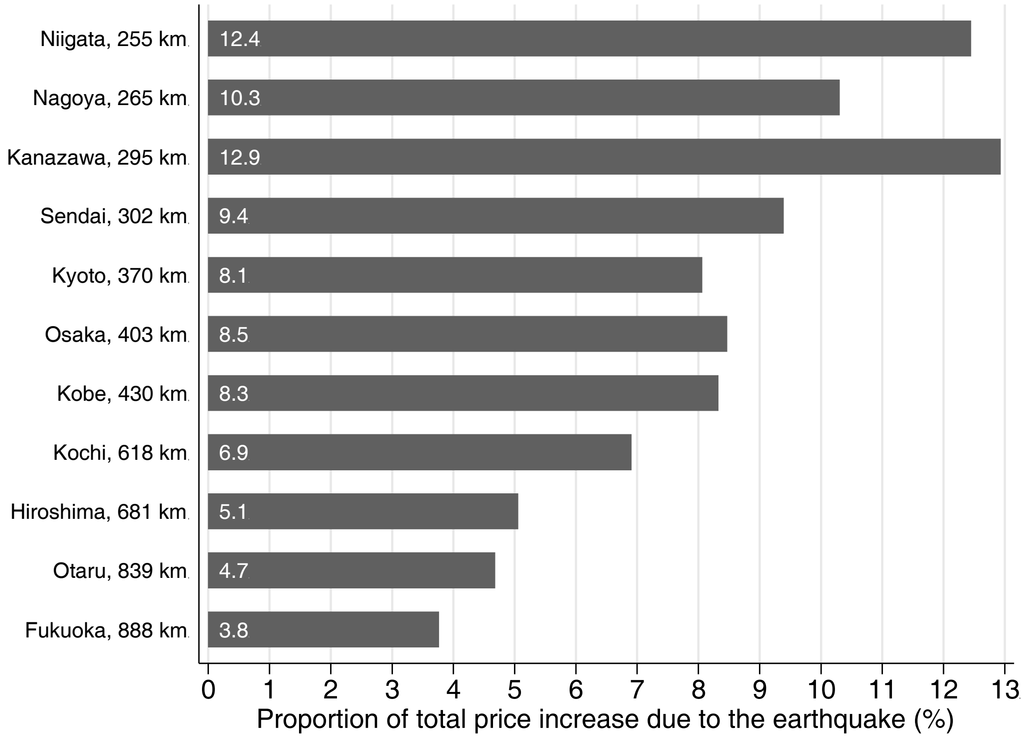


Figure 4: Impact of the earthquake on wholesale price of rice in provincial cities by distance from Tokyo

Notes: The length of the bar shows the estimated increase in price due to the earthquake as a proportion of the total increase in price from the period from May 1921 to August 1923 to the period from September 1923 to December 1925, calculated using our baseline estimates reported in Table 3. Both the increase in price caused by the earthquake and the total increase in price between the period up to August 1923 and the period after September 1923 in each provincial city are reported in Table A.4.

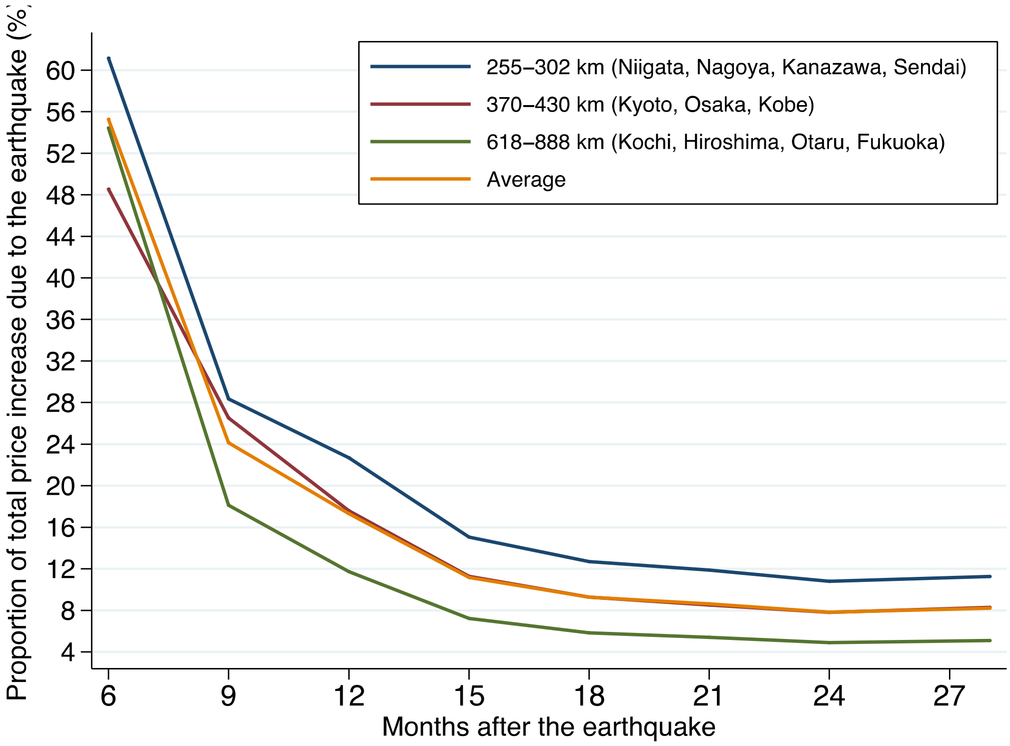


Figure 5: Proportion of increase in rice price due to the earthquake, by distance

Notes: The solid lines show the estimated increase in price due to the earthquake as a proportion of the total increase in price from the period from May 1921 to August 1923 to the period after September 1923 in each area (see Figure A.2 in Appendix A for the magnitude in each provincial city). The post-earthquake periods are set at 6, 9, 12, 15, 18, 21, 24, and 28 months, respectively. For each period, the estimated coefficients used to calculate the increase in price due to the earthquake, are 1.349, 1.601, 1.530, 1.528, 1.484, 1.528, and 1.623, respectively (see column 3 of Table 4).

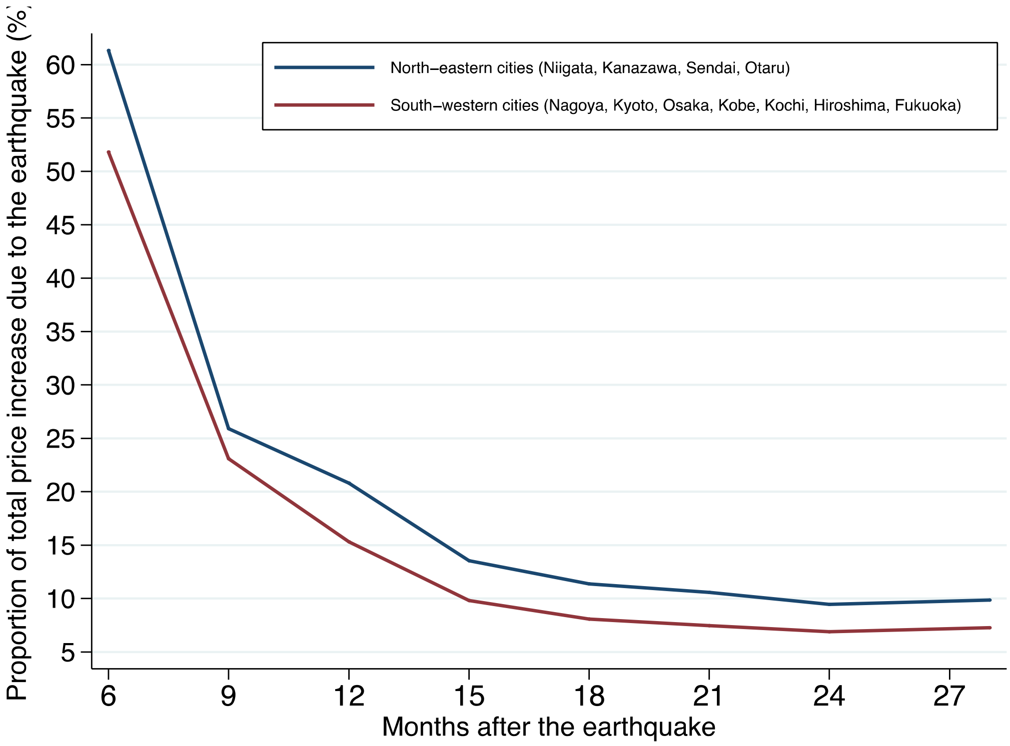
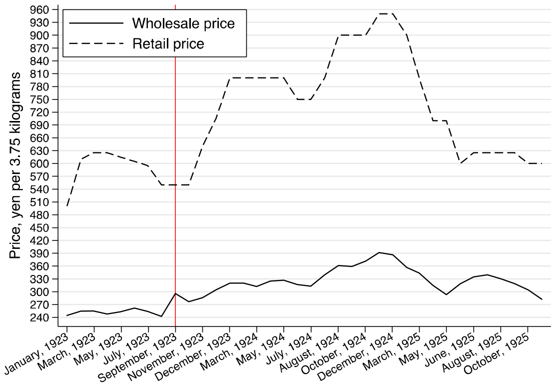
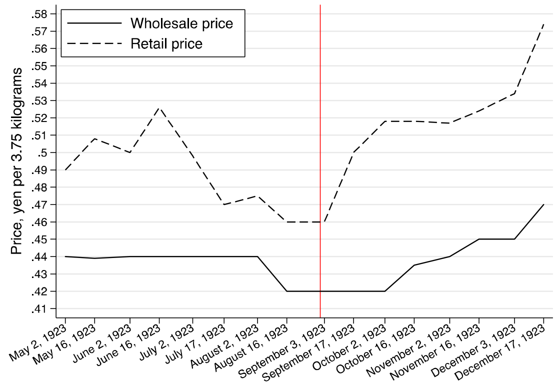


Figure 6: Proportion of increase in rice price due to the earthquake, by region

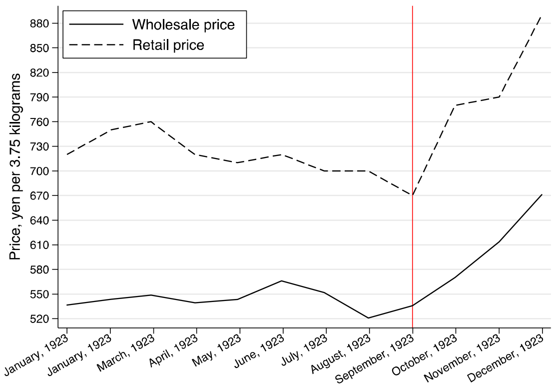
Note: The solid lines show the increase in price due to the earthquake as a proportion of the total increase in price from the period from May 1921 to August 1923 to the period after September 1923 in north–eastern and in south–western cities (see Figure A.2 in Appendix A for the magnitude in each provincial city). The north–eastern cities include Niigata, Kanazawa, Sendai, and Otaru. The south–western cities include Nagoya, Kyoto, Osaka, Kobe, Kochi, Hiroshima, and Fukuoka. The geospatial characteristics of those cities are shown in Table 1. The post–earthquake periods are set at 6, 9, 12, 15, 18, 21, 24, and 28 months, respectively. For each period, the estimated coefficients used to calculate the increase in price due to the earthquake, are 1.349, 1.601, 1.530, 1.528, 1.484, 1.528, and 1.623, respectively (see column 3 of Table 4).



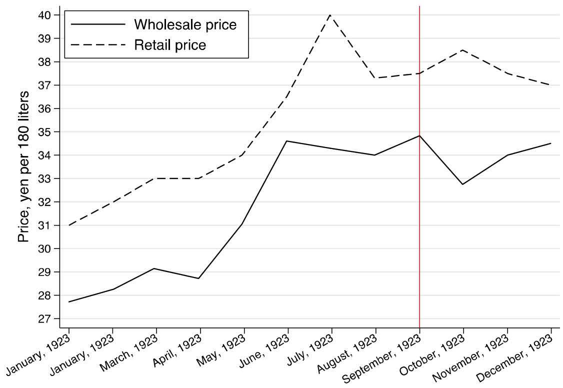
(a) Cotton yarn in Tokyo, yen per 3.75 kg



(b) Charcoal in Osaka, yen per 3.75 kg



(c) Cotton yarn in Fukuoka, yen per 3.75 kg



(d) White rice in Fukuoka, yen per 3.75 kg

Figure 7: Observed disparities between wholesale and retail prices in Tokyo, Osaka, and Fukuoka city

Notes: The end point of the period in each graph is due to the availability of data. Tokyo city is included in the devastated area. The geospatial distances from Tokyo to Osaka and Fukuoka city are 403 km and 888 km, respectively. The red line shows September 1923. The solid line shows the retail price. The dashed line shows the wholesale price. Sources: Tokyo Chamber of Commerce (1927); Osaka Chamber of Commerce (1923); Hakata Chamber of Commerce (1923).

Appendix A Additional Figures and Tables

Table A.1: Results of unit root tests for wholesale prices

	Wholesale prices						
Test statistics	Rice	Wheat	Cotton yarn	Pine board	Calcium superphosphate	Coal	Charcoal
P-statistic p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Z-statistic p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
L^*-statistic p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
P_m-statistic p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Number of cities	11	11	11	11	11	11	11
Average number of months	56	55.3	56	55.7	55.4	56	56

Notes:
The results of Fisher-type panel unit-root tests based on augmented Dickey-Fuller (ADF) tests are reported in this table. Fisher-type unit-root tests are used because of the lack of balance and finite number of panels of our sample. See Choi 2001 for the details of the tests. The null hypothesis is that all the panels contain unit roots, whereas the alternative hypothesis is that at least one panel is stationary. In all specifications, the process under null hypothesis is assumed to be a random walk with drift. The demeaned data are used to deal with the effect of cross-sectional dependence. The number of lagged differences in the ADF regression equation is set as one. The results presented herein are not affected by the number of lagged differences.

Table A.2: Baseline estimates for May 1921 to December 1925, by product, Osaka and Kobe city in the same cluster

	Dependent variable						
	(1)Rice	(2)Wheat	(3)Cotton yarn	(4)Pine board	(5)Calcium superphosphate	(6)Coal	(7)Charcoal
Closeness×*Post*	1.829**	0.073	2.735	0.082	-0.064	-0.880	-1.446
	(0.643)	(0.661)	(3.397)	(0.251)	(0.105)	(0.752)	(4.571)
Lagged dependent variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic p-value on joint significance of covariates	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000
City- and month- fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.9741	0.9514	0.9819	0.9116	0.9452	0.9802	0.9400
Number of observations	605	594	605	600	594	605	605

Notes: Observations are at the city-year level. The unit of all wholesale prices are yen. *Closeness* is the reciprocal of the distance from Tokyo (100 km) described in Table 1. *Post* is an indicator variable that equals one for periods after September 1923. Control variables include the natural logarithm of the total population, the natural logarithm of annual tonnage, the number of factories per 100 people, monthly average of temperature, and monthly average of precipitation. Details of the data sources of each variable used in the regression are provided in Section Appendix B. ** represents statistical significance at the 5% level. Cluster-robust standard errors are in parentheses. Osaka and Kobe city are in the same cluster.

Table A.3: Bootstrap technique for issue of small number of clusters

	Dependent variable						
	(1)Rice	(2)Wheat	(3)Cotton yarn	(4)Pine board	(5)Calcium superphosphate	(6)Coal	(7)Charcoal
Closeness×*Post*	1.829**	0.073	2.735	0.082	-0.064	-0.880	-1.446
Wild bootstrap *p*-value	0.032	0.886	0.490	0.754	0.594	0.292	0.800
Lagged dependent variable	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
City- and month- fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.9741	0.9514	0.9819	0.9116	0.9452	0.9802	0.9400
Number of observations	605	594	605	600	594	605	605
Number of clusters	11	11	11	11	11	11	11

Notes: Observations are at the city-year level. The unit of all wholesale prices are yen. *Closeness* is the reciprocal of the distance from Tokyo (100 km) described in Table 1. *Post* is an indicator variable that equals one for periods after September 1923. Control variables include the natural logarithm of the total population, the natural logarithm of annual tonnage, the number of factories per 100 people, monthly average of temperature, and monthly average of precipitation. Details of the data sources of each variable used in the regression are provided in Section Appendix B. ** represents statistical significance at the 5% level. Wild bootstrap *p*-value with 1,000 replications are reported.

Table A.4: Magnitude of impact of the Great Kanto Earthquake on wholesale price of rice in provincial cities

Name of cities	[A]Increase in price due to the earthquake	Average price of rice, yen			Magnitude of the earthquake
(in order of distance)	(1.829×Closeness, yen)	Before August 1923	After September 1923	[B]Increase in price	([A]/[B], percentage points)
Niigata	0.71	31.98	37.71	5.73	12.4
Nagoya	0.70	33.18	39.93	6.75	10.3
Kanazawa	0.62	33.54	38.35	4.81	12.9
Sendai	0.60	31.70	38.13	6.43	9.4
Kyoto	0.49	35.97	42.10	6.13	8.1
Osaka	0.46	35.28	40.68	5.40	8.5
Kobe	0.42	35.06	40.12	5.05	8.3
Kochi	0.29	31.54	35.77	4.24	6.9
Hiroshima	0.27	33.32	38.74	5.43	5.1
Otaru	0.22	33.39	38.08	4.69	4.7
Fukuoka	0.20	32.27	37.61	5.35	3.8
Average	0.46	33.38	38.84	5.46	8.4

Notes: The increase in price due to the earthquake is calculated as the estimated coefficient of *Closeness*×*Post* in baseline specification (*i.e.*, equation 1 in Section 4) multiplied by *Closeness* in each provincial city. *Closeness* is the reciprocal number of the distance listed in Table 1. The magnitude of the effect of the earthquake on the wholesale price of rice is the increase in price due to the earthquake as a proportion of the total increase in price from the period from May 1921 to August 1923 to the period after September 1923 to December 1925.

Table A.5: Magnitude of impact of the Great Kanto Earthquake on wholesale price of pine board in provincial cities

Name of cities	[A]Increase in price due to the earthquake	Average price of pine board, yen			Magnitude of the earthquake
(in order of distance)	(0.824×Closeness, yen)	Before August 1923	After September 1923	[B]Increase in price	([A]/[B], percentage points)
Niigata	0.32	2.18	2.27	0.09	350.6
Nagoya	0.31	2.35	2.81	0.46	68.2
Sendai	0.27	2.29	2.73	0.44	62.1
Osaka	0.21	3.05	3.76	0.71	29.2
Hiroshima	0.12	2.33	2.43	0.10	128.7
Fukuoka	0.09	1.65	1.75	0.10	92.6
Average	0.25	0.21	2.34	2.62	73.6

Notes: Kanazawa, Kyoto, Kobe, Kochi, and Otaru city are excluded because those cities experienced a decline in wholesale price of pine board. The increase in price due to the earthquake is calculated as the estimated coefficient of *Closeness*×*Post* in baseline specification (*i.e.*, equation 1 in Section 4) multiplied by *Closeness* in each provincial city. *Closeness* is the reciprocal number of the distance listed in Table 1. The magnitude of the impact of the earthquake on wholesale price of pine boards is the increase in price due to the earthquake as a proportion of the total increase in price from the period from May 1921 to August 1923 to the period after September 1923 to November 1923.

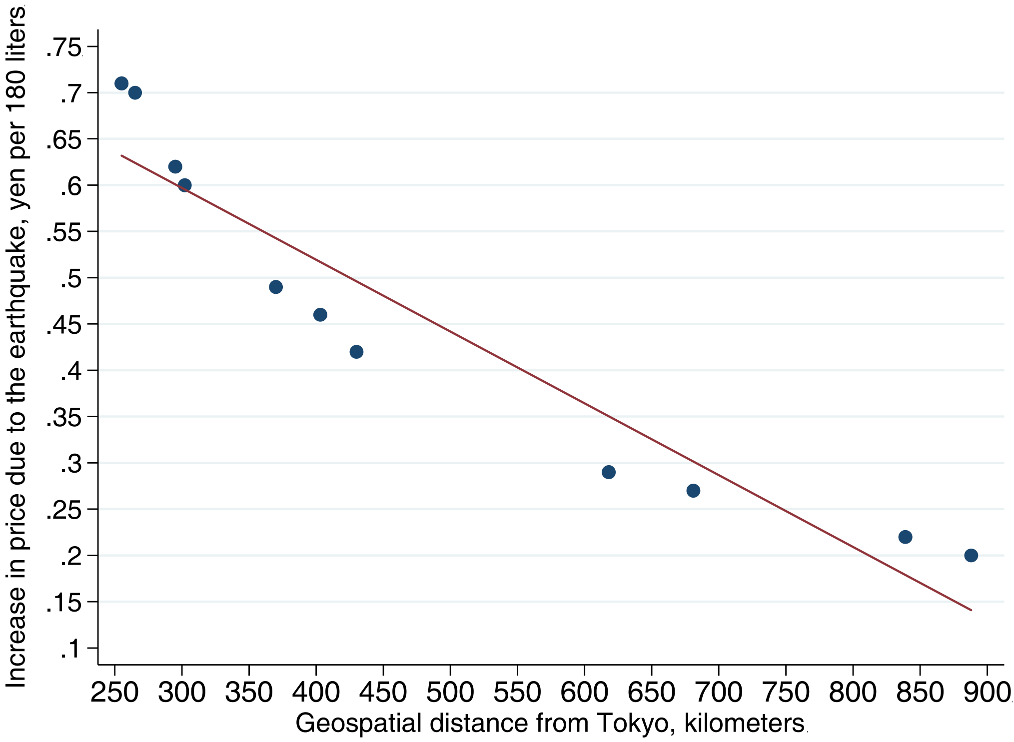


Figure A.1: Correlation between the increase in rice price due to the earthquake and geospatial distance from Tokyo

Notes: The estimates of the increase in the price of rice due to the earthquake are calculated by using the baseline estimate for May 1921 to December 1925 reported in Table 3. The increases in the price of rice due to the earthquake in each provincial city are from the second column in Table A.4. The geospatial distances from Tokyo are from the third column in Table 1. The regression line illustrated as a solid line in the graph is $\widehat{Price}_i = 0.8297 - 0.0008 Distance_i, \quad \text{SE} = 0.00008, \quad R^2 = 0.9052$. The number of cities is 11.

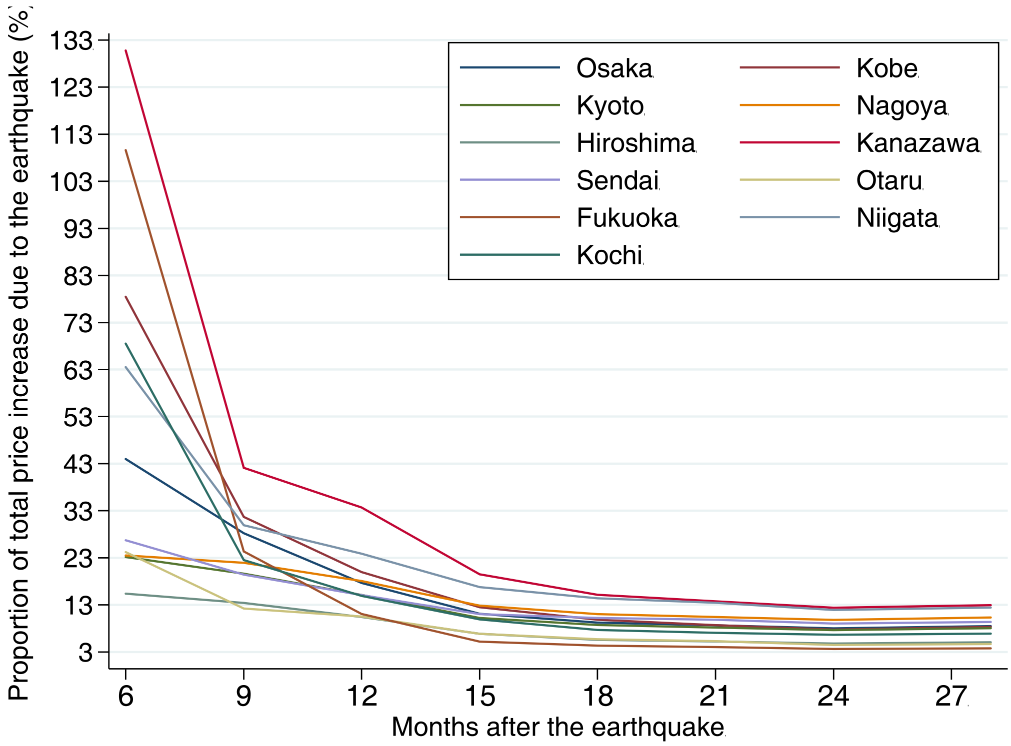


Figure A.2: Increase in rice price due to the earthquake as a proportion of the total increase in price

Notes: The solid lines show the increase in price due to the earthquake as a proportion of the total increase in price from the period from May 1921 to August 1923 to the period after September 1923 in each provincial city. The post-earthquake periods are set at 6, 9, 12, 15, 18, 21, 24, and 28 months, respectively. For each period, the estimated coefficients used to calculate the increase in price due to the earthquake, are 1.349, 1.601, 1.530, 1.528, 1.484, 1.528, and 1.623, respectively (see column 3 of Table 4).

Appendix B Data appendix

A. Wholesale and retail prices

The data on wholesale prices are from the *Oroshiuri Bukka Tōkeihyō* (Tables of Statistics of Wholesale Prices) published by the Statistical Section of the Ministry of Commerce and Industry in 1926. The digital archive is available in the National Diet Library Digital Collections (http://dl.ndl.go.jp/info:ndljp/pid/1710197). The cities reported in this document are Tokyo, Yokohama, Niigata, Nagoya, Kanazawa, Sendai, Kyoto, Osaka, Kobe, Kochi, Hiroshima, Otaru, and Hakata. This document recorded the monthly wholesale prices for several goods in these cities in order to compile price data for the convenience of general users (see Introduction to this statistical report). The data on retail prices are from several documents that were issued by the local Chambers of Commerce in each city. The information on retail prices in Tokyo city are from the *Tōkyō Shōgyō Kaigisho Tōkei Nenpō* (Annual Statistical Report of Tokyo Chamber of Commerce) for 1925 published by the Tokyo Chamber of Commerce in 1927. The information on retail prices in Osaka city is from the *Tōkei Nenpō* (Annual Statistical Report) for 1923 published by Osaka Chamber of Commerce in 1923. The information on retail prices in Hakata (part of Fukuoka city) are from the *Hakata Shōgyō Kaigisho Tōkei Nenpō* (Annual Statistical Report of Hakata Chamber of Commerce) for 1924 published by Hakata Chamber of Commerce in 1924.

B. Geospatial distances between Tokyo and provincial cities

We calculated the minimum distances between each city and Tokyo city using the spheroid (GRS80) of the Geospatial Information Authority of Japan (GIAJ) based on the information on the longitude and latitude of each city. The Application Programming Interface is publicly available on
http://vldb.gsi.go.jp/sokuchi/surveycalc/agreement.html (in Japanese). The data on latitude and longitude are obtained from the database of the GIAJ; these data are publicly available at http://www.gsi.go.jp/KOKUJYOHO/kencho/kenchobl.html.

C. Covariates

The annual data on population numbers are from *Nihon Teikoku Jinkō Dōtai Tōkei* (Vital Statistics of the Empire of Japan; VSEJ) (1921–1925 editions) published by the Statistics Bureau of the Cabinet between 1924 and 1926. The data on the number of factories are taken from *Kōjō Tōkeihyō* (Table of Statistics of Factories; TSF) (1921–1925 editions) published by the Statistical Section of the Ministry of Agriculture and Commerce (1923, 1924 and 1925) and the Statistical Section of the Ministry of Commerce and Industry (1926 and 1927). The annual data on total tonnage are from *Nihon Teikoku Tōkei Nenkan* (Statistical Yearbook of the Empire of Japan; SYEJ) (volumes 42 to 46) published by the Statistics Bureau of the Cabinet between 1924 and 1927. For meteorological variables, both monthly average temperature and monthly average precipitation are from the database of the Japan Meteorological Agency (JMA), at http://www.data.jma.go.jp/gmd/risk/obsdl/index.php. Since meteorological observation stations are located in each large city, we replicate missing data on the observations in 2 of the 12 cities by using the nearest meteorological observation station. To be specific, Sendai city in Miyagi prefecture is represented by the data for Shiogama city in the same prefecture, while Otaru city in Hokkaido prefecture is represented by the data for Sapporo city in the same prefecture.