

Stationarity of Price, Income and Wage During the Great Japanese Empire

Makoto KUROSAKA¹⁾

Abstract

This study investigates the stationarity of price, income and wage during the Great Japanese Empire. This is after Nelson and Plosser (1982) who found that long historical time series for the United States are non-stationary stochastic processes with no tendency to return to a trend line. The analysis suggests that, by contrast, during the Great Japanese Empire, consumer-and aggregate expenditure prices, nominal-and real GNP, and monetary wages followed a difference stationary process. Findings also indicates that real wages followed a trend stationary process.

Keywords: trend stationary, difference stationary, economic fluctuation, real wage, the Great Japanese Empire

JEL classification: E31, E32

1. Introduction

This study investigates the stationarity of prices, income, and wages during the Great Japanese Empire, after Nelson and Plosser (1982) who found that long historical time series for the United States are non-stationary stochastic processes with no tendency to return to a trend line. If their results also hold for the macroeconomic time series of the Great Japanese Empire, it suggests that the macroeconomy during that period had no tendency to return to a trend line. Nelson and Plosser (1982) also argued that real (non-monetary) disturbances were more important sources of output fluctuations than monetary disturbances. The question arises if these findings are also true for the macroeconomic time series of the Great Japanese Empire.

Regarding the macroeconomy of the Great Japanese Empire, Nakamura (1985) noted that Japan experienced economic growth with moderate inflation after the Meiji era and also observed that moderate inflation was desirable for firms, as it facilitated investment. He stated that since the adoption of the gold standard system in 1890, Japan's economy has become closely connected to the world economy. The economic crises of 1910 and 1914 were caused by a decline in exports due to the global economic crisis, while Sato (1981) noted that the macroeconomy from 1915 to 1940 was characterized by price flexibility. Yoshikawa and Shioji (1990) maintained that nominal prices in the prewar era were more flexible than in the post war period. Shinohara (1961) maintained that real wages during the Great Japanese Empire

1) Corresponding author: E-mail: makoto@osaka-ue.ac.jp

were low given the inflow of rice from the Korean Peninsula. Shinohara (1961) also insisted that low real wages led to high profits and stimulated investments, thus contributing to industrialization. His argument aligned with Lewis's (1954) argument, that real wages in the urban sector remain at subsistence levels because of an unlimited supply of labor from the rural sector. Kurosaka (2024) examined the stationarity of real wages during Japan's Rule over the Korean Peninsula and suggests that the real wages of skilled workers followed a difference stationary process whereas those of unskilled workers in the northern region followed a trend stationary process. Hamori and Hamori (2000) analyzed the economic fluctuations in Japan's economy before the World War II using a vector error-correction model. In those years of Japanese economy, they found that causality ran from the real sector to the monetary sector, but not vice versa.

As noted above, one view suggests that the flexibility of the price mechanism quickly resolved the economic disequilibrium at that time. Another view suggested that a high profit level was secured, leading to active investment, since real wages tend to remain low. These views were based on the traditional perspective of the economy, as summarized by Blanchard and Fisher (1989, Chapter 1). They stated that the traditional business cycle approach characterizes the economy as a smooth trend path, from which it is distributed by cyclical fluctuations.

Nelson and Plosser (1982) found that they could not reject the hypothesis that the long historical time series of macroeconomic variables for the United States was a non-stationary stochastic process with no tendency to return to a trend line. According to these studies, it is common in macroeconomics to decompose real variables into secular trends, growth and cyclical components. Many economists have practiced detrending time series as noted by Nelson and Plosser. The residuals were interpreted as the cyclical components that must be explained using the business cycle theory.

Nelson and Plosser (1982) maintained that the secular movement of macroeconomic variables need not be modeled by a deterministic trend, and noted that the class of integrated stochastic processes, such as the random walk, exhibited secular movement and did not follow a deterministic path. Campbell and Mankiw (1987) stated that traditional business cycle theories rested on two fundamental premises. First, fluctuations in output were primarily driven by shocks to aggregate demand. Second, shocks to aggregate demand had only a temporary effect on output, and in the long run, the economy returned to its natural rate.

Regarding Nelson and Plosser's (1982) analysis of U. S. historical data, Perron (1989) argued that if the 1929 crash and the post-1973 slowdown were not an underlying time-invariant stochastic process but instead exogenous shocks, then most macroeconomic time series did not exhibit a unit root process. He states that fluctuations are stationary around a deterministic trend. Zivot and Andrews (1992) found weaker evidence against the unit-root hypothesis than that of Perron by treating breakpoints as endogenous.

If the macroeconomic variables during the Great Japanese Empire had followed a difference stationary process, they would have no tendency to return to a trend line. Economic fluctuations at that time may be interpreted as having arisen from the stochastic fluctuations of the real factors. If real wages followed a difference stationary process, they would have

no tendency to return to the trend line. Consequently, Shinohara's (1961) view loses theoretical foundation, because real wages lack a trend line. The economic fluctuations at that time were primarily driven by changes in aggregate supply, such as shifts in available production technology. Given this, fiscal and monetary policies do not contribute enough to stabilize the economy, given that these policies have no permanent effect.

Based on this, I investigate the stationarity of prices, wages, and income during the Great Japanese Empire. The analysis suggests that consumer price, aggregate expenditure price, nominal and, real GNP, and monetary wages follow a difference stationary process. Additionally the analysis suggests that real wages follow a trend stationary process, implying that the time series of real wage tends to return to the trend line.

The remainder of this paper is organized as follows: Section 2 provides descriptive statistics on price, income and wage during the Great Japanese Empire. Section 3 analyzes the autocorrelation function for price, income and wage. Section 4 conducts Augmented Dickey-Fuller tests to investigate whether price, income and wage follow a difference stationary process or a trend stationary process. Finally, Section 5 presents the concluding remarks.

2. Descriptive Statistics of Prices, Income and Wages During the Great Japanese Empire

I obtained data on consumer and aggregate expenditure prices from Ohkawa et al. (1967) and data on income from Ohkawa et al. (1974). Table 1 presents the descriptive statistics for the consumer price index, the aggregate expenditure price index, nominal GNP, real GNP, monetary wages, and real wages. All the data are annual. The data on consumer prices and aggregate expenditure prices cover the period 1879–1938, with a sample size of 59 observations. The data on nominal and real GNP covers the period 1885–1940, with a sample size of 56 observations. The data on monetary wage covers the period 1882–1939, while the data

Table 1 Descriptive statistics of Prices, Income and Wages During the Great Japanese Empire

Variable	Average Rate of Change (%)	Standard Deviation (%)	Coefficient of Variation	Maximum value (year)	Minimum value (year)
Consumer Price Index (1879–1938)	2.22	9.15	4.12	34.59 (1918)	−14.14 (1883)
Aggregate Expenditure Price Index (1879–1938)	2.28	8.73	3.82	33.25 (1917)	−12.0 (1882)
Nominal GNP (1885–1940)	7.20	9.81	1.36	39.75 (1917)	−9.92 (1930)
Real GNP (1885–1940)	3.29	4.04	1.23	12.50 (1924)	−4.56 (1923)
Nominal Wage (1882–1939)	3.92	10.23	2.61	47.30 (1919)	−18.11 (1884)
Real Wage (1882–1938)	1.69	7.57	4.49	26.49 (1920)	−15.26 (1884)

on real wage covers the period 1882–1938.

Note that the coefficients of variation for the consumer price index and real wages are high compared to other variables. Additionally, the maximum value was observed at the end time of the First World War.

Next, I consider the fluctuation characteristics of price, income and wage by depicting their figures using natural logarithmic values.

An upward trend is observed in Figure 1, 2, 3, and 4.

Figure 1. Consumer Price Index in Natural Logarithm Value

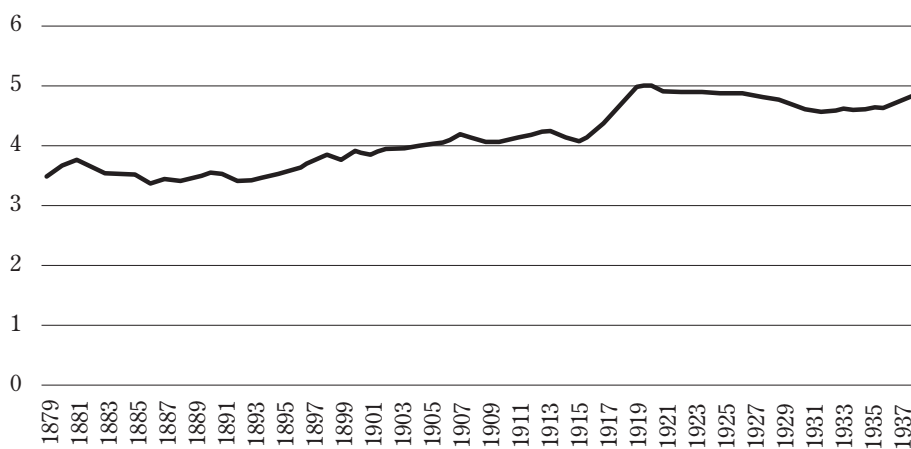


Figure 2. The Aggregate Expenditure Price in Natural Logarithm Value

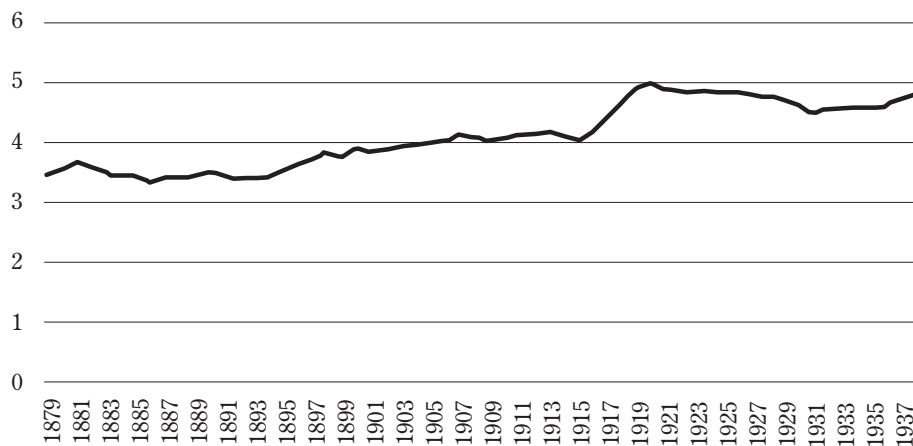


Figure 3. Nominal GNP in Natural Logarithm Value

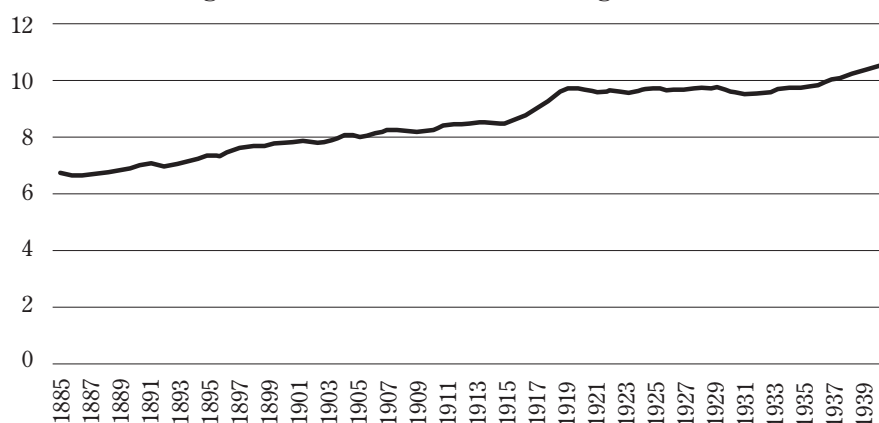


Figure 4. Real GNP in Natural Logarithm Value

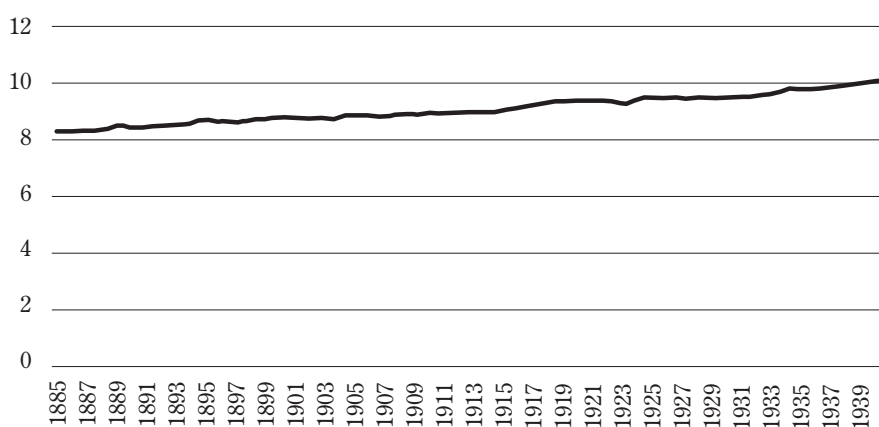


Figure 5. Monetary Wage in Natural Logarithm Value

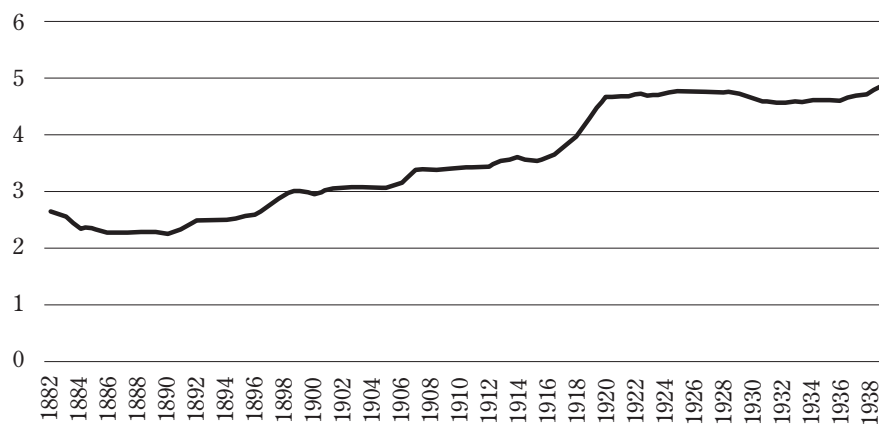
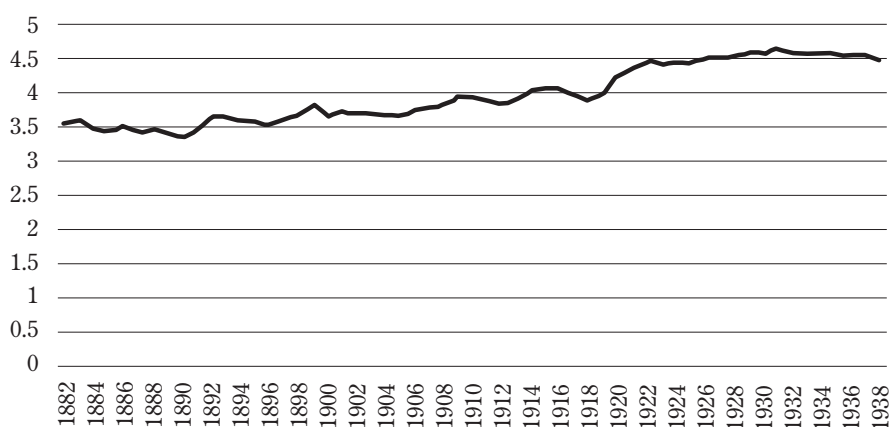


Figure 6. Real Wage in Natural Logarithm Value



3. Analysis of Sample Autocorrelations of the Consumer Price Index, Aggregate Expenditure Price Index, Nominal GNP, Real GNP, Monetary Wages, and Real Wages

I analyze the autocorrelations for the consumer price index, aggregate expenditure price index, nominal and, real GNP, monetary and real wages. Table 2 presents the autocorrelations for these variables. The time period for each data remains the same as that in Table 1. A logarithmic transformation was applied to the data.

Table 2 Autocorrelations of the Natural logs of Annual data for Consumer Price Index, Aggregate Expenditure Price Index, Nominal GNP, Real GNP, Monetary Wage, and Real Wage

Variable	r_1	r_2	r_3	r_4	r_5	r_6
Consumer Price Index	0.96	0.91	0.87	0.83	0.79	0.74
Aggregate Expenditure Price Index	0.93	0.97	0.87	0.81	0.75	0.70
Nominal GNP	0.94	0.88	0.83	0.77	0.72	0.67
Real GNP	0.93	0.97	0.87	0.81	0.75	0.70
Monetary Wage	0.97	0.93	0.89	0.84	0.80	0.75
Real Wage	0.96	0.92	0.87	0.82	0.78	0.73

Table 2 presents the autocorrelations of each macroeconomic variables from the first to sixth lags. The first- and second- order autocorrelation functions of each variable were similar at 1. The autocorrelations do not decay with increasing lags. This finding suggests that the macroeconomic variables follow a difference stationary process. Table 3 shows the autocorrelations of the first differences in the natural logs of macroeconomic variables.

Table 3 Autocorrelations of the First Difference of the Natural logs of Macroeconomic Variables

Variable	r(1)	r(2)	r(3)	r(4)	r(5)	r(6)
Consumer Price Index	0.49	0.09	0.14	0.02	0.05	0.02
Aggregate Expenditure Price Index	0.52	0.12	0.12	0.05	0.003	0.01
Nominal GNP	0.62	0.21	−0.07	−0.17	−0.09	−0.01
Real GNP	−0.12	0.01	0.06	0.08	0.05	0.09
Monetary Wage	0.59	0.28	0.08	0.03	0.02	0.05
Real Wage	0.13	−0.10	−0.26	−0.20	0.13	0.28

As Nelson and Plosser (1982) pointed out, the positive autocorrelation at lag one only suggests that these series are generated by a difference stationary process. Our results for the first differences in the consumer price index, the aggregate expenditure price index, and monetary wages indicate a difference stationary process. The autocorrelation function of the MA(1) (Moving Average) process exhibits one spike and then decrease to zero (Enders 2015, Chapter 2). The differenced series of the consumer price index, aggregate expenditure price index, and monetary wages are suggested as following MA (1) process. As Enders (2015, Chapter 4) pointed out, an invertible MA process arises when the first difference is taken in a trend stationary process. The autocorrelation function of the first differenced series does not decay if the MA process has a unit root. Looking at the autocorrelation of real wage in Table 3, we can observe that this process does not decay, suggesting that real wage follows a trend stationary process.

Table 4 Autocorrelations of Deviations from the Time Trend in Macroeconomic Variables

Variable	d(1)	d(2)	d(3)	d(4)	d(5)	d(6)
Consumer Price Index	0.91	0.72	0.51	0.33	0.20	0.08
Aggregate Expenditure Price Index	0.91	0.73	0.53	0.35	0.20	0.07
Nominal GNP	0.92	0.75	0.55	0.36	0.20	0.05
Real GNP	0.78	0.61	0.46	0.29	0.17	0.05
Monetary Wage	0.88	0.71	0.53	0.36	0.21	0.07
Real Wage	0.77	0.49	0.32	0.25	0.25	0.23

Table 4 presents the results of fitting a linear trend to the data and calculating the sample autocorrelations of the residuals. The sample autocorrelations for the consumer price index, aggregate expenditure index, nominal GNP, and monetary wages are close to 1. As Enders (Chapter 4) points out, detrending a difference stationary process does not affect autocorrelations, suggesting these variables follow difference stationary processes. In contrast, for real

GNP and real wages, the sample autocorrelation functions do not exhibit the same behavior.

In summary, the consumer price index, aggregate expenditure index, nominal GNP, and monetary wages are indicative of a difference stationary process. Determining whether real GNP follows a difference stationary process remains challenging. Real wage indicates a trend stationary process.

4. Analysis Using Augmented Dickey-Fuller Tests

Next, I conducted Augmented Dickey-Fuller tests, following Dickey and Fuller (1979) and Nelson and Plosser (1982). Figure 1~4 illustrate an upward trend in the consumer price index, aggregate expenditure price index, nominal GNP, and real GNP. As Enders (2015) pointed out, these economic variables are thought to follow either a trend stationary process or a unit root process with a drift term. In this case, the following equation was estimated:

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=2}^p \beta_i \Delta y_{t-i+1} + \varepsilon_t \quad (1)$$

Symbol y_t represents the economic variables mentioned above. All the variables were transformed into natural logarithms. Δ denotes the first difference of variable. ε_t represents the error term at the period t , which is independently distributed with mean zero and variance σ_ε^2 . The issue for consideration is whether the series of the aforementioned economic variables follows a trend stationary process or a unit root process with a drift. We aim to test whether γ differs from 0 (the null hypothesis). If the null hypothesis is not rejected, it implies that the variable y_t has a unit root and follows a difference stationary process. Conversely, if the null hypothesis is rejected, it indicates that y_t follows a trend stationary process. The degree of lag in the Augmented Dickey-Fuller test was determined using the Akaike Information Criterion (AIC). The results are summarized in the Table 5. The entries in parentheses represent the t-values. Therefore, it is necessary to use the Dickey-Fuller critical values. The

Table 5 Results of the Augmented Dickey-Fuller tests

Variable	Degree of lag	a_0	a_2	γ	$\gamma+1$
Consumer Price Index (1879-1938)	1	0.47 (3.26)	0.004 (3.26)	-0.14 (-3.29)*	0.86
Aggregate Expenditure Price Index (1879-1938)	5	0.55 (2.98)	0.005 (2.79)	-0.17 (-2.92)	0.83
Nominal GNP (1885-1940)	1	0.88 (3.40)	0.01 (3.24)	-0.13 (-3.31)*	0.87
Real GNP (1885-1940)	0	1.20 (0.75)	0.004 (1.80)	-0.14 (-1.71)	0.86
Monetary Wage (1882-1939)	1	0.23 (3.03)	0.006 (2.86)	-0.04 (-2.92)	0.96
Real Wage (1882-1938)	1	0.93 (3.53)	0.007 (3.51)	-0.28 (-3.52)**	0.72

symbols * and, ** indicates that the null hypothesis was rejected at the 10 and 5% significance levels, respectively.

In the case of real wages, the null hypothesis that γ equals zero can be rejected at the 5% significance level. For the other variables, the null hypothesis was not rejected. At the 5% significance level, the critical value for t-statistic is $-3.50^{2)}$.

In summary, the consumer price, expenditure price, nominal GNP, and real GNP indicate a difference stationary process. Real wages, however, are indicative of a trend stationary process.

5. Concluding Remarks

This study investigated the stationarity of prices, wages, and income during the Great Japanese Empire. The analysis suggests that the consumer price index, aggregate expenditure price index, nominal GNP, Real GNP and monetary wages followed a difference stationary process. By contrast, real wage followed a trend stationary process, indicating that the time series of real wages tended to return to the trend line.

To summarize, economic fluctuations during this period were thought to be mainly driven by supply side shocks, as the main macroeconomic variables followed a difference stationary process. Alternatively, shocks to aggregate demand did not contribute sufficiently to stabilizing the economy.

However, this conclusion is mainly based on ADF tests, which do not consider the structural change. Figures 1~6 suggest, that in 1918, a possible structural change occurred in the economy. Due to limited data, it was insufficient to perform tests that incorporate structural changes. If the dataset is increased through linear interpolation and tests are performed that consider the structural changes, the conclusions may change. However, this issue can be addressed in future studies.

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