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Disentangling the Effects of Multiple Treatments − Measuring the Net Economic Impact of the 1995 Great Hanshin-Awaji Earthquake

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Abstract

We propose a panel data approach to disentangle the impact of “one treatment” from the “other treatment” when the observed outcomes are subject to both treatments. We use the Great Hanshin-Awaji earthquake that took place on January 17, 1995 to illustrate our methodology. We find that there were no persistent earthquake effects. The observed persistent effects are due to structural change in Hyogo prefecture.

Keywords: Multiple Treatment Effects; Panel Data; Great Hanshin-Awaji Earthquake
JEL classification: C18, C23, C52

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1. Introduction

To evaluate the impact of certain "treatment" on some economic entity, one has to compare the outcomes of this entity in a "treated" and "untreated" states. Unfortunately, econometricians often only have data in "one" or the "other" state, not simultaneously in both states. Therefore, in evaluating the impact of a "treatment", econometricians have to construct "counterfactuals". Econometricians have come up with many ingenious approaches to construct counterfactuals (e.g. Abadie, Diamond and Hainmueller (2010), Heckman and Robb (1985), Heckman et.al. (1998), Hsiao, Ching and Wan (2012), Rosenbau and Rubin (1983)). A fundamental assumption of all these approaches is that the observed data for an entity under the "treatment" is only the outcomes of this specific "treatment" after controlling the impact of certain causal factors. However, in many cases, the observed outcomes could be due to several "treatments" working simultaneously. In this paper we propose a panel data approach to disentangle the impact of "one treatment" from the "other" when the observed data are the outcomes of "both" working in the same time using the Great Hanshi-Awaji earthquake impact as an illustrative example.

The Great Hanshin-Awaji earthquake took place on January 17, 1995. "The quake killed sixty-four hundred people, left more than three hundred thousand homeless, and did more than a hundred billion of dollars in damage" (James Surowiecki (2011)). However, there are disagreements about the long-term impact of the earthquake on the Kobe region (Hyogo prefecture). On the one side, Horwich (2000) and Becker (2005), etc. claimed that the quake did not have much impact on Kobe region itself beyond the first couple of years. On the other side, DuPont and Noy (2012) claim that the "evidence shows a persistent and still continuing adverse impact of the quake on the economy of Kobe more than 15 years after the event". In addition to the wealth effect, there is also an argument of the creative destruction mechanism at work that claims natural disaster leads to a speeding-up of adoption of new technologies and improvement in infrastructure (Skidmore and Toya (2002)). There is also evidence of profound structural change before and after the quake.

For instance, the port of Kobe was the sixth busiest port in the world in 1994. It was still ranked 27th in 1995 during the quake year but has fallen to the 39th in the year 2005. Can one attribute this dramatic declines to the Great Hanshin-Awaji Earthquake or due to the competition of other lower cost ports in Asia such as Pusan, Hong Kong or Singapore, etc.? Similarly, one of the most important local industries, the chemical shoe industry has been on the decline even before the quake and continues to decline thereafter due to the competition of the cheaper shoes from China and the expensive shoes from Italy and France as can be seen in Chart 1 and 2.

In section 2, we review the related studies. Section 3 discusses the data issues. Section 4 presents the estimates of combined quake and structural change effects using Hsiao, Ching and Wan (2012) methodology. Section 5 proposes a method to disentangle "one treatment effects" from the other and presents the estimated net "quake" effects from the "structural change" effects. Concluding remarks are in section 6.

2. Literature Review

(2.1) Definition of the losses from natural disaster

According to Hallegatte and Przyluski (2010), researchers usually distinguish between direct and indirect losses depending on their purposes of estimation. Direct losses are immediate consequence of disaster, especially physical phenomenon, such as the loss of buildings or houses. Among direct losses, direct market losses are estimated by the repair or replacement cost. These estimates are essential for the payments of insurance or government subsidy to the damaged area. There are also non-market direct losses, such as loss of lives, loss of natural assets. Indirect losses include all losses that are not provoked by the disaster itself, but by its consequences.

Direct loss is a "stock" concept. They are loss of wealth and human capital. The methods to estimate the direct losses are straightforward, in contrast, there is lack of consensus on how to measure indirect losses. There exists several methods to estimate indirect losses. Those include (1) firm or household level micro data estimates, (2) econometric estimates from national or regional data, (3) input-output model at the national and regional level, (4) computable general equilibrium model at the national and regional level.

(2.2) Estimates of economic losses due to the Great Hanshin-Awaji Earthquake

The estimates of economic losses due to the Great Hanshin-Awaji Earthquake vary from methods to methods.

A. Direct market losses

The most cited official estimate of direct losses was done by Hyogo prefecture government on April 5, 1995. Their estimates of direct market losses were 9.9 trillion Japanese yen. Those included in the losses are: losses for constructions for about 5.8 trillion Japanese yen, losses for ports for about 1 trillion Japanese yen, losses for expressways for about 0.56 trillion Japanese yen. The number of damaged houses was 639,686. Regarding the non-market losses, the number of casualties was 6,434, and the number of injuries was 43,792.

B. Direct market losses and indirect losses obtained from the firm level estimates

Toyoda and Kawauchi (1997) use a survey from the firms in the disaster area to estimate the average direct loss, and impute their estimates to the rest of firms in disaster area with some adjustment depending on how serious the firms are damaged to obtain total losses in the disaster area. According to their method, direct losses are 6 trillion yen and the indirect loss are 7.2 trillion yen. They revised the estimated losses in the manufacture and commerce sectors of the Hyogo Prefecture to 13.2 trillion yen, rather than 9.9 trillion yen.

C. Indirect losses obtained of the econometric estimates from national or regional data

Okuyama (undated) regresses gross regional product per capita data on Kobe city on its own lagged value, Japanese GDP, lagged Japanese GDP based on pre-earthquake data to generate forecast of gross regional product without the earthquake. He shows a small negative initial shock followed by positive impacts due to demand injection for a few years. His results are consistent with the observation by Horwich (2000) that the economic activity of Kobe area, manufacturers or retailers, recovered from the negative shock in about two or three years.

D. Indirect losses obtained from the input-output model at the national and regional level

Takahashi, Ando and Mun (1996) use regional Input-output table to obtain an estimate of the loss in Hyogo prefecture at 2.2 trillion yen. According to this study, the disaster area experience the decline of the output about US$73 billion (or 7.3 trillion Japanese yen if $1=100 yen). Ashiya and Zinushi (2001) use the input-output table to analyze the disaster area economy and conclude that the direct loss of the physical assets estimated in the amount of 10 trillion yen were fully reconstructed from 1995 to 1997.

E. Synthetic Control Methods

DuPont and Noy (2012) use a control group that consists of other untreated prefectures, optimally weighted, to construct the counterfactual for Hyogo prefecture GDP in the absence of quake. They find a significant and long-term adverse effect of the disaster: about 13% of average per capita prefecture GDP as of 2007.

3. Data

The focus of our study is to try to measure the “indirect loss”. Although the government recovery act provided stimulating effect on the damaged area economy at the time, its long-run impact is hard to gauge. Servicing the debt arising from financing the government recovery act could crowd out local consumption and investment. It could also impede government’s expenditure on education and welfare in future. The loss of wealth and human capital could also affect the consumption and investment in the damaged area. There is also the “creative destruction” argument that natural disaster speeds up the adoption of new technologies and improvement in infrastructure (e.g. Hayashi (2011)). The “indirect impact" of a natural disaster is essentially a "flow" concept. We therefore use the real GDP (RGDP) or real GDP per capita (RGDPPC) over time as a basis for measurement.

(3.1) Data on Prefecture GDP Series

Japanese regional aggregate data is published by each prefecture, and the latest data on Hyogo prefecture is available up to fiscal year 2009. The Cabinet Office of the Government of Japan collects data from each prefecture, and publishes them altogether around February of each year.

The prefecture aggregates are revised every year, and the consistent constant price data do not exist because of the changes in the base years. Moreover, the estimates are compiled based on two different methods of the system of national account; the 1968 System of National Account (SNA) or the 1993 SNA. Currently, we have the following four series: (i) from 1955 to 1974, the 1968 SNA, constant price at 1980; (ii) from 1975 to 1999, the 1968 SNA, constant price at 1990; (iii) from 1990 to 2003, the 1993 SNA, constant price at 1995; (iv) from 1996 to 2009, the 1993 SNA, constant price at 2000.

The Japanese Cabinet Office selects the following series as the official estimates; from 1975 to 1989, the 1968 SNA, constant price at 1990, from 1990 to 1995, the 1993 SNA, constant price at 1995, from 1996 to 2009, 1993 SNA, constant price at 2000. We use the data on the nominal gross prefecture expenditure and its deflator and population from 1995 to 2009. We also use the data for private consumption and nominal GDP by sectors for robustness checks.

Regarding the nominal gross prefecture expenditure, there are jumps in the series in 1995, 1990 and 1974. We adjust the discontinuity by the ratio of estimates in 1990 and 1995 for two series. For example, Chart 3 shows adjusted series and original series for Hokkaido region.

Regarding the deflator, we use the constant price deflator for expenditure. We use the growth rate for prefecture CPI data to estimate the unavailable data series for four areas, Fukushima 1975-1979, Saitama 1975-1976, Okayama 1975-1984, and Okinawa 1975-1980.

Since there is a jump in the series in 1995, 1990 and 1974, we adjust the discontinuity by the ratio of estimates in 1990 and 1995 for two series available. Data from 1955 to 1974 are scaled down by the ratio of 1980 estimates divided by 100, since we know the series from 1955 to 1974 is based on the constant prices for year 1980. For example, Chart 4 shows the adjusted deflator series and original deflator series for Hokkaido region.

We will also discuss the data on private consumption and nominal GDP by sectors in the later sections for robustness checks.

(3.2) Data on Hyogo Prefecture and Disaster area

Hyogo Prefecture government has provided estimates of the prefecture product for the disaster area (ten cities and ten towns). The Great Hanshin-Awaji Earthquake occurred in January of 1995. The estimate of fiscal year 1994, from April 1994 to March 1995, is the series that reflects the impact of the earthquake for the first time. Chart 5 shows the gross product of national,prefectural and disaster area which can give an idea of the overall impact of the Great Hanshin-Awaji Earthquake.

According to Chart 5, based on GDP statistics, there are negative effects in fiscal year 1994 in Hyogo prefecture and disaster area, but they increased from fiscal year 1995 to 1997. Since then, disaster area seems to be lagging behind the national level, and from fiscal year 1998 to fiscal year 2000, they were below the level of calendar year 1994, before the Great Hanshin-Awaji Earthquake.

From this statistics, Hayashi (2011, p.182) concludes that the recovery period from the Great Hanshin-Awaji Earthquake started form 1994 and ended in 1998 fiscal year. After the fiscal year 1999, Hyogo prefecture has experienced a structural change for the economy as documented by the decrease in capital stock. Including the recovery demand, Hayashi identified the effects of the Great Hanshin-Awaji Earthquake as the gap between the level of fiscal year 1993 and fiscal years 1994 to 1998 in the amount of 7.7 trillion yen on value added basis and 14.4 trillion yen in output level. He also found that about 89% of 7.7 trillion yen (for five years) value added was supplied by the outside prefectures. The direct market loss of 9.9 trillion yen estimated by the Hyogo Prefecture is close to his estimates.

4. Estimates of the Combined Effects of Earthquake and Structural Change

We first present the estimates of combined earthquake and structural change effects based on Hsiao, Ching and Wan (HCW) method (2012). HCW assumes that the observed outcome of a variable y for the ith unit at time t, y_{it}, is a function of K common factors (across individual unit), $\underset{\sim}{f}_t$, the fixed idiosyncratic component, α_i, and the random idiosyncratic component ϵ_{it},

$$y_{it} = \alpha_i + \underset{\sim}{b}_i' \underset{\sim}{f}_t + \epsilon_{it}, \quad \begin{array}{l} i = 1, \ldots, N, \\ t = 1, \ldots, T. \end{array} \tag{4.1}$$

Stacking the $N \times 1$ y_{it} into a vector yields,

$$\underset{\sim}{y}_t = B \underset{\sim}{f}_t + \underset{\sim}{\alpha} + \underset{\sim}{\epsilon}_t, \tag{4.2}$$

when $\underset{\sim}{y}_t = (y_{it}, \ldots, y_{Nt})', \underset{\sim}{\alpha} = (\alpha_1, \ldots, \alpha_N)', \underset{\sim}{\epsilon}_t = (\epsilon_{it}, \ldots, \epsilon_{Nt})'$, and B is the $N \times K$ factor loading matrix, $B = (\underset{\sim}{b}_1, \ldots, \underset{\sim}{b}_N)'$. The contemporaneous covariance between y_{it} and y_{jt} is then equal to

$$\text{Cov } (y_{it}, y_{jt}) = \underset{\sim}{b}_i' E(\underset{\sim}{f}_t \underset{\sim}{f}_t') \underset{\sim}{b}_j. \tag{4.3}$$

Therefore, in principle one element of $\underset{\sim}{y}_t$ can be predicted by other elements of $\underset{\sim}{y}_t$. In other words, we can write y_{1it} as a function of $\tilde{\underset{\sim}{y}}_t$ where $\tilde{\underset{\sim}{y}}_t = (y_{2t}, \ldots, y_{Nt})'$,

$$y_{1it} = E(y_{1it} \mid \tilde{\underset{\sim}{y}}_t) + u_{1it}. \tag{4.4}$$

Suppose all N units did not receive the treatment for $t = 1, \ldots, T_1$, i.e., $\underset{\sim}{y}_t = \underset{\sim}{y}_t^0$. From period $T_1 + 1$ onwards, the first unit received treatment, $y_{1t} = y_{1t}^1, t = T_1 + 1, \ldots, T$, while the rest of units did not, $y_{it} = y_{it}^0, t = 1, \ldots, T, i = 2, \ldots, N$. HCW suggests predicting

$$\begin{aligned} \hat{y}_{1t}^0 &= E(y_{1t}^0 \mid \tilde{\underset{\sim}{y}}_t) \\ &= a + \underset{\sim}{b}' \tilde{\underset{\sim}{y}}_t, \ \ t = T_1 + 1, \ldots, T. \end{aligned} \tag{4.5}$$

HCW suggests using the data from 1 to T_1 to obtain estimates of $a, \underset{\sim}{b}$ based on the least squares regression of y_{1t} on a subset of $\tilde{\underset{\sim}{y}}_t$, selected from some model selection criterion

(AIC (Akaike (1974)) or BIC (Schwarz 1978)). Then estimate the treatment effects after period $T_1 + 1$ as

$$\begin{aligned}\hat{\Delta}_t &= y_{1t} - \hat{y}^0_{1t} \\ &= y_{1t} - \hat{a} - \hat{\underset{\sim}{b}}' \tilde{\underset{\sim}{y}}_t, \quad t = T_1 + 1, \dots, T.\end{aligned} \tag{4.6}$$

Under the assumption that u_{1it} are independently, identically distributed with mean 0 and variance σ^2_u, the covariance matrix of $(a, \underset{\sim}{b}')$ is given by

$$\text{Cov} \begin{pmatrix} a \\ \underset{\sim}{\beta} \end{pmatrix} = \sigma^2_u (X'X)^{-1}, \tag{4.7}$$

where $X = (1, \tilde{\underset{\sim}{y}}'_t)$ is a $T_1 \times k$ matrix and k is the dimension of $(1, \tilde{\underset{\sim}{y}}'_t)$. Then the heteroscedastic prediction error variance of $\hat{y}^0_{1t}$ for $t = T_1 + 1, \dots, T$ is equal to

$$\begin{aligned}\sigma^2_{y^0_t} &= E(\hat{y}^0_{1t} - y^0_{1t})^2 \\ &= \sigma^2_u \left\{1 + \underset{\sim}{x}'_t (X'X)^{-1} \underset{\sim}{x}_t\right\}, \ t = T_1 + 1, \dots,\end{aligned} \tag{4.8}$$

where $\underset{\sim}{x}'_t = (1, \tilde{\underset{\sim}{y}}'_t)$. Hence the confidence band of the treatment effects can be constructed as

$$\hat{\Delta}_t \ \pm \ c_\Delta \sigma_{y^0_t}, \quad t = T_1 + 1, \dots, \tag{4.9}$$

where c_Δ is the critical value of a standard normal or t-distribution for the given confidence level, say c_Δ=1.96 for 95% confidence level.

We apply the method of Hsiao, Ching and Wan (2012) to the log of real per capita GDP, log of real GDP, log of nominal GDP per capita, and log of nominal GDP on Hyogo Prefecture before and after the Great Hanshin-Awaji Earthquake.

(4.1) The number of prefectures to estimate counterfactual

Since we have 46 other prefectures to estimate the trend of Hyogo Prefecture, we have 9,366,819 combinations of data series to consider if we follow the Hsiao, Ching and Wan (2012) approach. As we have 39 pre-event observations and 55 total observations for 46 prefectures, we suppose that a maximum of six prefecture would be appropriate initial choice of numbers of prefectures used for forecasts.

(4.2) Correlation matrix

A unique feature of Japanese prefecture data series is that they are pretty similar. We begin our analysis by looking at the correlation matrix of the prefecture data series, and then we move on selecting prefectures for the sake of creating the counterfactual trend for Hyogo Prefecture without the Great Hanshin-Awaji Earthquake.

Chart 6 through 9 shows the simple correlation coefficients of Hyogo Prefecture and other prefectures for log real GDP per capita, log real GDP, log nominal GDP per capita and log nominal GDP in descending orders for the whole sample period, for the subsample period from 1955 to 1993 (before the Great Hanshin-Awaji Earthquake) and for the subsample period from 1994 to 2009 (after the Great Hanshin-Awaji Earthquake).

Chart 6, based on the data on log real GDP per capita, shows three things. First, in overall samples, the simple correlation coefficients are well above 0.99 for all prefectures. Second, before the Great Hanshin-Awaji Earthquake, the correlations are much higher. Finally, after the Great Hanshin-Awaji Earthquake, the correlations get lower, and in some regions even negative. Only Osaka, the neighbor prefecture, has the correlation of 0.8175. Based on those observations, given our objective is to trace the data before the Great Hanshin-Awaji Earthquake, we select five prefectures with highest correlations, due to ties, Tochigi, Tottori, Fukui, Toyama, and Gifu to start with. Charts 7, 8 and 9 show similar results although the prefectures with the highest correlations vary from data to data. In some cases, there are ties in rank six, and in such a situation we select five prefectures.

(4.3) Regression Results

Charts 10 through 13 show the results of forecasting models the data for Hyogo prefecture before the Great Hanshin-Awaji Earthquake using the six or five prefectures.

For example, the first row of Chart 10 reports the results of regressing the log real GDP per capita for Hyogo prefecture on Tochigi, Fukui, Gifu, Toyama, and Tottori. As we anticipate, while the goodness of the fit is great, there seems to be the effects of multi-collinearity. In the second, third and fourth row of Chart 10 reports the results of regression when we dropped the variables which did not become significant one by one, Fukui, Toyama and Gifu. We end up choosing two prefectures, Tochigi and Tottori for the forecast of Hyogo prefecture without quake as reported in the fourth row of Chart 10. Using the OLS coefficients reported in the fourth row, our forecasts are computed as[1]

$$\hat{y}_{1t} = 0.433\,Tochigi_t \ + \ 0.367\,Tottori_t \ + 0.261 \tag{4.10}$$

.

We proceed in the same way in the other variables as can be seen in Chart 11, 12 and 13. We use three prefectures for forecasting log real GDP, and we use two prefectures for forecasting log nominal GDP per capita and log nominal GDP.

(4.4) Counterfactual and Economic Impacts

The upper panels in Charts 14 through 17 report the actual data and counterfactuals constructed as the forecast of the regression model defined in (4.3). The lower panels in Charts 14 though 17 report the combined economic impacts if the effects of Great Hanshin-Awaji Earthquake, which are defined as the gap between the counterfactual and the actual data after the fiscal year 1994 (Note that January 1995 is in the fiscal year 1994).[2][3]

Chart 18 summarizes the impact of the Great Hanshin-Awaji Earthquake since 1994 to 2008: its mean, standard error, maximum and minimum. The upper panel is constructed from the original series of economic impact, and the lower panel is constructed from the adjusted series. They differ in their average, long run average and percentage to the 1993 data. Since the standard errors are large, except for the case of nominal GDP per capita, one could argue that the mean economic impacts are negligible.

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[1] DuPont and Noy (2012) use all the rest of 46 prefecture data from 1975 to 2009 to estimate the counterfactual.

[2] DuPont and Noy (2012) seem to assume that the effect of the Great Hanshin-Awaji Earthquake show up in the data on 1995 (page 9, line 8, or Figure 3). We assumed they used the same dataset on fiscal year basis, and thus their estimates must be interpreted with caution.

[3] DuPont and Noy (2012) regard all of the statistical effects; 13% of decrease in per capita nominal GDP, as of 2007 as the effects of the Great Hanshin-Awaji Earthquake (page 17, first paragraph).

The estimated quake effects are autocorrelated. The evolvement of quake effects over time could be better captured by a time series model. We use autogressive (AR) models to capture the evolvement of quake effects over time. Since there are only 16 time series observations, we limit the choice to AR(1), AR(2) and AR(3) for the log real GDP per capita (RGDPPC), log real GDP (RGDP), log nominal GDP per capita (NGDPPC), and log nominal GDP (NGDP) respectively. They also appear sufficient to capture the serial correlations in the treatment effects from the Q-statistics. Based on the BIC criterion, AR(1) is chosen for the RGDPPC and the RGDP, respectively (Chart 19 and 20). The implied long-run impact for RGDPPC is estimated as $(1 - .785)^{-1} \times (-0.031) = -0.144$. The implied long-run impact for RGDP is $(1 - .737)^{-1} \times (-0.04) \simeq -0.152$. Either estimates are much higher than the simple averages reported in Chart 18. However, one should treat those point estimates with caution. For instance, the lagged coefficient for the RGDPPC model has a large standard error, casting doubt on the reliability of the estimated long-run impact. Nevertheless, the qualitative inference is the same, that is, there appears a persistent negative impact as asserted by DuPont and Noy (2012).[4]

(4.5) Extensions

We also use the HCW methodology to analyze components of GDP.

A. Consumption Behavior

We consider four private consumption series; log real private consumption per capita, log real private consumption, log nominal private consumption per capita, and log nominal private consumption reported in Prefecture GDP statistics. Consumption deflators are constructed in a similar way as we construct GDP deflators, including the method of connecting discontinuous series and method of filling the missing variables using CPI.

Chart 21 shows the correlation with Hyogo Prefecture and other prefectures based on

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[4] DuPont and Noy (2012) report 13% decrease in per capita nominal GDP as of 2007 compared with the counterfactual level. We estimate 8.9% decrease as of 2007 compared with counterfactual. The discrepancy could be due to differences in constructing counterfactuals. It could also be that they assume the effects of quake begin at 1995 data, while we correctly assume it began at the 1994 data.

log real private consumption per capita. Compared with Chart 6, where we used log real per GDP per capita, we see that the correlations are much higher, and above 0.99 before the Great Hanshin-Awaji Earthquake. Other three consumption series also yield similar correlation matrices. We choose six (sometimes three or seven due to the tie) prefectures that show the highest correlation with Hyogo prefecture before the Great Hanshin-Awaji Earthquake. We forecast the consumption series of Hyogo prefecture using the series of those prefectures, and the fitted values are used as the counterfactual series without the Great Hanshin-Awaji Earthquake. Charts 22 through 25 report the counterfactuals constructed as the forecast of the regression model and economic impacts of the Great Hanshin-Awaji Earthquake defined as the gap between the counterfactual and the actual data after the fiscal year 1994.

As Charts 22 through 25 show, that unlike GDP, all estimates of the impact have only a small decline in 1994, when the earthquake hit in January 1995. However, after the year 1995, all show persistent decline. Chart 26 summarizes the impact of the Great Hanshin-Awaji Earthquake from 1994 to 2008, by showing its mean, standard error, maximum and minimum. Again there are serial correlations in the impacts, we use a time series model to capture the evolvement of quake effects. We estimate AR models up to order of AR(3). As summarized in the sixth to eighth column of Chart 26, the long-run impacts, scaled by the level of each variable in 1993 are large for real and nominal consumption per capita. It suggests a 44% decline of the real private consumption.

B. Construction and Service Sectors

More can be said about the breakdown of GDP statistics by sector. Since the literature shows that the significant impacts exist in the construction sector (positive) and service sector (negative), it is useful to apply our approach to the GDP by sector: construction, wholesale and retail and services. We do not have the deflators for those data, and we simply link the three nominal official series for each sector. We normalize the data by the size of population.

We compute the correlation with Hyogo Prefecture and other prefectures for log per capita construction, log per capita wholesale and retail, and log per capita services sector in turn and construct the counterfactual as in the previous sections.

Charts 27 through 29 show the economic impact. Adjusted economic impact for construction industry data shows a strong positive impact in the first few years after the Great Hanshin-Awaji Earthquake, as is often suggested by the other research but returned to about the pre-quake level with the expiration of government recovery act. On the other hand the quake impact per capita wholesale and retail or services appear negligible.

(4.6) Are the Effects Due to Earthquake or Structural Change?

The components analysis appears to point out a strong possibility that the post-quake data contain both the earthquake and structural change effects. There are persistent fall in the consumption expenditure and service sectors, but strong construction activities in the first few years after quake, but decline to about the pre-quake level in later years. There are substantial evidence that the persistent decline in Hyogo economy is due to structural change rather than the earthquake. For instance, the annual report of Kobe indicates that the Kobe port was the second busiest port in the world in the year 1972 (measured by the amount of containers), and it was sixth busiest port in the world in 1994 (the year before the Great Hanshin-Awaji Earthquake). The Great Hanshin-Awaji Earthquake destroyed almost all important facilities in the port of Kobe, and the port stopped dealing with the containers coming from abroad at the time. However, the port facility was reconstructed within two years. The number of ships arriving at the port of Kobe rebounded strongly in the year 1996 and 1997, but it never raised above the number of the arriving ships in the year 1994. Can we attribute this persistent decline to the Great Hanshin-Awaji Earthquake? We breakdown the analysis of the number of arriving ships in three parts.

First, regarding the coast ships except of the ferry boats, the damage due to the Great Hanshin-Awaji Earthquake seems to be limited to the year 1995 and 1996 (Chart 30, the purple bars).

Second, regarding the number of arriving coastal ferry boats, we see dramatic decrease in the year 1998 (Chart 30, the green bars). The decrease can be attributed to the opening of the new bridge, called “Akashi-Kaikyo-Ohashi” that linked Kobe city and Awaji-island on April 1998. Since then trucks travelling from Shikoku Island to Honshu move away from ferries to the express way going through the new bridge. The new bridge had been under construction before the Great Hanshin-Awaji Earthquake, and the decline of arrival of coastal ferry boats seems to have nothing to do with the Great Hanshin-Awaji Earthquake.

Third, regarding the number of ocean-going ships, it was true that ships moved away from the port of Kobe to other Japanese ports, such as Tokyo, Osaka or Yokohama immediately after the Great Hanshin-Awaji Earthquake (Chart 30, the red bars). However, the decrease in the arriving ocean-going ships in the port of Kobe reflect another long-run factor: the loss of competitiveness with other East Asian ports. For example, after the introduction of regular container sea route between Korea and China in 1993, many traders prefer to use Pusan instead of Kobe as a hub terminal to trade with China, partly because Pusan was closer to China and partly because the cost of the Pusan port was cheaper than Kobe. The dramatic decrease in the transshipment and the percentage of transshipment in the port of Kobe (Chart 31) should be attributed to the effects of competition with other East Asian ports. One can find a similar decrease in the shipments in the other Japanese ports, such as Yokoyama. For example, the world ranking of shipments in the port of Yokoyama fell from 8th in the year 1995 to 27th in the year 2005. In this sense, one could equally argue that the Great Hanshin-Awaji Earthquake simply accelerated the decline of the activity of the port of the Kobe.

The decline in Hyogo is not just due to the decline in the port of Kobe, but also due to the changing industry structure of Hyogo. Chemical shoes industry was one of the most important local industries in the city of Kobe since the 1950s. About 1,600 shoe producers located in Nagata Word and Suma Word of Kobe City in the year 1995. About 80 percent of the factories were burned down due to the fires arising from the Great

Hanshin-Awaji Earthquake. The immediate economic losses from the Great Hanshin-Awaji Earthquake amounted to 300 billion yen in this industry alone. However, as shown in Chart 1 and 2, the data regarding the decline in the output and employment of the member firms of the chemical shoes industry associations are indicative. The level of production increased to about 80% of the pre-earthquake level in the year 1999; nonetheless, it kept on decreasing since then. The number of employees remains low after the Great Hanshin-Awaji Earthquake. This decline in the shoe industry probably should be attributed to the competition of the cheaper shoes from China and the expensive shoes from Italy and France, which would happen irrespective of the occurrence of the quake.

5. Disentangle the Net Earthquake Effect from the Effect of Structural Change

Suppose the net effect of natural disaster happened at time $T_1 + 1$ is transitory and suppose from period $T_2 + 1$ onwards,

$$y_{1t} = y_{1t}^2, \text{ for } t = T_2 + 1, \dots, T. \tag{5.1}$$

Using the similar methodology as HCW, we can construct

$$\begin{aligned} y_{1t} &= E(y_{1t} \mid \underset{\sim}{\tilde{y}}_t) + \eta_t, \\ &= c + \underset{\sim}{d}' \underset{\sim}{\tilde{y}}_t^* + \eta_t, \ t = T_2 + 1, \dots, T, \end{aligned} \tag{5.2}$$

where $\underset{\sim}{\tilde{y}}_t^*$ is a subsector of $\underset{\sim}{\tilde{y}}_t$. Then by the similar reasoning as HCW, we can backcast y_{1t} under the new structure for the period before T_2 using the estimated c and $\underset{\sim}{d}$ based on data from $T_2 + 1$ to T,

$$\hat{y}_{1t}^2 = \hat{c} + \hat{\underset{\sim}{d}}' \underset{\sim}{\tilde{y}}_t^*, \quad t = 1, \dots, T_2. \tag{5.3}$$

Again, the prediction error variance of $\hat{y}_{1t}^2$ for $t = 1, \dots, T_2$ can be computed using the formula

$$\begin{aligned} \text{Var } (\hat{y}_{1t}^2) &= E\left[\left(\hat{y}_{1t}^2 - y_{1t}^2\right)^2\right] \\ &= \sigma_\eta^2 \left[1 + \underset{\sim}{x}_t^{*'} \left(X^{*'} X^*\right)^{-1} \underset{\sim}{x}_t^*\right] \\ &= \sigma_{y_t^2}^2, \text{ for } t = 1, \dots, T_2, \end{aligned} \tag{5.4}$$

where $\underset{\sim}{x}_t^{*'} = (1, \underset{\sim}{\tilde{y}}_t^{*'}), X^*$ is a $(T_2 - T_1) \times k^*$ matrix with the j-th row being $\underset{\sim}{x}_{t+j}^{*'}$ and k^* is the dimension of $\underset{\sim}{x}_t^{*'}$. Given $\hat{y}_{1t}^0$ and $\hat{y}_{1t}^2$, the combined earthquake and structural change effects can be estimated by

$$\hat{\Delta}_t = (y_{1t} - \hat{y}_{1t}^0), \text{ for } t = T_1 + 1, \ldots, T; \tag{5.5}$$

the net earthquake effects by

$$\hat{Q}_t = (y_{1t} - \hat{y}_{1t}^2), \text{ for } t = T_1 + 1, \ldots, T_2; \tag{5.6}$$

and the structural change effects by

$$\hat{S}_t = (\hat{y}_{1t}^2 - \hat{y}_{1t}^0), t = T_1 + 1, \ldots, T. \tag{5.7}$$

The confidence intervals for $\hat{\Delta}_t, \hat{Q}_t$ and $\hat{S}_t$ can be constructed using the formulas,

$$\hat{\Delta}_t \pm c_\Delta \sigma_{y_t^0}; \tag{5.8}$$

$$\hat{Q}_t \pm c_Q \sigma_{y_t^2}; \tag{5.9}$$

and

$$\hat{S}_t \pm c_S \sqrt{\sigma_{y_t^0}^2 + \sigma_{y_t^2}^2}, \tag{5.10}$$

where c_Δ, c_Q and c_S are the critical values of the standard normal or t-distribution with given confidence level, say 1.96 for 95% confidence level.

We apply this methodology to separate the net earthquake from the structural change effects. Our selection of T_2 is based on two considerations: (i) The observed value of y_{1t} from $T_2 + 1$ onwards no longer contains the earthquake effect; (ii) There are reasonably large number of post-T_2 observations to get a reliable approximation of $E\left(\hat{y}_{1t}^2 \mid \underset{\sim}{\tilde{y}}_t^n\right)$ for t from $T_2 + 1$ onwards.

Consideration of (i) favors pushing T_2 far ahead from the quake year 1995. Consideration of (ii) favors pushing T_2 as close to 1995 as possible. There are 15 post-quake observations. Hayashi (2011) (or Horwich (2000)) has concluded that the recovery period ended in the 1998 fiscal year. Thereafter, Hyogo prefecture has experienced a structural change. Chart 32 shows that the backcast Hyogo time series are sensitive to where T_2 is chosen if T_2 falls between 1996 - 1999, but appear to be fairly stable from 2000 onwards.

The separation of the quake effects and structural break effects depends critically on the choice of T_2. To further check if setting $T_2 =$ year 2000 is a reasonable choice, we consider two approaches. The first approach treats the backcast $\hat{y}^2_{1t}$ as if they were the actual outcomes of Hyogo economy under the new economic structure, then use the pre-1995 hypothetically generated data to generate counterfactuals under the post 2000 structure in the absence of quake.

Treating the hypothetically generated $\hat{y}^2_{1t}$ for the period $t = 1, \ldots, T_1$, as if they were y_{1t} under the new structure, and using the similar methodology as HCW, we can let

$$\hat{y}^2_{1t} = \utilde{b}_1^{*'} \utilde{f}_t + \alpha_1^* + \epsilon_{1t}^*. \tag{5.13}$$

Then

$$\begin{pmatrix} \hat{y}^2_{1t} \\ \tilde{\utilde{y}}_t \end{pmatrix} = B^* \utilde{f}_t + \utilde{\alpha}^* + \utilde{\epsilon}_t^*, \quad t = 1, \ldots, T_1, \tag{5.14}$$

where $B^* = (\utilde{b}_1^*, \utilde{b}_2, \ldots, \utilde{b}_N)', \utilde{\alpha}^* = (\alpha_1^*, \alpha_2, \ldots, \alpha_N)'$ and $\utilde{\epsilon}_t^* = (\epsilon_{1t}^*, \epsilon_{2t}, \ldots, \epsilon_{Nt})'$. There will have a $1 \times N$ vector $\tilde{w}$ such that $\tilde{\utilde{w}}' B^* = \utilde{0}'$. Therefore, we can let

$$\hat{y}^2_{1t} = E(\hat{y}^2_{1t} \mid \tilde{\utilde{y}}^n_t) + v_t, \quad t = 1, \ldots, T_1, \tag{5.15}$$

where $\tilde{y}^n_t$ denotes the vector $\tilde{\utilde{y}}_t$ after deleting the prefectures $\tilde{\utilde{y}}^*_t$ that are used to generate $\hat{y}^2_{1t}$.

Approximating $E(\hat{y}^2_{1t} \mid \tilde{\utilde{y}}^n_t)$ using the data from 1955 to 1993 yields

$$E(\hat{y}^2_{1t} \mid \tilde{y}^n_t) \simeq \hat{a}^* + \hat{\utilde{b}}^{*'} \tilde{\utilde{y}}^n_t = \hat{y}^{2*}_{1t}. \tag{5.16}$$

Using (5.16) to generate $\hat{y}^{2*}_{1t}$ for $t = T_1 + 1, \ldots, T$, We can obtain the estimated net earthquake effects

$$\hat{Q}_t = y_{1t} - \hat{y}^{2*}_{1t}, \ t = T_1 + 1, \ldots, T_2, T_2 + 1, \ldots, T. \tag{5.17}$$

Given our assumption, the net earthquake effects ended at year 2000. However, we can plot $\hat{Q}_t$ for the post 2000 period. If the selection of T_2=year 2000 is a reasonable one, then $\hat{Q}_t$ should be close to zero after $T_2 + 1$. Chart 33 provides the results of back casting model for RGDPPC. Chart 34 provides the estimated models for generating predicted Hyogo log RGDPPC under the new structure in the absence of quake,

$$\hat{y}_{1t}^{2*} = 1.293\ Saitama_t - 0.916\ Chiba_t\ + 0.413\ Miyazaki_t\ + 0.438\ + \hat{v}_{1t}. \tag{5.18}$$

Chart 35 plots the estimated combined quake and structural change effects, the economic adjustment effects and the net quake effects together with their respective 95% confidence intervals for the log RGDPPC when T_2 is set at the year 2000. Indeed, the estimated net quake effects after year 2000 is close to zero.

Chart 36 provides the results of backcasting model for RGDP. We start with six prefectures with highest correlations with Hyogo prefecture from 2001 to 2009, and select Kanagawa, Fukushima and Aichi based on BIC. Chart 37 reports the results of forecasting for the backcast data series generated by our predicted model for the log RGDP,

$$\hat{y}_{1t}^{2*} = 0.692\ Osaka_t + 0.423\ Oita_t - 1.761. \tag{5.19}$$

Chart 38 plots the estimated net earthquake, structural change and combined effects and their respective 95% confidence intervals. Again, the estimated net quake effects for log RGDP after year 2000 is negligible.

To further check if T_2=2000 is a reasonable choice, we consider fitting a stock adjustment model of the form,

$$y_{1t} - y_{1,t-1} = \gamma(y_{1t}^* - y_{1,t-1}), \tag{5.20}$$

to the Hyogo RGDP series for the period after the quake, where $0 < \gamma < 1$, and y_{1t}^* is the potential value of y_{1t} under new structure. Suppose

$$y_{1t}^* = \underset{\sim}{\beta}\underset{\sim}{y}_t^n + u_t, \tag{5.21}$$

Then

$$y_{1t} = (1-\gamma)y_{1,t-1} + \underset{\sim}{\beta}'\underset{\sim}{\tilde{y}}_t^n + u_t \tag{5.22}$$

for t from year 2000 onwards. Chart 39 presents some estimated stock-adjustment models for log Hyogo real GDP (RGDP) by letting t^*=1999. As one can see that no matter which prefectures are chosen to predict y_{1t} for $t \geq t^*$, the estimated lagged hyogo coefficient is insignificantly different from zero, which implies an instant adjustment to the new equilibrium state y_{1t}^*, (i.e. $\gamma = 1$). This evidence appears to further support the selection of T_2=2000.

It is interesting to note that our approach indicates that the net stimulating quake effect on Hyogo real GDP due to government recovery effort is underestimated by the standard approach due to ignoring the presence of structural change $(\hat{y}_{1t}^2 - \hat{y}_{1t}^0)$ for the period 1995 to 1997 $\sim$ 1998. Neither do we find persistent quake effects after 1998 with the conclusion of government recovering acts. The persistent effects on Hyogo RGDP can be attributed to structural change in Hyogo prefecture.

6. Concluding Remarks

Isolating the impact of one factors from other factors can be tricky, in particular, when the outcomes are the working of a number of factors. This paper suggests a panel data approach to separate one impact from another. We applied our method to the analysis of the impact of the Great Hanshin-Awaji Earthquake on January 17, 1995. We found stronger stimulation effects due to the government recovering act in the period 1995 - 1998 and smaller negative quake impact in 1999 and 2000 than the convention estimates. We did not find persistent negative quake effects. We attributed the Hyogo per capita GDP lagging behind national average to the changes in the economic structure, not to the earthquake.

Many issues remain such as the reliability or unavailability of the data and the selection of proper regressors when the number of candidates far exceed the available time series observations, etc. This study is only a first attempt to separate the impacts of one "treatment" from another when the observed outcomes are the working of both or more. We hope to further work on the improvement of our method in future studies.

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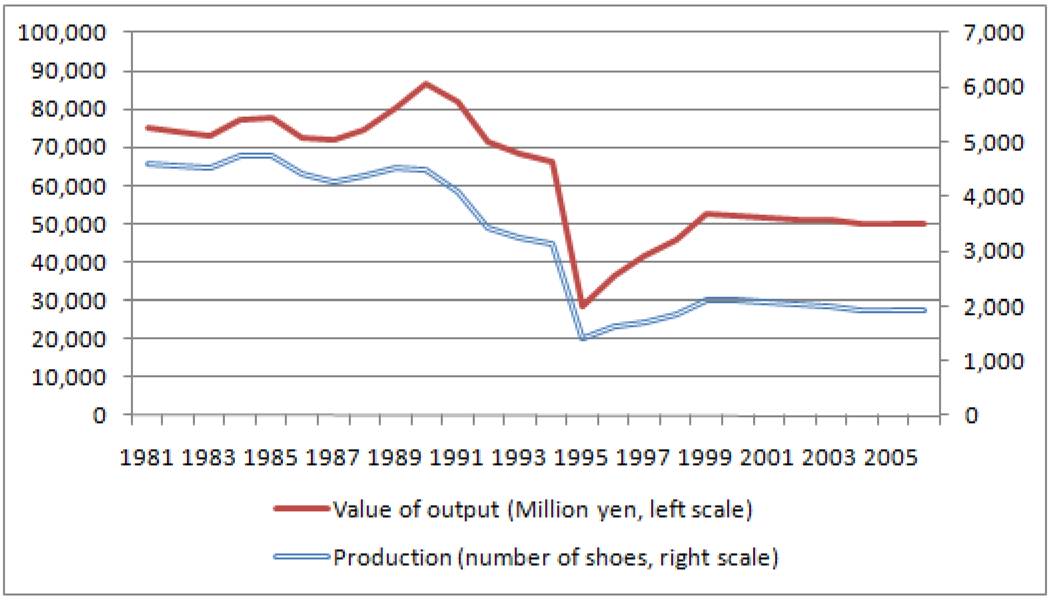
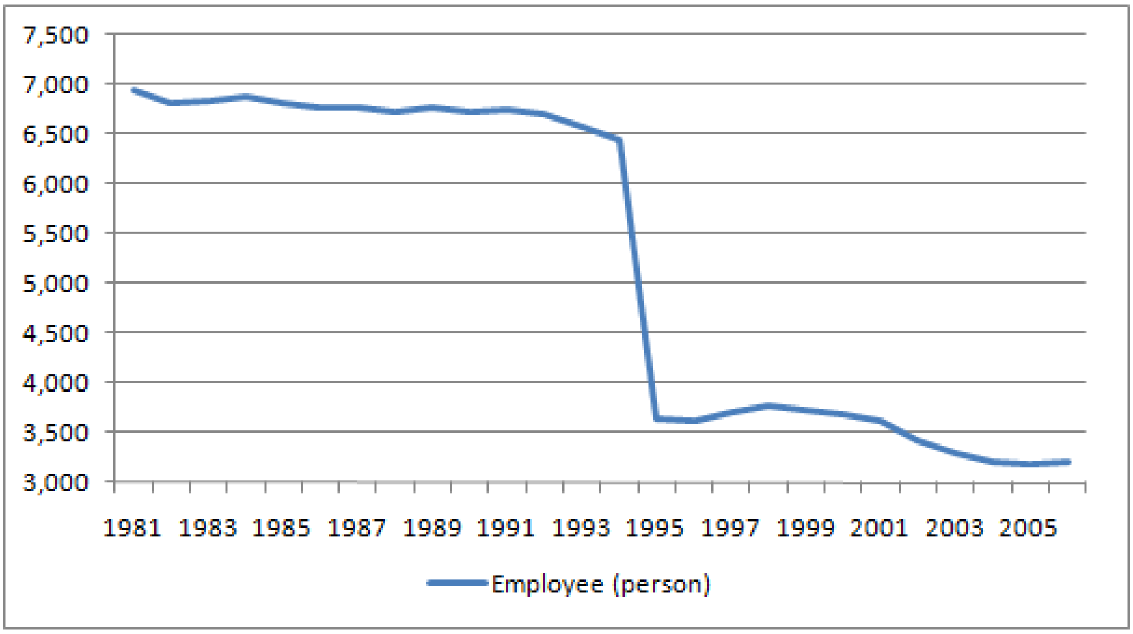
Chart 1: Output of Chemical Shoe Industry



Data source: http://www.csia.or.jp/toukei/data/gaikyou.pdf (in Japanese)

Chart 2: Employment of Chemical Shoe Industry



Data source: http://www.csia.or.jp/toukei/data/gaikyou.pdf (in Japanese)

Chart 3: Adjusted Series and Original Series for Hokkaido Region, Gross Prefecture Expenditure (Million Yen)

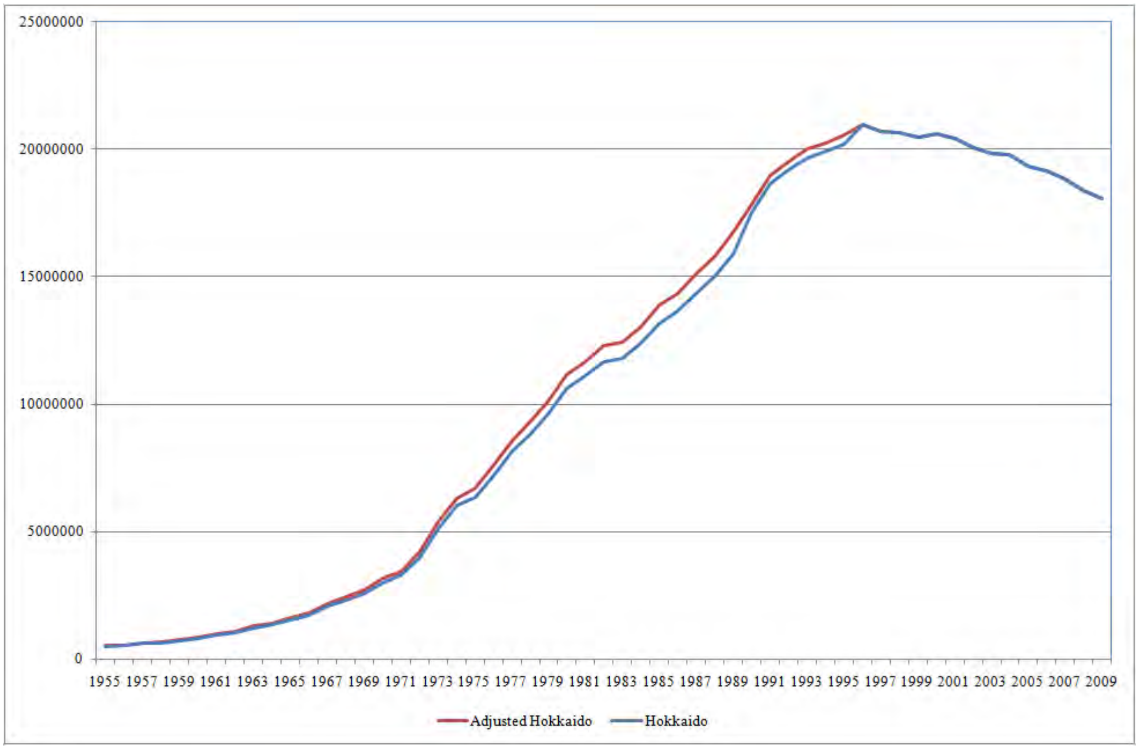


Chart 4: Adjusted Series and Original Series for Hokkaido Region, Deflator for Gross Prefecture Expenditure

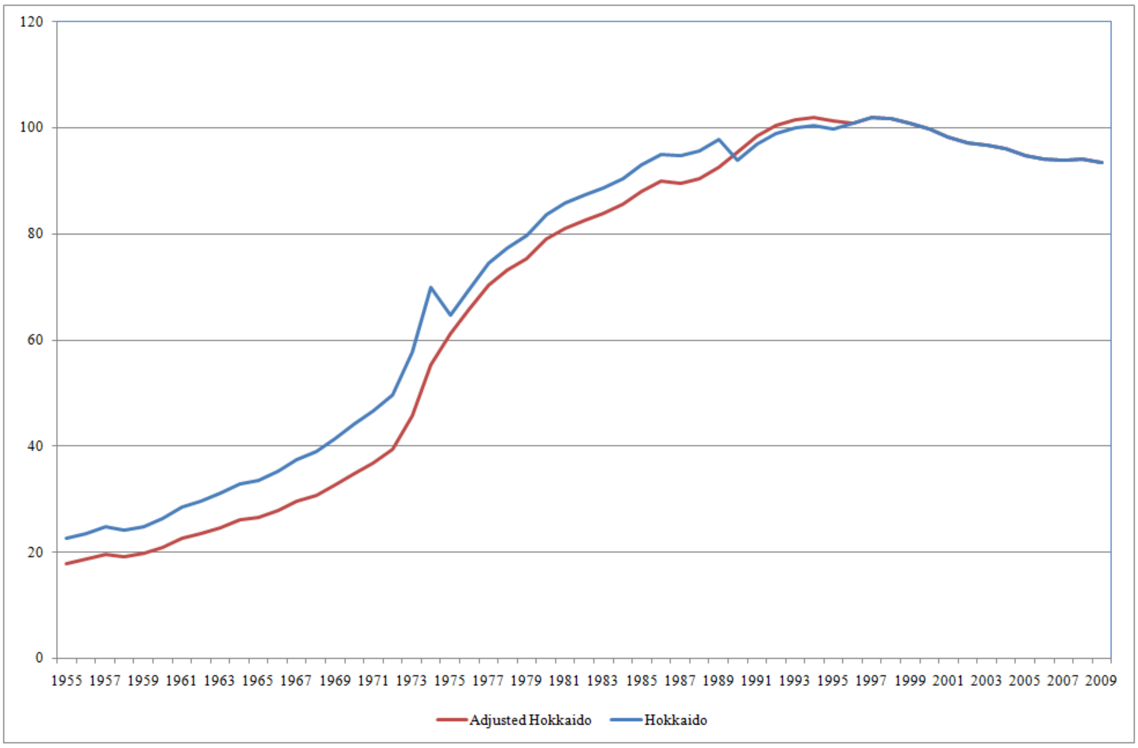
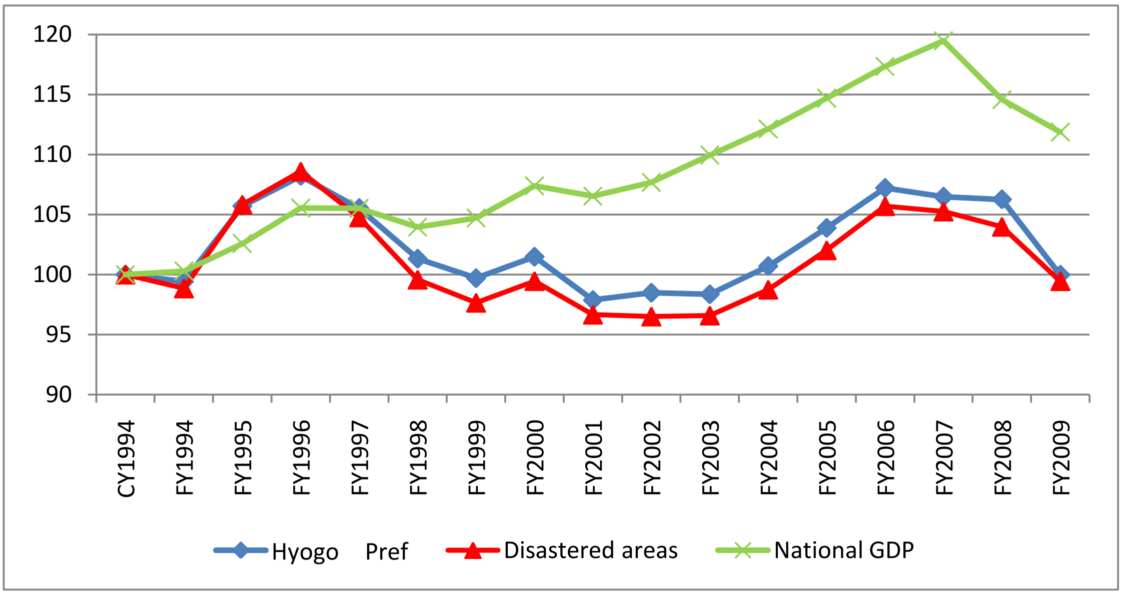
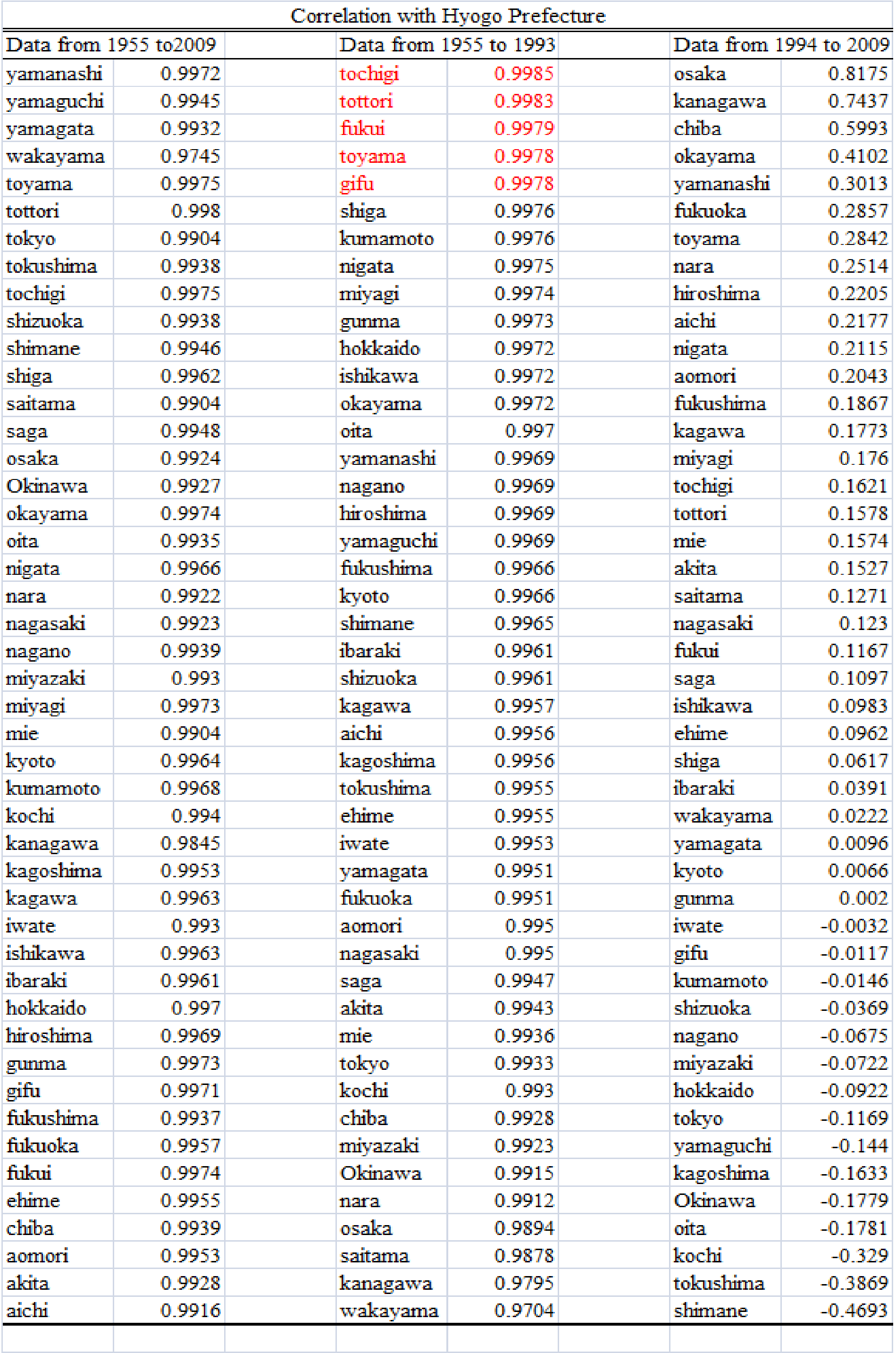


Chart 5: The gross product of national, prefectural and disaster area



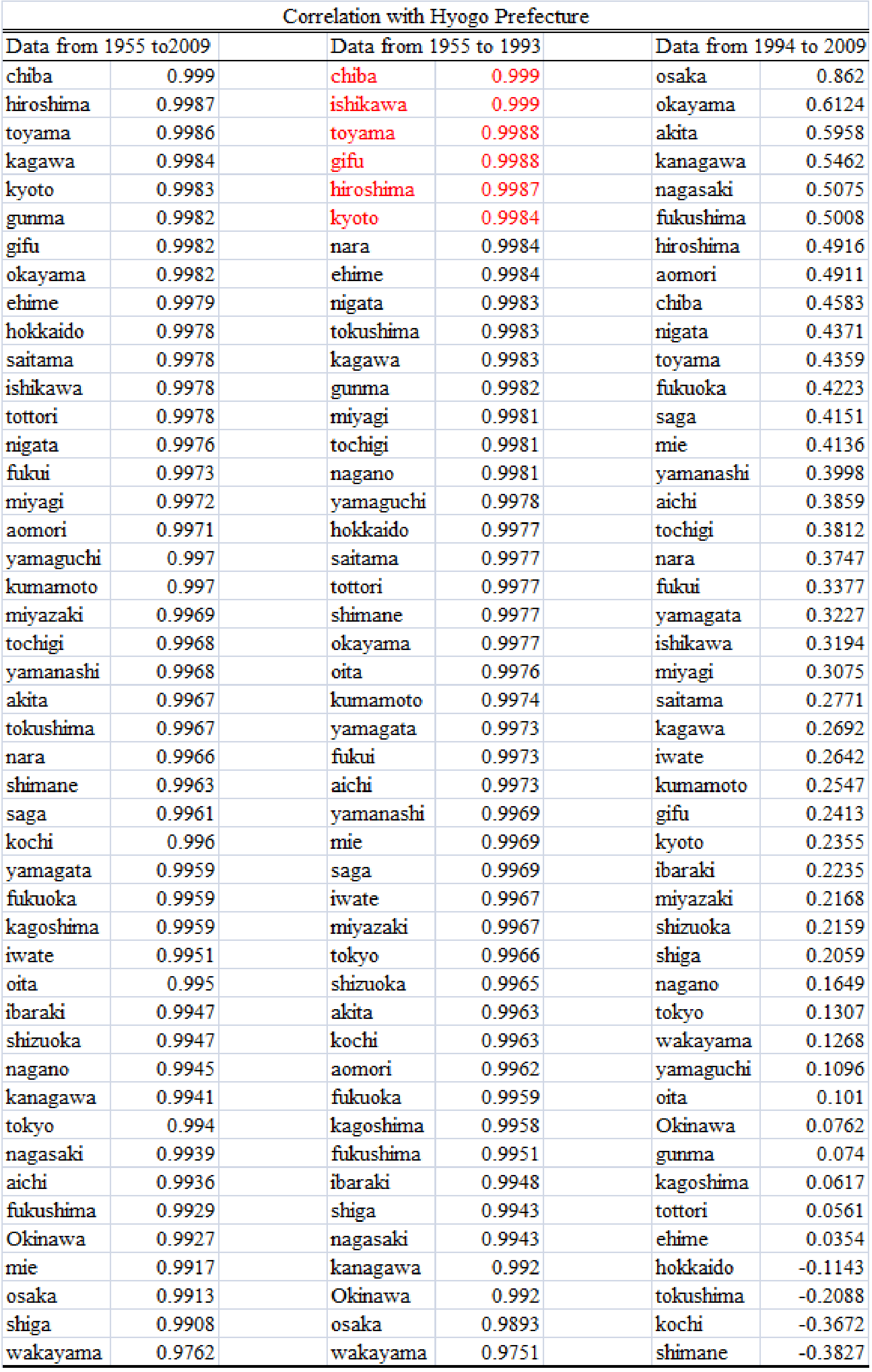
Note: Set the level of calendar year 1994 to be 100.

Chart 6: Correlation with Hyogo Prefecture based on log real GDP per capita



Correlation with Hyogo Prefecture					
Data from 1955 to2009		Data from 1955 to 1993		Data from 1994 to 2009	
yamanashi	0.9972	tochigi	0.9985	osaka	0.8175
yamaguchi	0.9945	tottori	0.9983	kanagawa	0.7437
yamagata	0.9932	fukui	0.9979	chiba	0.5993
wakayama	0.9745	toyama	0.9978	okayama	0.4102
toyama	0.9975	gifu	0.9978	yamanashi	0.3013
tottori	0.998	shiga	0.9976	fukuoka	0.2857
tokyo	0.9904	kumamoto	0.9976	toyama	0.2842
tokushima	0.9938	nigata	0.9975	nara	0.2514
tochigi	0.9975	miyagi	0.9974	hiroshima	0.2205
shizuoka	0.9938	gunma	0.9973	aichi	0.2177
shimane	0.9946	hokkaido	0.9972	nigata	0.2115
shiga	0.9962	ishikawa	0.9972	aomori	0.2043
saitama	0.9904	okayama	0.9972	fukushima	0.1867
saga	0.9948	oita	0.997	kagawa	0.1773
osaka	0.9924	yamanashi	0.9969	miyagi	0.176
Okinawa	0.9927	nagano	0.9969	tochigi	0.1621
okayama	0.9974	hiroshima	0.9969	tottori	0.1578
oita	0.9935	yamaguchi	0.9969	mie	0.1574
nigata	0.9966	fukushima	0.9966	akita	0.1527
nara	0.9922	kyoto	0.9966	saitama	0.1271
nagasaki	0.9923	shimane	0.9965	nagasaki	0.123
nagano	0.9939	ibaraki	0.9961	fukui	0.1167
miyazaki	0.993	shizuoka	0.9961	saga	0.1097
miyagi	0.9973	kagawa	0.9957	ishikawa	0.0983
mie	0.9904	aichi	0.9956	ehime	0.0962
kyoto	0.9964	kagoshima	0.9956	shiga	0.0617
kumamoto	0.9968	tokushima	0.9955	ibaraki	0.0391
kochi	0.994	ehime	0.9955	wakayama	0.0222
kanagawa	0.9845	iwate	0.9953	yamagata	0.0096
kagoshima	0.9953	yamagata	0.9951	kyoto	0.0066
kagawa	0.9963	fukuoka	0.9951	gunma	0.002
iwate	0.993	aomori	0.995	iwate	-0.0032
ishikawa	0.9963	nagasaki	0.995	gifu	-0.0117
ibaraki	0.9961	saga	0.9947	kumamoto	-0.0146
hokkaido	0.997	akita	0.9943	shizuoka	-0.0369
hiroshima	0.9969	mie	0.9936	nagano	-0.0675
gunma	0.9973	tokyo	0.9933	miyazaki	-0.0722
gifu	0.9971	kochi	0.993	hokkaido	-0.0922
fukushima	0.9937	chiba	0.9928	tokyo	-0.1169
fukuoka	0.9957	miyazaki	0.9923	yamaguchi	-0.144
fukui	0.9974	Okinawa	0.9915	kagoshima	-0.1633
ehime	0.9955	nara	0.9912	Okinawa	-0.1779
chiba	0.9939	osaka	0.9894	oita	-0.1781
aomori	0.9953	saitama	0.9878	kochi	-0.329
akita	0.9928	kanagawa	0.9795	tokushima	-0.3869
aichi	0.9916	wakayama	0.9704	shimane	-0.4693

Chart 7: Correlation with Hyogo Prefecture based on log real GDP



Correlation with Hyogo Prefecture					
Data from 1955 to2009		Data from 1955 to 1993		Data from 1994 to 2009	
chiba	0.999	chiba	0.999	osaka	0.862
hiroshima	0.9987	ishikawa	0.999	okayama	0.6124
toyama	0.9986	toyama	0.9988	akita	0.5958
kagawa	0.9984	gifu	0.9988	kanagawa	0.5462
kyoto	0.9983	hiroshima	0.9987	nagasaki	0.5075
gunma	0.9982	kyoto	0.9984	fukushima	0.5008
gifu	0.9982	nara	0.9984	hiroshima	0.4916
okayama	0.9982	ehime	0.9984	aomori	0.4911
ehime	0.9979	nigata	0.9983	chiba	0.4583
hokkaido	0.9978	tokushima	0.9983	nigata	0.4371
saitama	0.9978	kagawa	0.9983	toyama	0.4359
ishikawa	0.9978	gunma	0.9982	fukuoka	0.4223
tottori	0.9978	miyagi	0.9981	saga	0.4151
nigata	0.9976	tochigi	0.9981	mie	0.4136
fukui	0.9973	nagano	0.9981	yamanashi	0.3998
miyagi	0.9972	yamaguchi	0.9978	aichi	0.3859
aomori	0.9971	hokkaido	0.9977	tochigi	0.3812
yamaguchi	0.997	saitama	0.9977	nara	0.3747
kumamoto	0.997	tottori	0.9977	fukui	0.3377
miyazaki	0.9969	shimane	0.9977	yamagata	0.3227
tochigi	0.9968	okayama	0.9977	ishikawa	0.3194
yamanashi	0.9968	oita	0.9976	miyagi	0.3075
akita	0.9967	kumamoto	0.9974	saitama	0.2771
tokushima	0.9967	yamagata	0.9973	kagawa	0.2692
nara	0.9966	fukui	0.9973	iwate	0.2642
shimane	0.9963	aichi	0.9973	kumamoto	0.2547
saga	0.9961	yamanashi	0.9969	gifu	0.2413
kochi	0.996	mie	0.9969	kyoto	0.2355
yamagata	0.9959	saga	0.9969	ibaraki	0.2235
fukuoka	0.9959	iwate	0.9967	miyazaki	0.2168
kagoshima	0.9959	miyazaki	0.9967	shizuoka	0.2159
iwate	0.9951	tokyo	0.9966	shiga	0.2059
oita	0.995	shizuoka	0.9965	nagano	0.1649
ibaraki	0.9947	akita	0.9963	tokyo	0.1307
shizuoka	0.9947	kochi	0.9963	wakayama	0.1268
nagano	0.9945	aomori	0.9962	yamaguchi	0.1096
kanagawa	0.9941	fukuoka	0.9959	oita	0.101
tokyo	0.994	kagoshima	0.9958	Okinawa	0.0762
nagasaki	0.9939	fukushima	0.9951	gunma	0.074
aichi	0.9936	ibaraki	0.9948	kagoshima	0.0617
fukushima	0.9929	shiga	0.9943	tottori	0.0561
Okinawa	0.9927	nagasaki	0.9943	ehime	0.0354
mie	0.9917	kanagawa	0.992	hokkaido	-0.1143
osaka	0.9913	Okinawa	0.992	tokushima	-0.2088
shiga	0.9908	osaka	0.9893	kochi	-0.3672
wakayama	0.9762	wakayama	0.9751	shimane	-0.3827

Chart 8: Correlation with Hyogo Prefecture based on log Nominal GDP per capita

Correlation with Hyogo Prefecture					
Data from 1955 to2009		Data from 1955 to 1993		Data from 1994 to 2009	
tochigi	0.9993	miyagi	0.9996	kanagawa	0.9707
toyama	0.9993	tochigi	0.9996	osaka	0.9642
hokkaido	0.9992	toyama	0.9996	chiba	0.863
miyagi	0.9992	shimane	0.9996	gunma	0.8372
gunma	0.9992	oita	0.9996	nara	0.7948
gifu	0.9992	hokkaido	0.9995	hokkaido	0.791
tottori	0.9992	aomori	0.9995	kochi	0.7799
ibaraki	0.9991	iwate	0.9995	kagawa	0.7581
shiga	0.9991	nigata	0.9995	ehime	0.7373
kyoto	0.9991	fukui	0.9995	miyagi	0.7371
kochi	0.9991	gifu	0.9995	tottori	0.7287
fukui	0.999	tottori	0.9995	fukuoka	0.7264
nagano	0.999	akita	0.9994	gifu	0.6966
yamagata	0.9989	fukushima	0.9994	shiga	0.6954
ishikawa	0.9989	ibaraki	0.9994	fukui	0.6862
fukuoka	0.9989	ishikawa	0.9994	nigata	0.6826
fukushima	0.9988	nagano	0.9994	fukushima	0.6617
nigata	0.9988	shizuoka	0.9994	okayama	0.6574
yamanashi	0.9988	aichi	0.9994	iwate	0.651
aichi	0.9988	shiga	0.9994	toyama	0.646
nara	0.9988	kyoto	0.9994	ishikawa	0.6359
kagawa	0.9988	kumamoto	0.9994	nagano	0.6053
ehime	0.9988	yamagata	0.9993	saitama	0.6049
kumamoto	0.9988	gunma	0.9993	hiroshima	0.6043
shizuoka	0.9987	tokushima	0.9993	yamanashi	0.555
osaka	0.9987	ehime	0.9993	tochigi	0.5128
aomori	0.9985	saga	0.9992	ibaraki	0.4972
iwate	0.9985	yamanashi	0.9991	aichi	0.428
okayama	0.9985	nara	0.9991	tokyo	0.4147
saga	0.9985	kochi	0.9991	yamagata	0.4066
akita	0.9984	miyazaki	0.9991	akita	0.3359
oita	0.9984	kagoshima	0.9991	kyoto	0.3326
saitama	0.9983	mie	0.999	saga	0.2329
hiroshima	0.9983	kagawa	0.999	nagasaki	0.1627
miyazaki	0.9983	fukuoka	0.999	shizuoka	0.0973
shimane	0.9981	yamaguchi	0.9988	aomori	-0.0127
yamaguchi	0.9981	nagasaki	0.9988	kumamoto	-0.0204
kagoshima	0.9981	osaka	0.9984	oita	-0.0824
tokushima	0.9979	okayama	0.9984	mie	-0.2015
nagasaki	0.9978	saitama	0.9983	wakayama	-0.2888
Okinawa	0.9978	tokyo	0.9983	shimane	-0.3197
mie	0.9977	hiroshima	0.9983	miyazaki	-0.3596
kanagawa	0.9976	Okinawa	0.998	yamaguchi	-0.3918
chiba	0.9975	wakayama	0.9971	Okinawa	-0.5169
tokyo	0.9972	kanagawa	0.9969	kagoshima	-0.5238
wakayama	0.9971	chiba	0.9968	tokushima	-0.6929

Chart 9: Correlation with Hyogo Prefecture based on log Nominal GDP

Correlation with Hyogo Prefecture					
Data from 1955 to2009		Data from 1955 to 1993		Data from 1994 to 2009	
toyama	0.9995	ishikawa	0.9997	osaka	0.9723
gifu	0.9995	nagano	0.9997	akita	0.9382
ehime	0.9995	gifu	0.9997	nagasaki	0.9267
gunma	0.9994	tokushima	0.9997	kagawa	0.8608
kyoto	0.9994	ehime	0.9997	fukushima	0.8466
okayama	0.9994	aichi	0.9996	kanagawa	0.8428
kochi	0.9994	kyoto	0.9996	ehime	0.8369
yamaguchi	0.9993	tochigi	0.9995	nigata	0.8078
kagawa	0.9993	toyama	0.9995	gunma	0.803
hokkaido	0.9992	shizuoka	0.9995	nara	0.798
akita	0.9992	nara	0.9995	kochi	0.785
tochigi	0.9992	okayama	0.9995	hokkaido	0.7833
ishikawa	0.9992	iwate	0.9994	iwate	0.7734
nagano	0.9992	miyagi	0.9994	tottori	0.7654
aomori	0.9991	gunma	0.9994	fukui	0.7485
yamagata	0.9991	saitama	0.9994	yamagata	0.748
chiba	0.9991	mie	0.9994	toyama	0.7254
hiroshima	0.9991	yamaguchi	0.9994	gifu	0.6939
saitama	0.999	kagawa	0.9994	ishikawa	0.6915
nigata	0.999	hokkaido	0.9993	hiroshima	0.6689
nara	0.999	aomori	0.9993	okayama	0.665
miyagi	0.9989	nigata	0.9993	aomori	0.659
shizuoka	0.9989	kochi	0.9993	miyagi	0.6352
iwate	0.9988	akita	0.9992	yamanashi	0.6339
fukui	0.9988	hiroshima	0.9992	nagano	0.6339
aichi	0.9988	miyazaki	0.9992	saga	0.6042
tottori	0.9988	chiba	0.9991	wakayama	0.5048
tokushima	0.9988	oita	0.9991	ibaraki	0.4912
fukuoka	0.9987	yamagata	0.999	yamaguchi	0.4829
kumamoto	0.9987	tokyo	0.999	fukuoka	0.4223
miyazaki	0.9987	fukui	0.9989	kyoto	0.337
ibaraki	0.9985	fukuoka	0.9989	tochigi	0.3169
oita	0.9985	kumamoto	0.9989	kumamoto	0.3126
saga	0.9983	ibaraki	0.9988	chiba	0.3124
fukushima	0.9982	tottori	0.9987	shimane	0.2551
kanagawa	0.9981	saga	0.9987	oita	0.2346
yamanashi	0.9981	shimane	0.9985	miyazaki	0.1981
wakayama	0.9981	fukushima	0.9984	shizuoka	-0.0136
shimane	0.998	yamanashi	0.9984	kagoshima	-0.0213
tokyo	0.9979	shiga	0.9983	aichi	-0.0858
nagasaki	0.9979	kagoshima	0.998	shiga	-0.1672
mie	0.9977	nagasaki	0.9979	saitama	-0.207
osaka	0.9977	wakayama	0.9977	mie	-0.2497
kagoshima	0.9977	kanagawa	0.9975	tokushima	-0.331
shiga	0.9972	Okinawa	0.9975	tokyo	-0.3379
Okinawa	0.997	osaka	0.9972	Okinawa	-0.8116

Chart 10: OLS regressions based on log real GDP per capita

	(1) hyogo	(2) hyogo	(3) hyogo	(4) hyogo
tochigi	0.305^{*}	0.307^{*}	0.301^{*}	0.433^{***}
	(0.144)	(0.138)	(0.131)	(0.100)
tottori	0.336	0.344^{**}	0.337^{**}	0.367^{**}
	(0.183)	(0.118)	(0.110)	(0.110)
fukui	0.00950			
	(0.158)			
toyama	-0.0255	-0.0280		
	(0.156)	(0.148)		
gifu	0.199	0.201	0.186	
	(0.156)	(0.149)	(0.122)	
_cons	0.251^{***}	0.252^{***}	0.249^{***}	0.261^{***}
	(0.0189)	(0.0177)	(0.00984)	(0.00551)
N	39	39	39	39
adj. R^2	0.998	0.998	0.998	0.998
BIC	-157.1	-160.8	-164.4	-165.6

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 11: OLS regressions based on log real GDP

	(1) hyogo	(2) hyogo	(3) hyogo	(4) hyogo
ishikawa	0.475^{*}	0.439^{**}	0.456^{**}	0.362^{**}
	(0.185)	(0.135)	(0.136)	(0.123)
hiroshima	0.148	0.166		
	(0.148)	(0.134)		
toyama	0.239	0.222	0.286^{*}	0.274^{*}
	(0.139)	(0.125)	(0.115)	(0.116)
chiba	0.305^{**}	0.295^{**}	0.310^{**}	0.221^{*}
	(0.109)	(0.103)	(0.103)	(0.0861)
gifu	-0.0655			
	(0.223)			
kyoto	-0.297	-0.313	-0.239	
	(0.179)	(0.167)	(0.157)	
_cons	4.187^{***}	4.116^{***}	4.110^{***}	3.383^{***}
	(0.719)	(0.668)	(0.673)	(0.483)
N	39	39	39	39
adj. R^2	0.999	0.999	0.999	0.999
BIC	-163.4	-166.9	-168.8	-169.9

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 12: OLS regressions based on log Nominal GDP per capita

	(1) hyogo	(2) hyogo	(3) hyogo	(4) hyogo
miyagi	-0.158	-0.126		
	(0.197)	(0.176)		
tochigi	0.0708			
	(0.189)			
toyama	0.416^{**}	0.444^{**}	0.383^{***}	0.418^{***}
	(0.149)	(0.125)	(0.0903)	(0.0785)
shimane	0.148	0.134	0.0979	
	(0.140)	(0.133)	(0.123)	
oita	0.426^{**}	0.451^{***}	0.420^{***}	0.484^{***}
	(0.139)	(0.120)	(0.111)	(0.0759)
_cons	0.133^{***}	0.136^{***}	0.143^{***}	0.124^{***}
	(0.0366)	(0.0348)	(0.0331)	(0.0226)
N	39	39	39	39
adj. R^2	1.000	1.000	1.000	1.000
BIC	-165.5	-169.0	-172.1	-175.1

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 13: OLS regressions based on log Nominal GDP

	(1) hyogo	(2) hyogo	(3) hyogo	(4) hyogo
ishikawa	0.468^{*}	0.459^{**}	0.446^{***}	0.458^{***}
	(0.185)	(0.147)	(0.115)	(0.0905)
nagano	-0.0235	-0.0257		
	(0.182)	(0.178)		
gifu	-0.0165			
	(0.200)			
tokushima	0.0328	0.0306	0.0312	
	(0.178)	(0.173)	(0.171)	
ehime	0.563^{**}	0.559^{**}	0.544^{***}	0.563^{***}
	(0.188)	(0.180)	(0.143)	(0.0978)
_cons	1.158^{***}	1.156^{***}	1.174^{***}	1.151^{***}
	(0.230)	(0.225)	(0.183)	(0.128)
N	39	39	39	39
adj. R^2	1.000	1.000	1.000	1.000
BIC	-162.8	-166.5	-170.1	-173.7

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 14: Actual, counterfactual, and economic impact based on log real GDP per capita

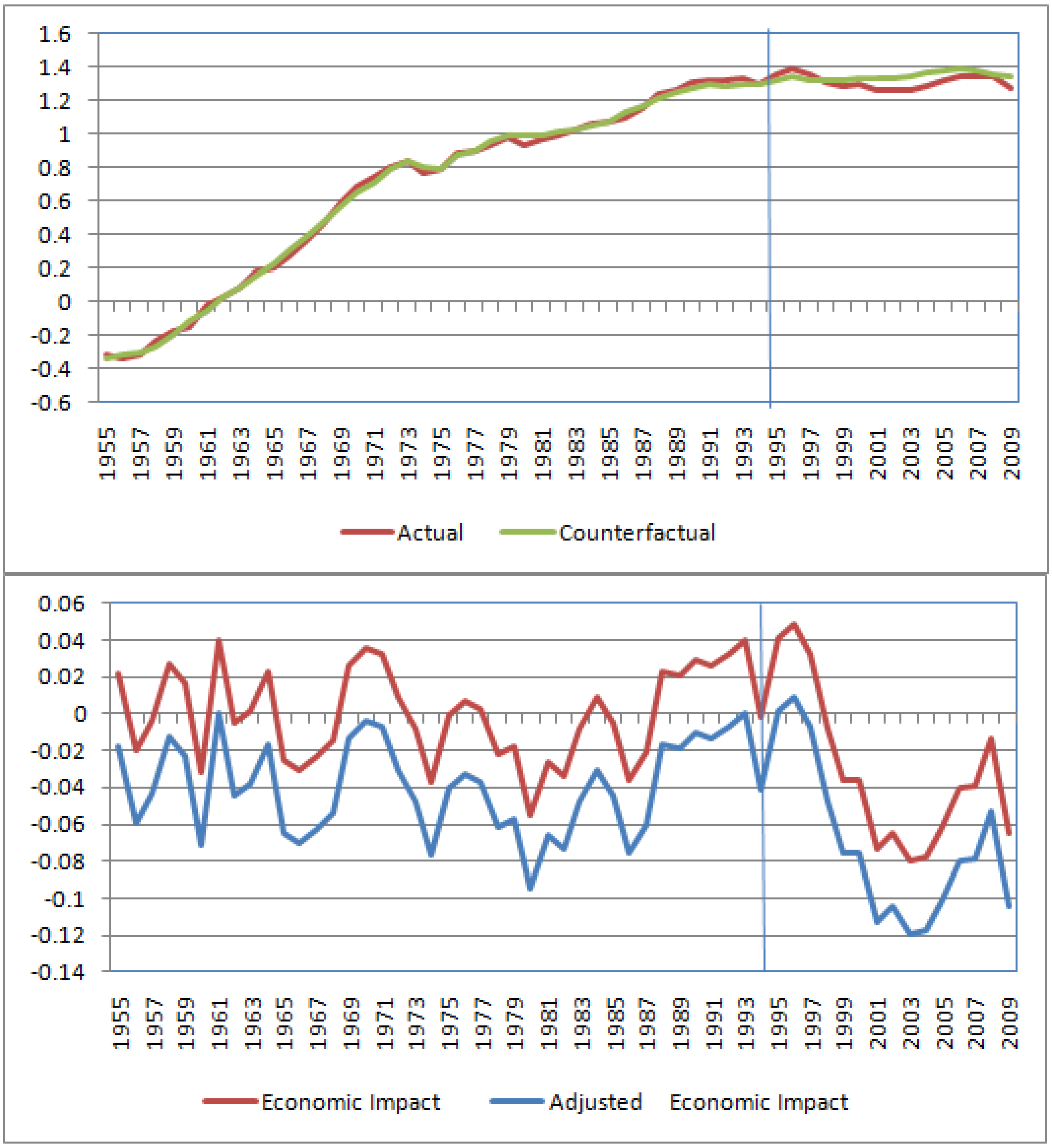


Chart 15: Actual, counterfactual, and economic impact based on log real GDP

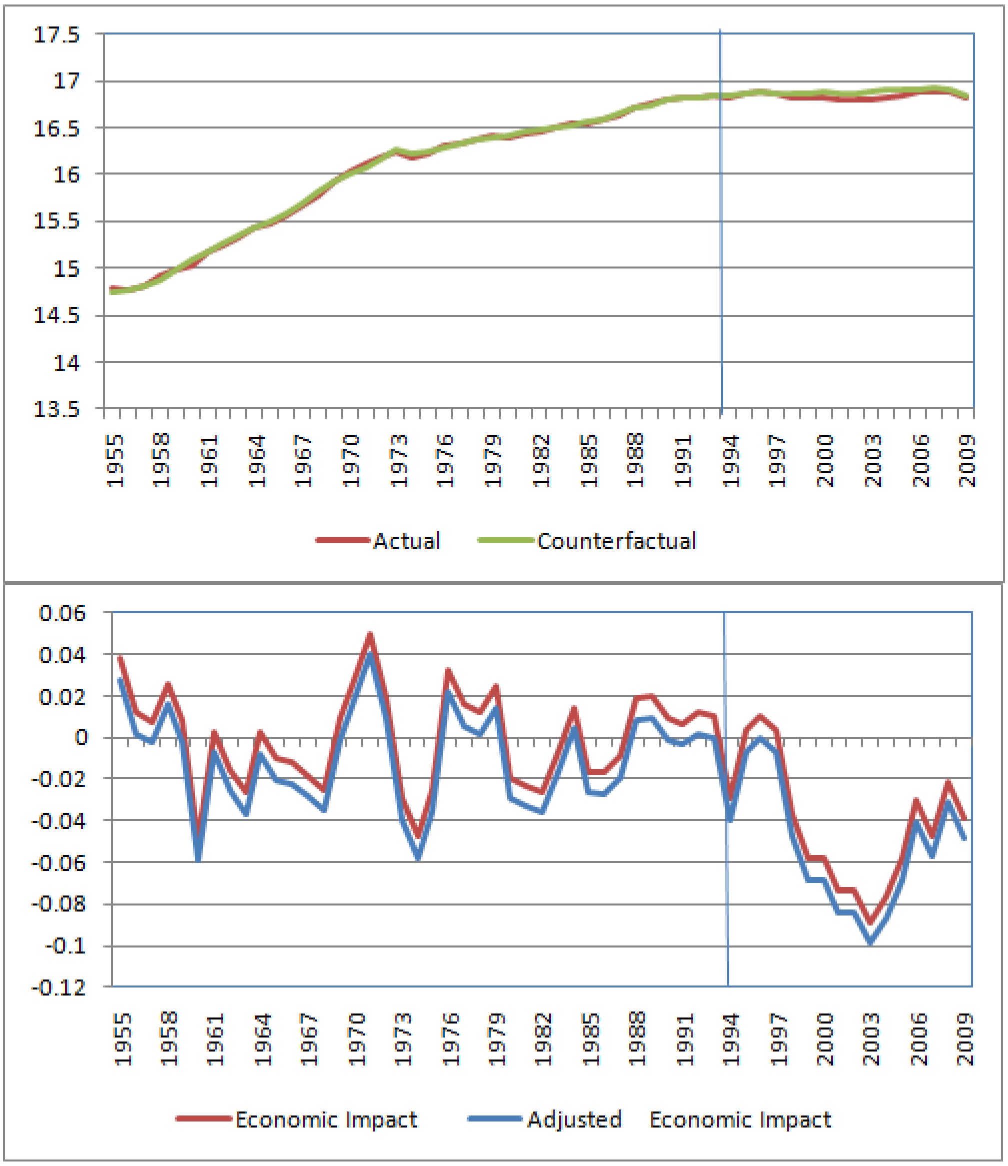


Chart 16: Actual, counterfactual, and economic impact based on log Nominal GDP per capita

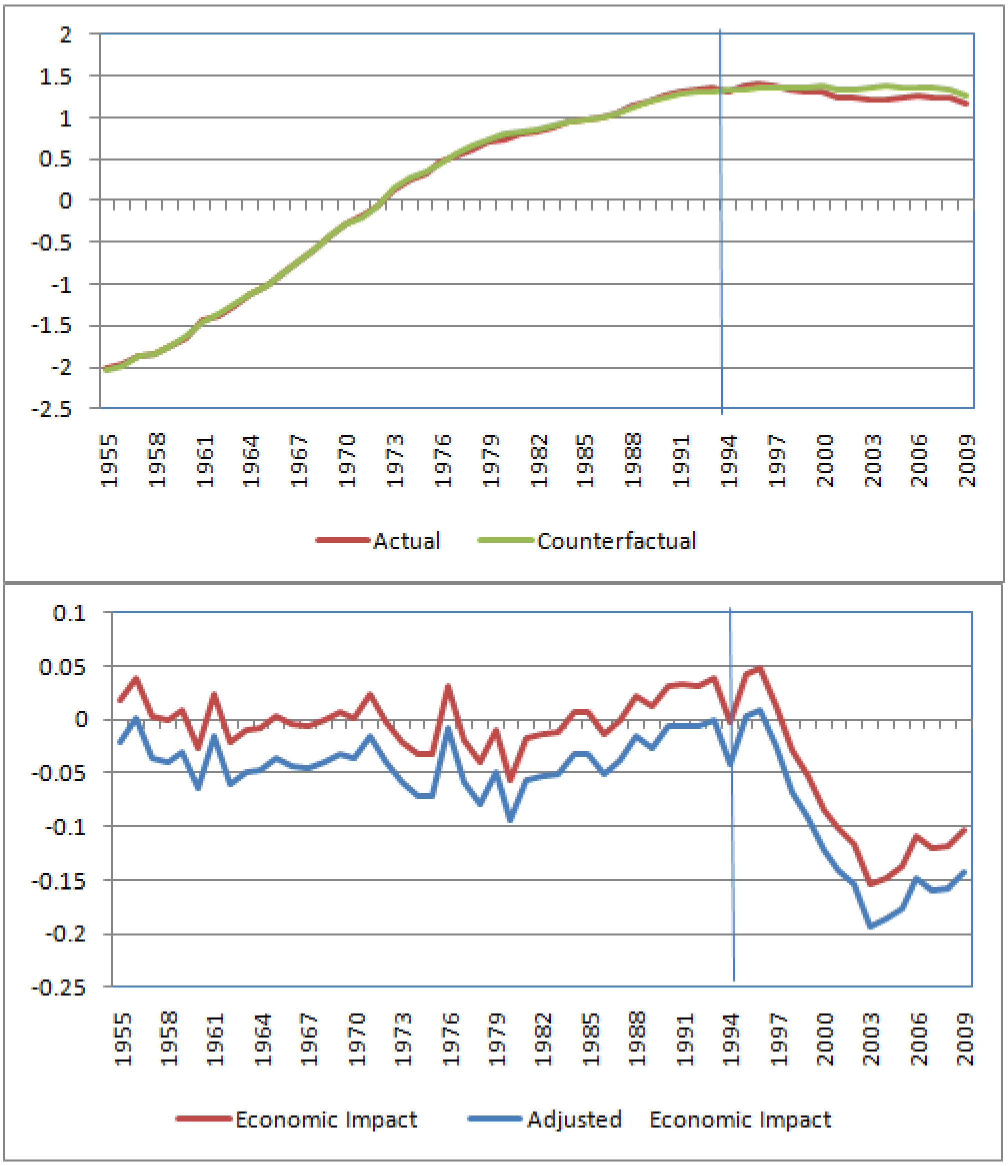


Chart 17: Actual, counterfactual, and economic impact based on log Nominal GDP

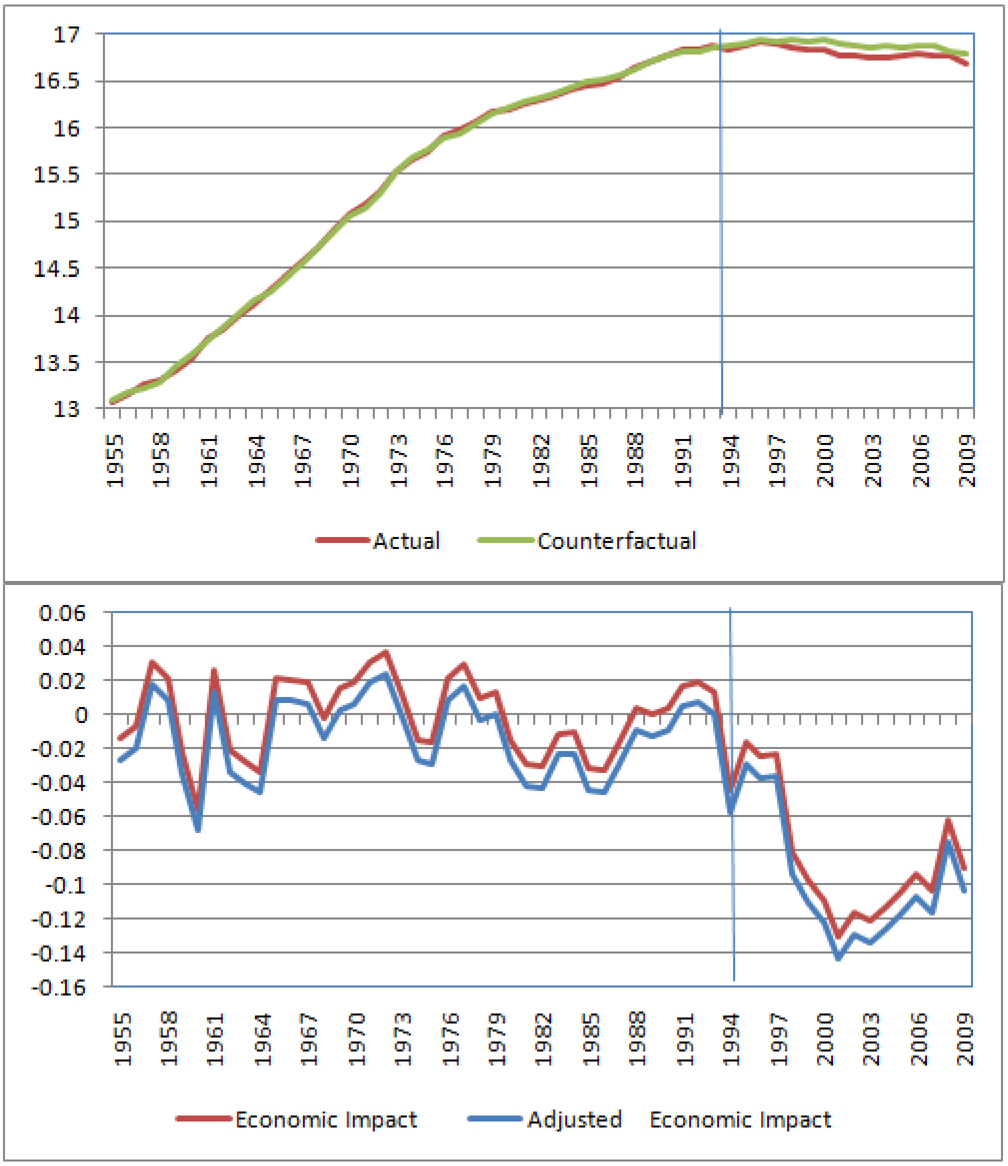
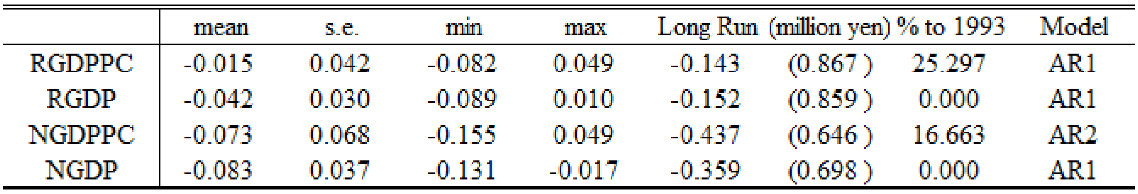


Chart 18 Summary statistics of Economic Impacts

Original series



	mean	s.e.	min	max	Long Run	(million yen)	% to 1993	Model
RGDPPC	-0.015	0.042	-0.082	0.049	-0.143	(0.867)	25.297	AR1
RGDP	-0.042	0.030	-0.089	0.010	-0.152	(0.859)	0.000	AR1
NGDPPC	-0.073	0.068	-0.155	0.049	-0.437	(0.646)	16.663	AR2
NGDP	-0.083	0.037	-0.131	-0.017	-0.359	(0.698)	0.000	AR1

(Long run impacts are converted to Japanese yen)

Adjusted Series

	mean	s.e.	min	max	Long Run	(million yen)	% to 1993	Model
RGDPPC	-0.030	0.042	-0.079	0.049	0.041	(1.042)	27.483	AR1
RGDP	-0.042	0.030	-0.089	0.010	-0.113	(0.893)	0.000	AR1
NGDPPC	-0.112	0.068	-0.194	0.010	-0.222	(0.801)	20.661	AR2
NGDP	-0.096	0.037	-0.143	-0.029	-0.301	(0.740)	0.000	AR1

(Long run impacts are converted to Japanese yen)

Chart 19: Economic impacts short run and long run (RGDP, RGDP per capita)

RGDPPC			
_cons	-0.0307	-0.0357	-0.0405*
	(0.0283)	(0.0270)	(0.0173)
ARMA			
L.ar	0.785***	1.032**	0.838**
	(0.211)	(0.379)	(0.302)
L2.ar		-0.302	0.326
		(0.449)	(0.690)
L3.ar			-0.593
			(0.346)
sigma			
_cons	0.0246***	0.0238***	0.0207***
	(0.00501)	(0.00443)	(0.00402)
N	16	16	16
Q	4.3207	1.4138	2.7791
P-value df (6)	0.6334 (6)	0.9650 (6)	0.8360 (6)
BIC	-63.92	-61.98	-62.46

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

RGDP			
_cons	-0.0400*	-0.0436**	-0.0477***
	(0.0178)	(0.0146)	(0.00857)
ARMA			
L.ar	0.737***	0.967**	0.818**
	(0.176)	(0.303)	(0.267)
L2.ar		-0.302	0.225
		(0.295)	(0.395)
L3.ar			-0.564*
			(0.226)
Sigma			
_cons	0.0187***	0.0179***	0.0151***
	(0.00491)	(0.00432)	(0.00327)
N	16	16	16
Q	5.3605	3.1090	3.4573
p-value (df)	0.4985(6)	0.7950(6)	0.7496(6)
BIC	-72.85	-71.25	-72.74

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 20: Economic impacts short run and long run (Nominal GDP, Nominal GDP per capita)

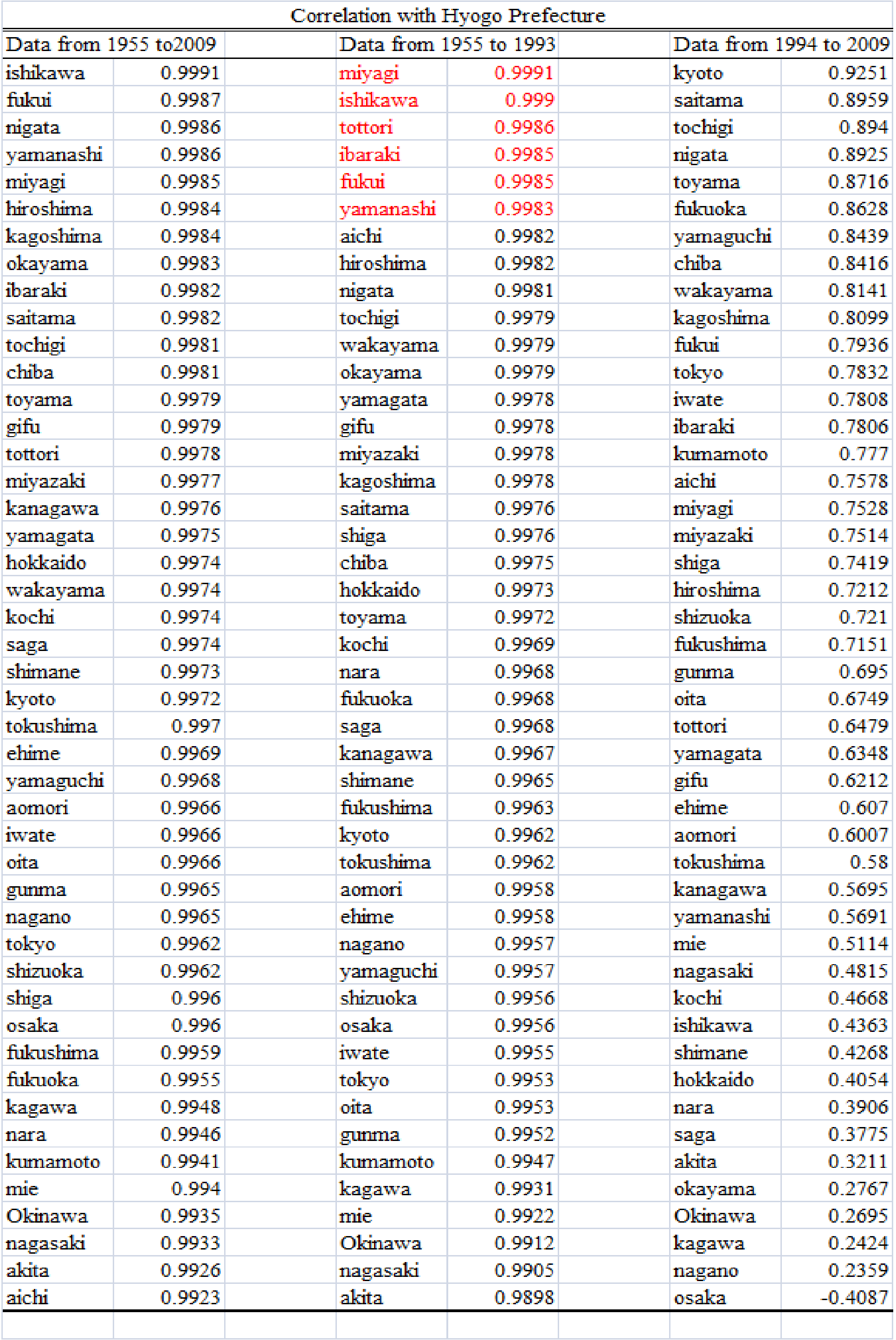
NGDPPC			
_cons	-0.0620	-0.0791**	-0.0808**
	(0.0487)	(0.0285)	(0.0269)
ARMA			
L.ar	0.912***	1.539***	1.456***
	(0.115)	(0.188)	(0.425)
L2.ar		-0.720***	-0.530
		(0.174)	(0.817)
L3.ar			-0.131
			(0.501)
Sigma			
_cons	0.0251***	0.0189***	0.0187***
	(0.00607)	(0.00439)	(0.00455)
N	16	16	16
Q	8.9224	2.0860	3.1040
p-value (df)	0.1780(6)	0.9116(6)	0.7957(6)
BIC	-62.47	-67.38	-64.83

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

NGDP			
_cons	-0.0783***	-0.0788***	-0.0860***
	(0.0220)	(0.0217)	(0.0135)
ARMA			
L.ar	0.782***	0.802*	0.742**
	(0.182)	(0.328)	(0.265)
L2.ar		-0.0269	0.494
		(0.328)	(0.408)
L3.ar			-0.629**
			(0.224)
Sigma			
_cons	0.0217***	0.0217***	0.0178**
	(0.00529)	(0.00532)	(0.00562)
N	16	16	16
Q	5.0415	4.6807	3.7591
p-value (df)	0.5385(6)	0.5854(6)	0.7092(6)
BIC	-67.87	-65.11	-67.24

Standard errors in parentheses * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 21: Correlation with Hyogo Prefecture based on log real private consumption per capita



Correlation with Hyogo Prefecture					
Data from 1955 to2009		Data from 1955 to 1993		Data from 1994 to 2009	
ishikawa	0.9991	miyagi	0.9991	kyoto	0.9251
fukui	0.9987	ishikawa	0.999	saitama	0.8959
nigata	0.9986	tottori	0.9986	tochigi	0.894
yamanashi	0.9986	ibaraki	0.9985	nigata	0.8925
miyagi	0.9985	fukui	0.9985	toyama	0.8716
hiroshima	0.9984	yamanashi	0.9983	fukuoka	0.8628
kagoshima	0.9984	aichi	0.9982	yamaguchi	0.8439
okayama	0.9983	hiroshima	0.9982	chiba	0.8416
ibaraki	0.9982	nigata	0.9981	wakayama	0.8141
saitama	0.9982	tochigi	0.9979	kagoshima	0.8099
tochigi	0.9981	wakayama	0.9979	fukui	0.7936
chiba	0.9981	okayama	0.9979	tokyo	0.7832
toyama	0.9979	yamagata	0.9978	iwate	0.7808
gifu	0.9979	gifu	0.9978	ibaraki	0.7806
tottori	0.9978	miyazaki	0.9978	kumamoto	0.777
miyazaki	0.9977	kagoshima	0.9978	aichi	0.7578
kanagawa	0.9976	saitama	0.9976	miyagi	0.7528
yamagata	0.9975	shiga	0.9976	miyazaki	0.7514
hokkaido	0.9974	chiba	0.9975	shiga	0.7419
wakayama	0.9974	hokkaido	0.9973	hiroshima	0.7212
kochi	0.9974	toyama	0.9972	shizuoka	0.721
saga	0.9974	kochi	0.9969	fukushima	0.7151
shimane	0.9973	nara	0.9968	gunma	0.695
kyoto	0.9972	fukuoka	0.9968	oita	0.6749
tokushima	0.997	saga	0.9968	tottori	0.6479
ehime	0.9969	kanagawa	0.9967	yamagata	0.6348
yamaguchi	0.9968	shimane	0.9965	gifu	0.6212
aomori	0.9966	fukushima	0.9963	ehime	0.607
iwate	0.9966	kyoto	0.9962	aomori	0.6007
oita	0.9966	tokushima	0.9962	tokushima	0.58
gunma	0.9965	aomori	0.9958	kanagawa	0.5695
nagano	0.9965	ehime	0.9958	yamanashi	0.5691
tokyo	0.9962	nagano	0.9957	mie	0.5114
shizuoka	0.9962	yamaguchi	0.9957	nagasaki	0.4815
shiga	0.996	shizuoka	0.9956	kochi	0.4668
osaka	0.996	osaka	0.9956	ishikawa	0.4363
fukushima	0.9959	iwate	0.9955	shimane	0.4268
fukuoka	0.9955	tokyo	0.9953	hokkaido	0.4054
kagawa	0.9948	oita	0.9953	nara	0.3906
nara	0.9946	gunma	0.9952	saga	0.3775
kumamoto	0.9941	kumamoto	0.9947	akita	0.3211
mie	0.994	kagawa	0.9931	okayama	0.2767
Okinawa	0.9935	mie	0.9922	Okinawa	0.2695
nagasaki	0.9933	Okinawa	0.9912	kagawa	0.2424
akita	0.9926	nagasaki	0.9905	nagano	0.2359
aichi	0.9923	akita	0.9898	osaka	-0.4087

Chart 22: Actual, counterfactual, and economic impact based on log real private consumption per capita

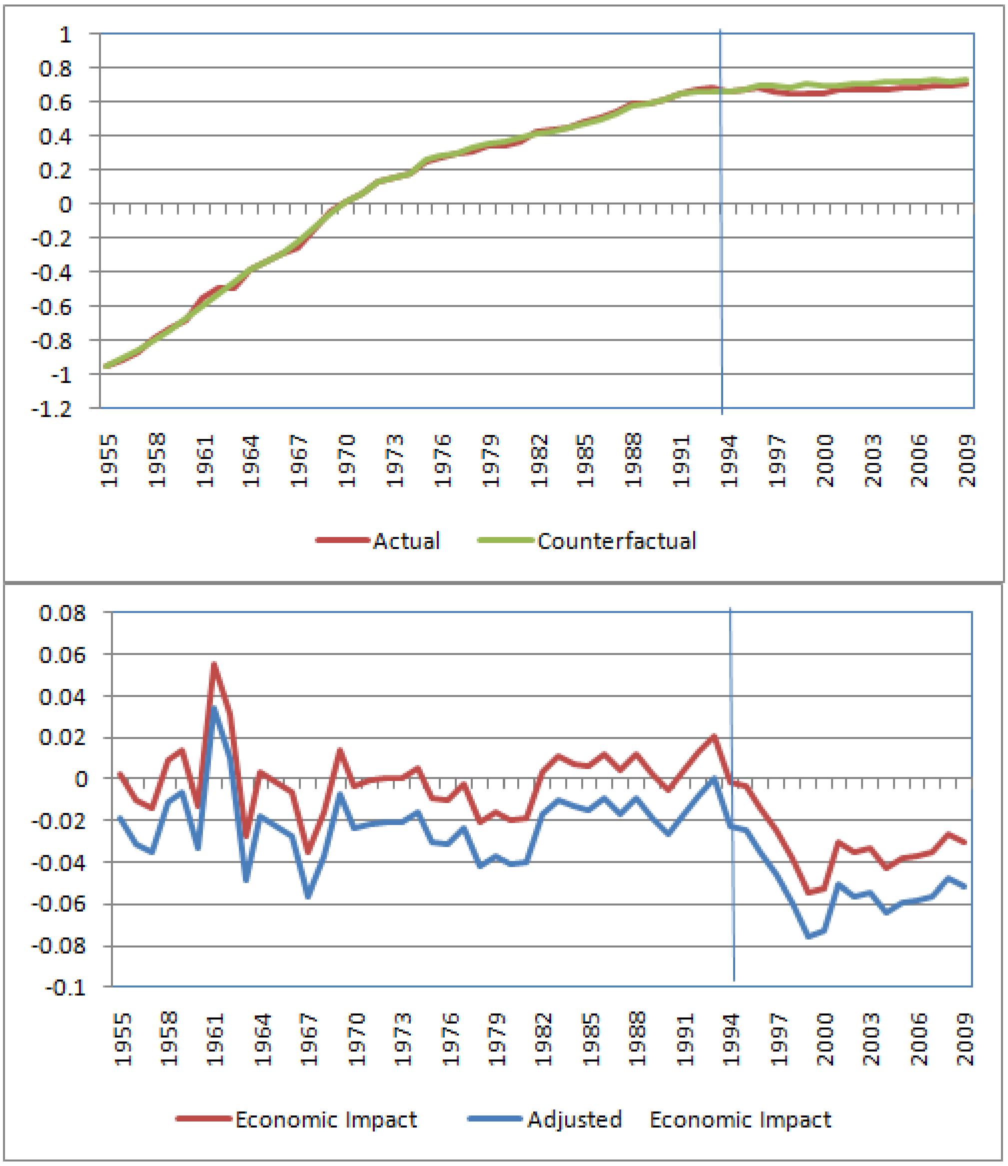


Chart 23: Actual, counterfactual, and economic impact based on log real private consumption

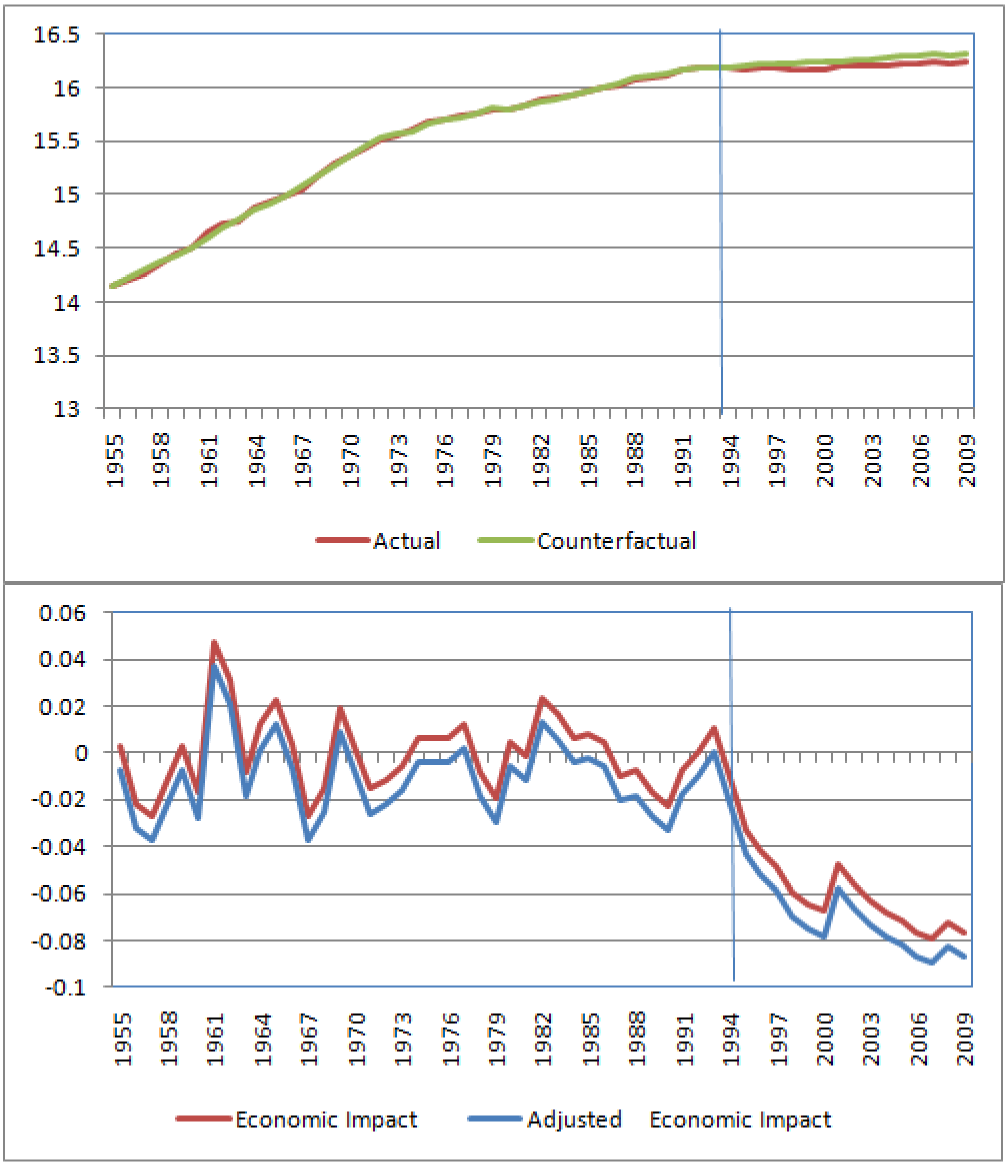


Chart 24: Actual, counterfactual, and economic impact based on log private consumption per capita

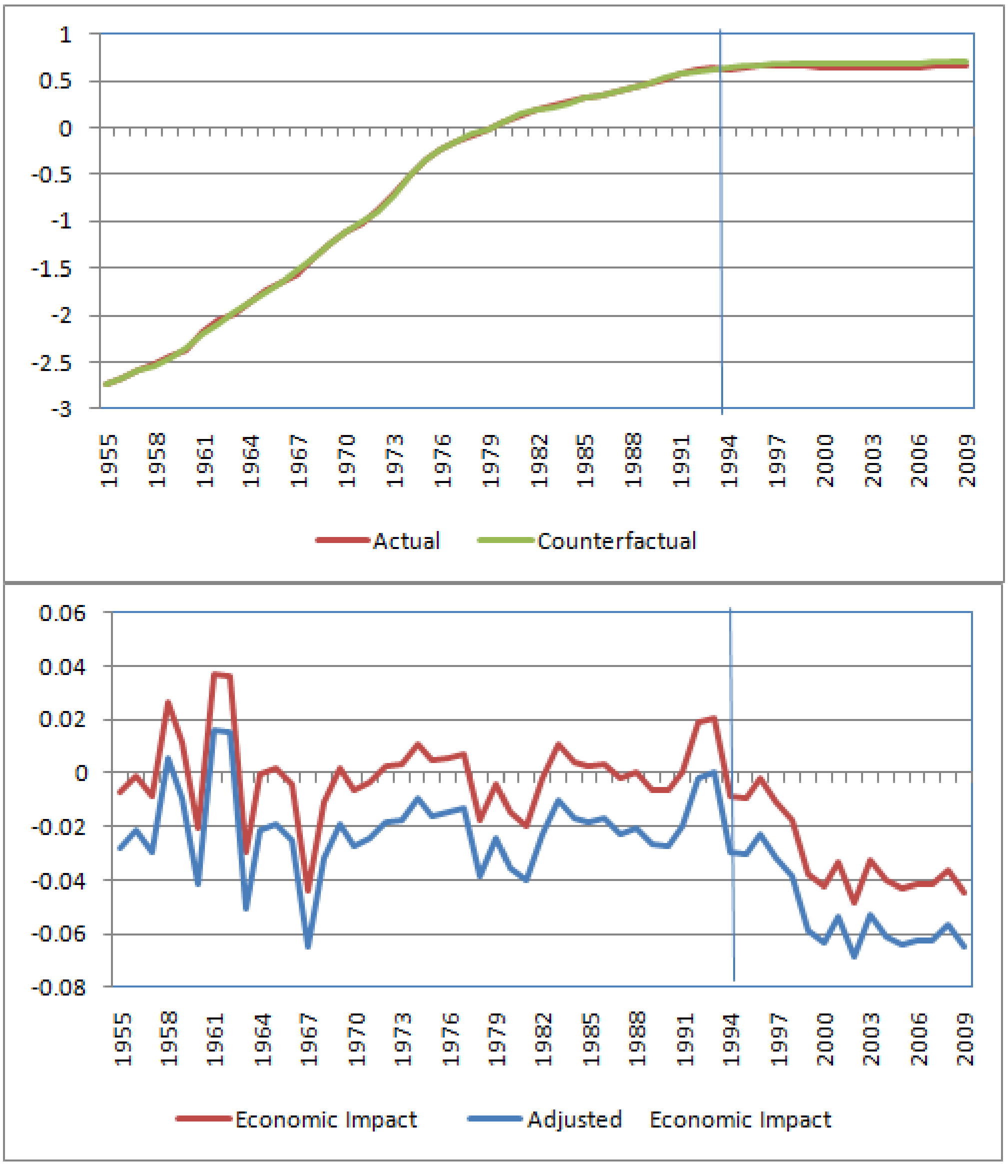


Chart 25: Actual, counterfactual, and economic impact based on log private consumption

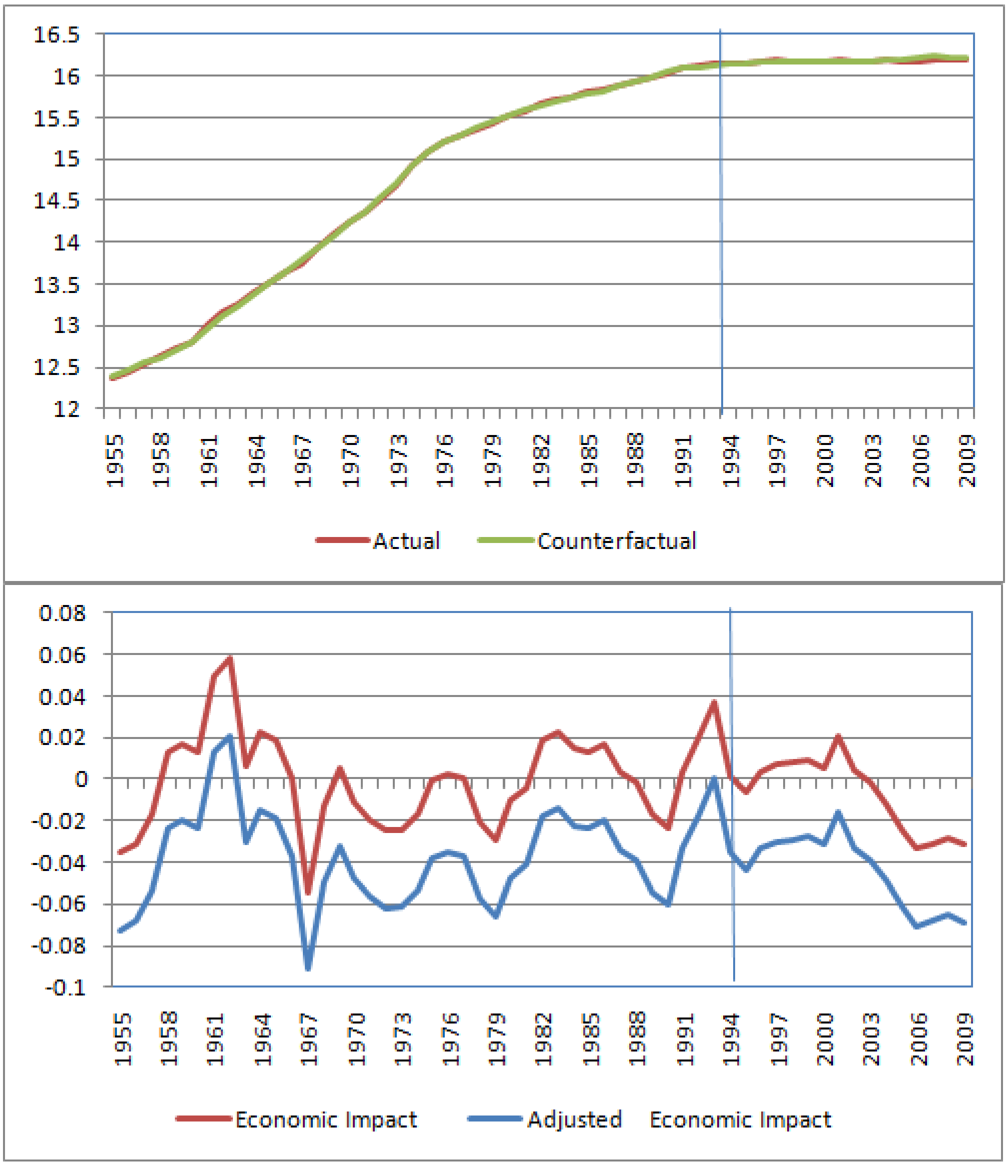


Chart 26 Summary statistics of Economic Impacts and Long Run Effects

Economic impact

	mean	s.e.	min	max	Long Run	(million yen)	% to 1993	Model
RCPC	-0.031	0.015	-0.055	-0.002	-0.135	(0.874)	44.148	AR1
RC	-0.059	0.018	-0.079	-0.011	-0.737	(0.479)	0.000	AR1
NCPC	-0.031	0.015	-0.048	-0.002	-0.158	(0.854)	44.906	AR1
NC	-0.007	0.018	-0.033	0.021	-0.086	(0.918)	0.000	AR1

Adjusted economic impact

	mean	s.e.	min	max	Long Run	(million yen)	% to 1993	Model
RCPC	-0.052	0.015	-0.076	-0.023	-0.026	(0.974)	49.211	AR(1)
RC	-0.069	0.018	-0.089	-0.021	-0.582	(0.559)	0.000	AR(1)
NCPC	-0.051	0.015	-0.069	-0.023	-0.045	(0.956)	50.256	AR(1)
NC	-0.044	0.018	-0.070	-0.016	0.212	(1.237)	0.000	AR(1)

Chart 27: Actual, counterfactual, and economic impact based on log per capita construction

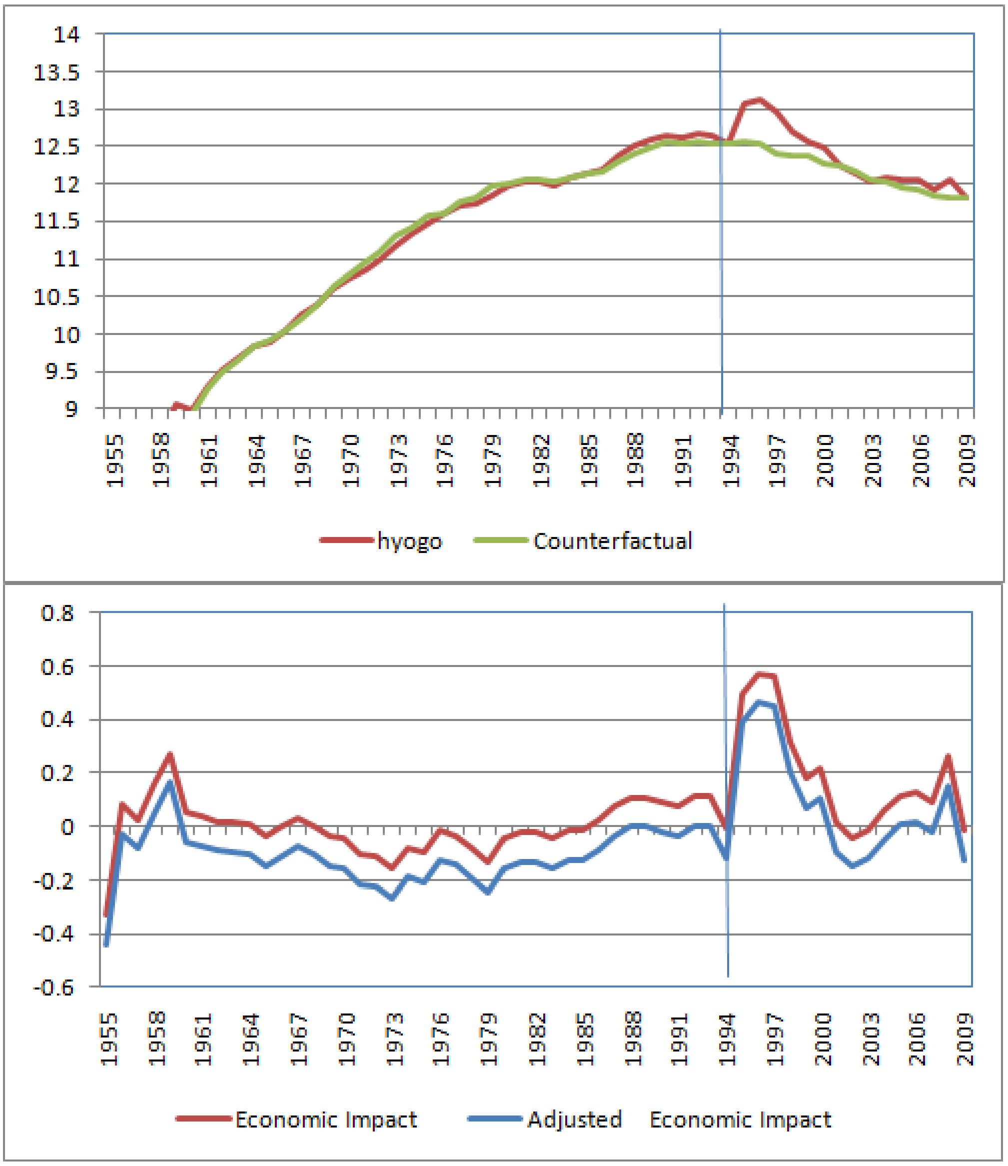


Chart 28: Actual, counterfactual, and economic impact based on log per capita wholesale and retail

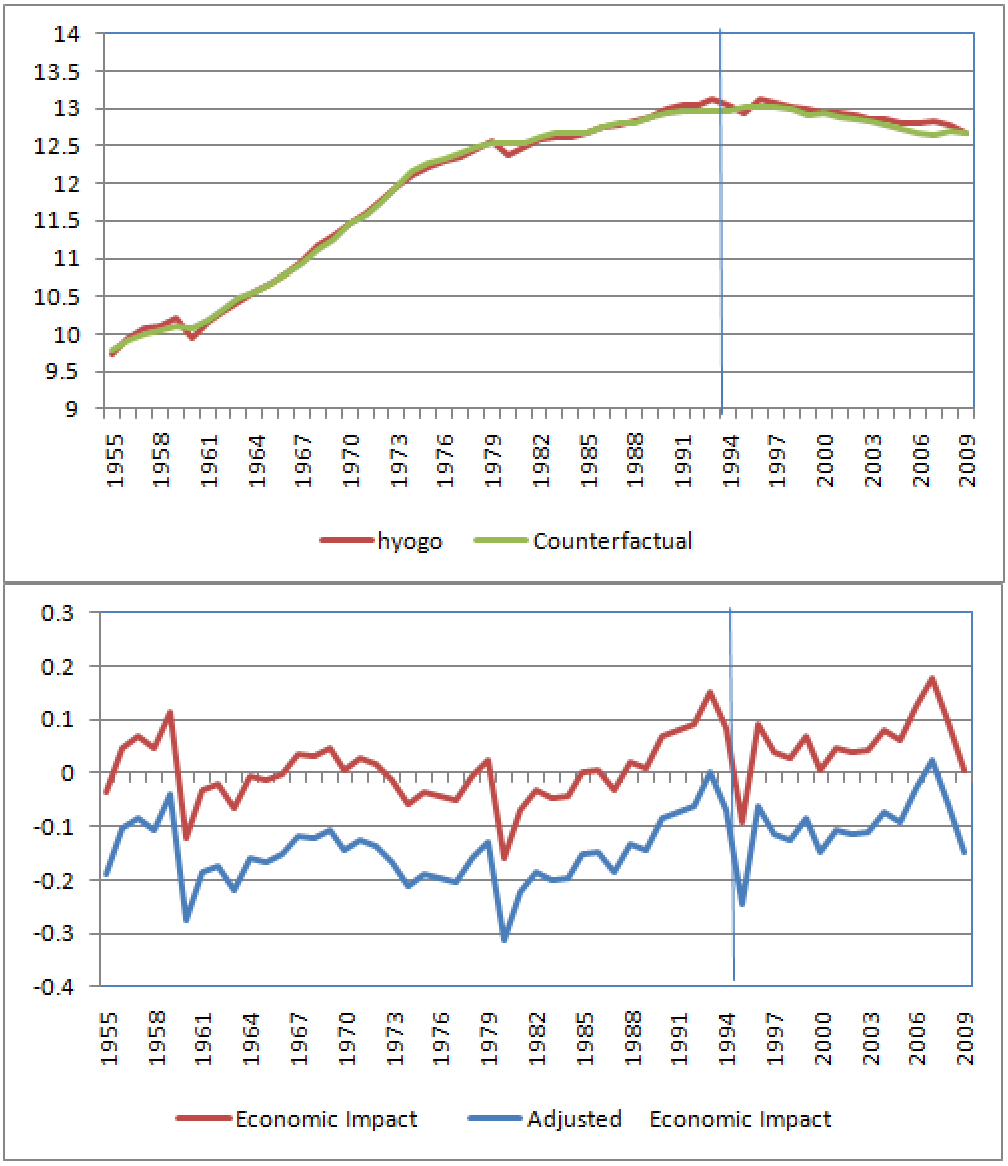


Chart 29: Actual, counterfactual, and economic impact based on log per capita services

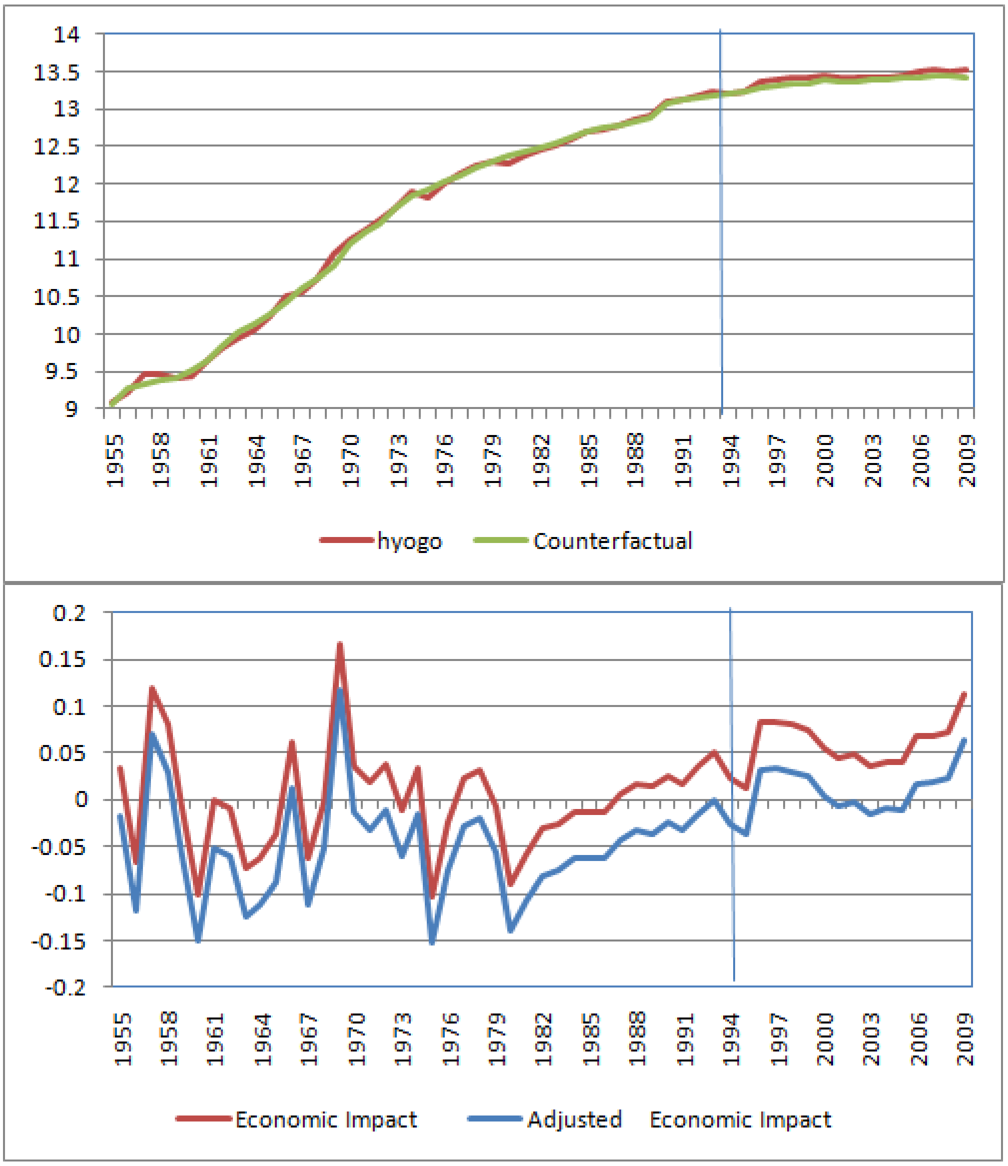


Chart 30 Number of Arriving Ships in Kobe Port

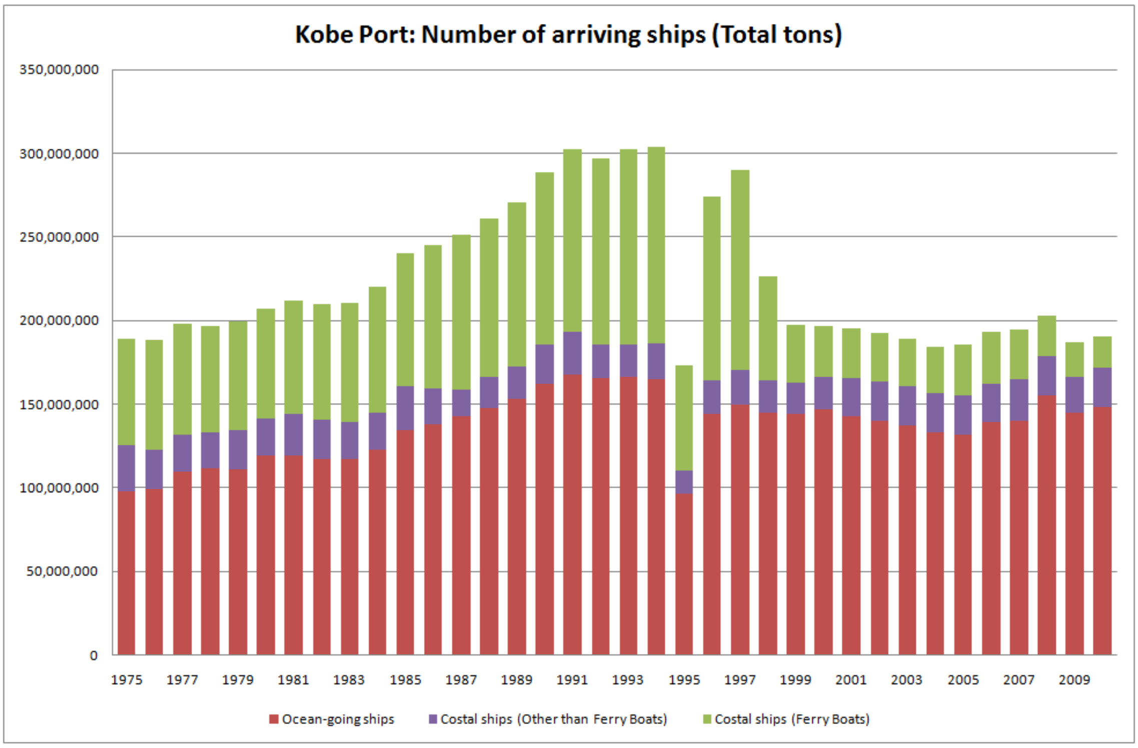


Chart 31 Transshipments in Kobe Port

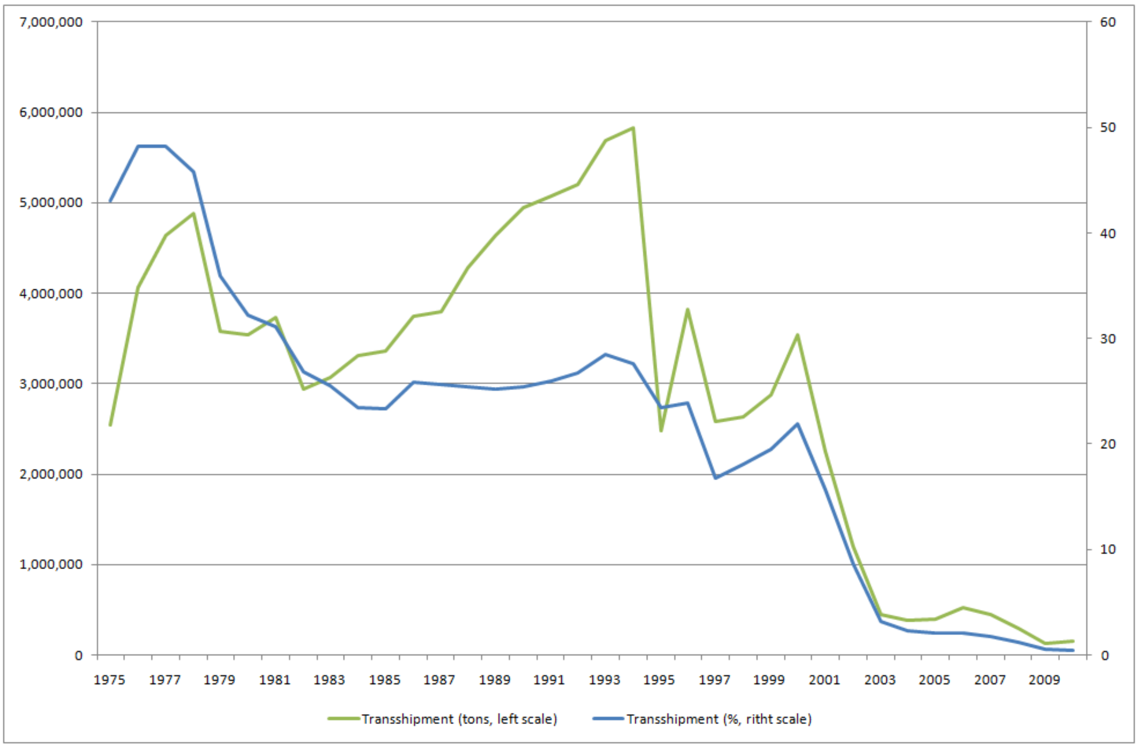


Chart 32: Choice of T2 and the Changes in the Backcasts

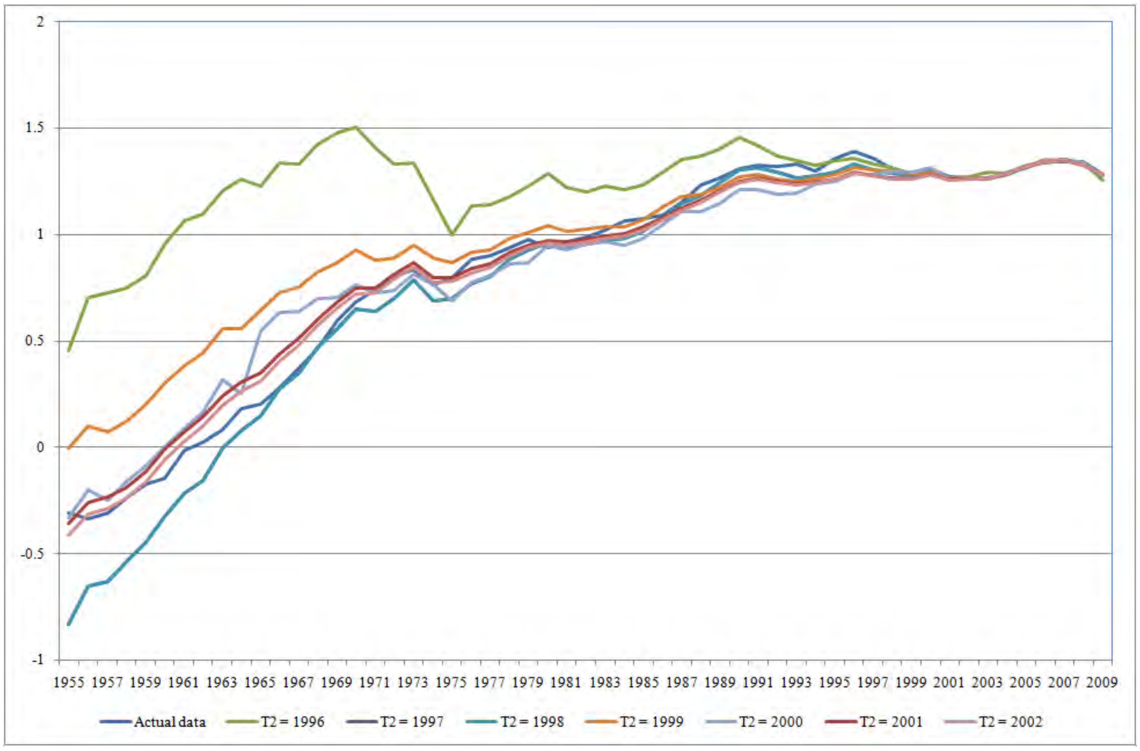


Chart 33: Backcast Moldel for Hyogo log RGDPPC, T_2=2000

	(1) hyogo	(2) hyogo	(3) hyogo	(4) hyogo	(5) hyogo
kanagawa	1.416*	1.352*	1.328**	0.861*	0.582*
	(0.294)	(0.254)	(0.257)	(0.225)	(0.174)
mie	-0.134				
	(0.192)				
kagoshima	0.686	0.617			
	(0.644)	(0.580)			
fukushima	0.552	0.524*	0.571**	0.404*	0.259*
	(0.134)	(0.117)	(0.110)	(0.116)	(0.0891)
okayama	-0.504	-0.547	-0.475		
	(0.239)	(0.210)	(0.203)		
hiroshima	-0.987	-1.051	-0.761*	-0.537	
	(0.414)	(0.367)	(0.250)	(0.319)	
_cons	0.139	0.298	0.467*	0.350	0.164
	(0.319)	(0.203)	(0.129)	(0.164)	(0.138)
N	9	9	9	9	9
adj. R^2	0.975	0.980	0.979	0.960	0.948
BIC	-65.45	-65.69	-65.01	-59.41	-57.56

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 34: Estimated Models for Hypothetically Generated Hyogo log RGDPPC

	(1) hyogob2000	(2) hyogob2000	(3) hyogob2000	(4) hyogob2000
saitama	1.046^{**}	1.138^{***}	1.128^{***}	1.293^{***}
	(0.323)	(0.266)	(0.263)	(0.243)
osaka	0.184			
	(0.356)			
nara	0.343	0.398	0.365	
	(0.276)	(0.252)	(0.243)	
chiba	-1.005^{**}	-0.973^{**}	-1.016^{**}	-0.916^{**}
	(0.326)	(0.317)	(0.306)	(0.304)
ehime	-0.174	-0.168		
	(0.277)	(0.273)		
miyazaki	0.479^{*}	0.458^{*}	0.383^{*}	0.403^{*}
	(0.217)	(0.211)	(0.170)	(0.173)
_cons	0.349	0.450^{***}	0.433^{***}	0.438^{***}
	(0.197)	(0.0305)	(0.0134)	(0.0130)
N	39	39	39	39
adj. R^2	0.986	0.986	0.987	0.986
BIC	-100.4	-103.7	-106.9	-108.1

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 35: Plot of the Net Earthquake Effects, Structural Change Effects and Combined Effects for Hyogo log RGPPC

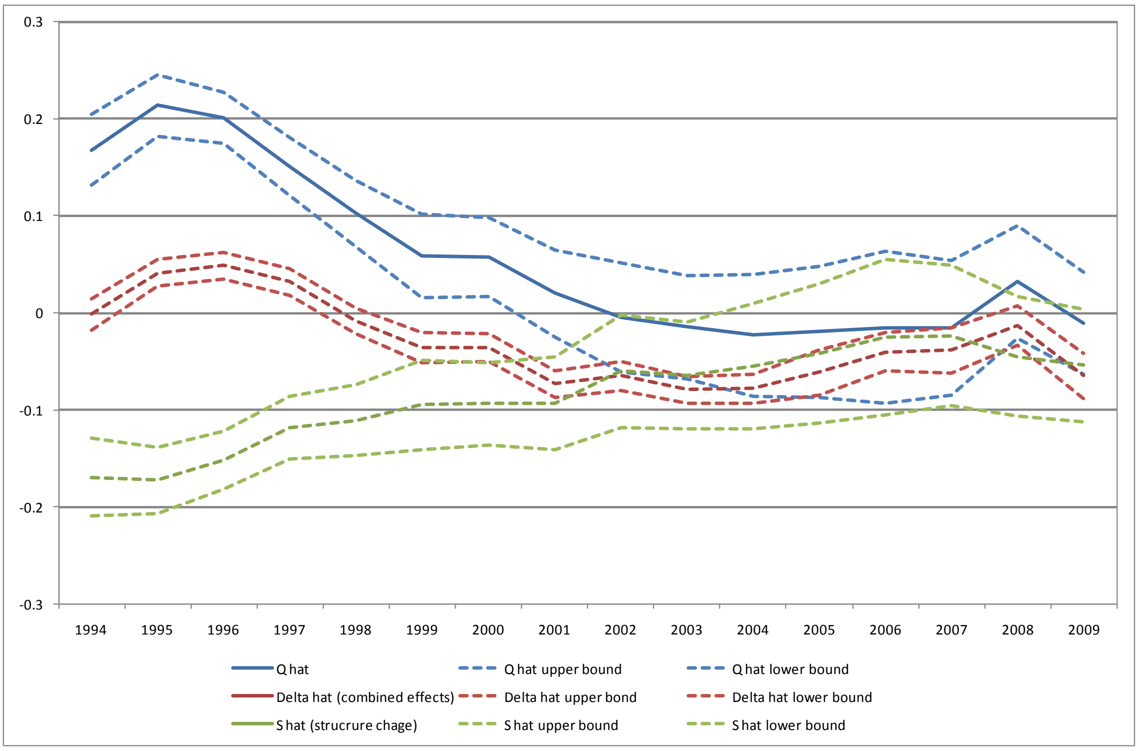


Chart 36: Backcast Model for Hyogo log RGDP, T_2=2000

	(1)	(2)	(3)	(4)	(5)	(6)
	hyogo	hyogo	hyogo	hyogo	hyogo	hyogo
kanagawa	0.761	0.518	0.615	0.916*	1.155*	0.835***
	(0.783)	(0.473)	(0.464)	(0.315)	(0.331)	(0.0711)
fukushima	0.365	0.412	0.405	0.401		
	(0.291)	(0.231)	(0.231)	(0.227)		
mie	0.489	0.588	0.508			
	(0.702)	(0.569)	(0.564)			
aichi	-0.695	-0.845	-0.687	-0.352	-0.192	
	(0.625)	(0.447)	(0.419)	(0.189)	(0.193)	
hiroshima	-0.262					
	(0.596)					
okayama	0.178	0.252				
	(0.338)	(0.251)				
_cons	3.607	2.695	3.630	0.705	0.186	2.385
	(5.172)	(4.049)	(3.945)	(2.203)	(2.540)	(1.230)
N	9	9	9	9	9	9
adj. R^2	0.942	0.958	0.958	0.959	0.945	0.945
BIC	-57.44	-58.81	-58.39	-58.93	-56.76	-57.59

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 37: Predicted Models for Hypothetic Hyogo Log RGDP

	(1) hyogob2001	(2) hyogob2001	(3) hyogob2001
osaka	0.668^{***}	0.684^{***}	0.692^{***}
	(0.0504)	(0.0448)	(0.0446)
oita	0.358^{**}	0.319^{**}	0.423^{***}
	(0.113)	(0.1000)	(0.0509)
shiga	-0.0642		
	(0.0852)		
shizuoka	0.161	0.103	
	(0.116)	(0.0856)	
_cons	-2.003^{***}	-1.744^{***}	-1.761^{***}
	(0.367)	(0.128)	(0.128)
N	39	39	39
adj. R^2	0.998	0.998	0.998
BIC	-138.8	-141.8	-143.9

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Chart 38: Plot of the net Earthquake Effects, Structural Change Effects and Combined Effects for Hyogo log RGDP

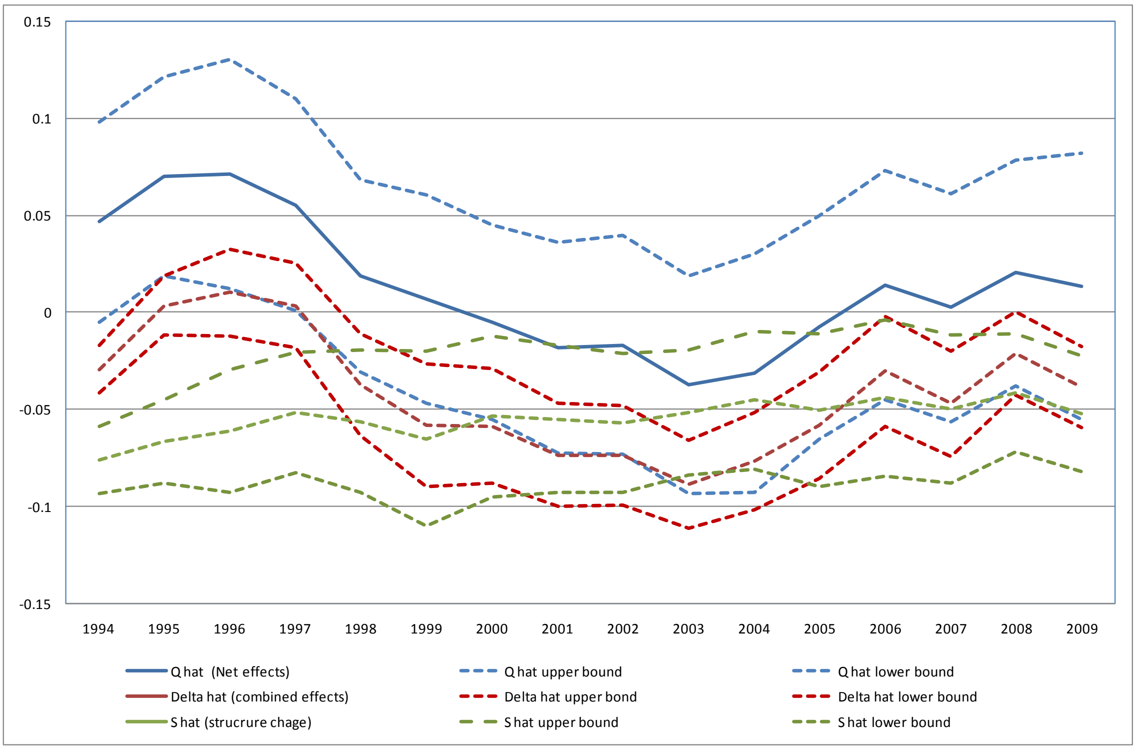


Chart 39: Estimated Stock Adjustment Model for log Hyogo real GDP

	(1) hyogo	(2) hyogo	(3) hyogo	(4) hyogo	(5) hyogo	(6) hyogo
L.hyogo	-0.0423	-0.0455	-0.119	-0.116	0.180	0.224
	(0.221)	(0.188)	(0.143)	(0.143)	(0.133)	(0.104)
kanagawa	1.479	1.457^{*}	1.301^{**}	1.111^{***}	0.799^{**}	0.888^{***}
	(0.505)	(0.362)	(0.260)	(0.178)	(0.193)	(0.108)
miyagi	-0.523	-0.504	-0.353			
	(0.559)	(0.437)	(0.350)			
kagoshima	-0.495	-0.530				
	(1.022)	(0.801)				
saga	-0.0328					
	(0.416)					
fukushima	0.662	0.666^{*}	0.656^{*}	0.614^{*}	0.0618	
	(0.271)	(0.231)	(0.218)	(0.214)	(0.109)	
mie	-0.427	-0.426	-0.552^{*}	-0.539^{*}		
	(0.324)	(0.281)	(0.195)	(0.194)		
_cons	0.386	0.388	0.0742	-0.104	-0.0794	-0.169
	(0.620)	(0.537)	(0.236)	(0.156)	(0.218)	(0.145)
N	11	11	11	11	11	11
adj. R^2	0.931	0.948	0.954	0.954	0.909	0.917
BIC	-68.28	-70.65	-71.91	-72.28	-65.60	-67.50

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$