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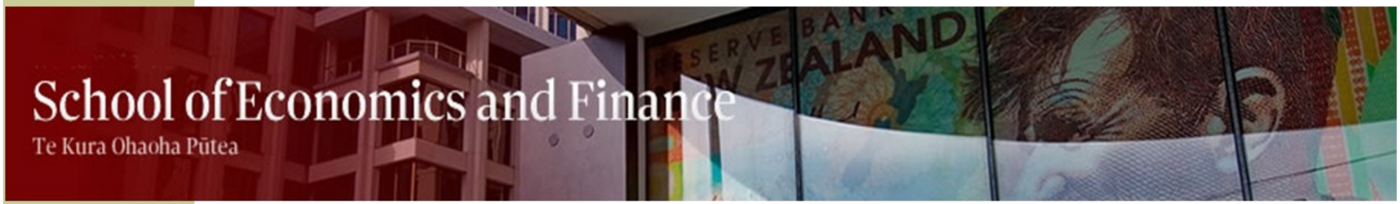

SEF Working paper: 09/2012
March 2012

What happened to Kobe? A reassessment of the impact of the 1995 earthquake in Japan

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Working Paper 09/2012

ISSN 2230-259X (Print)

ISSN 2230-2603 (Online)

What happened to Kobe?

A reassessment of the impact of the 1995 earthquake in Japan

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(March, 2012)

Abstract: The received wisdom is that the devastation wrought by the 1995 Kobe earthquake did not have any long-term impact on the Japanese economy, nor much impact on Kobe itself. We re-evaluate the evidence using a new methodology, synthetic control, and find a persistent and still continuing adverse impact of the quake on the economy of Kobe more than 15 years after the event. Using the methodology developed by Abadie et al. (2010), we construct counter-factual dynamics for the Kobe economy. We identify a decline in per capita GDP that is attributable to the quake and is persistent, long-term, and clearly observable even 15 years after the quake. GDP per capita in 2007 was 500,000 yen per person lower (13% decrease) than it would have been had the earthquake not occurred. Importantly, this adverse long-term impact is identified in a wealthy region of a developed country, and with the backing of a deep-pocketed fiscal authority.

JEL: O11, Q54, Q56, R11

Key words: Natural disaster, earthquake, Kobe, Great Hanshin, long-run impact

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What happened to Kobe? A reassessment of the impact of the 1995 earthquake in Japan

"Although the Kobe earthquake was an urban natural disaster of unprecedented economic magnitude, recovery proceeded with generally unexpected speed….these responses appear to have led the recovery and countered any macroimpact of the quake."

(Horwich, *Economic Development and Cultural Change*, 2000, p. 535)

1. Why Kobe?

The March 2011 catastrophic earthquake and tsunami in the Tohoku region of Japan has horrified all of us. In the weeks following this tragedy, there was much discussion in the media and among policymakers about the disaster's likely long-term economic impact. In any attempt to predict the impact on the region, the obvious comparison was the devastating earthquake that hit Kobe on January 17, 1995. At the time, this was the most destructive natural disaster to hit an industrial economy for many years. The received wisdom about the Kobe earthquake and its aftermath can be summarized with:

> "The quintessential example comes from Japan itself: in 1995, an earthquake levelled the port city of Kobe, which at the time was a manufacturing hub and the world's sixth-largest trading port. The quake killed sixty-four hundred people, left more than three hundred thousand homeless, and did more than a hundred billion dollars in damage (almost all of it uninsured). There were predictions that it would take years, if not decades, for Japan to recover. Yet twelve months after the disaster trade at the port had already returned almost to normal, and within fifteen months manufacturing was at ninety-eight per cent of where it would have been had the quake never happened."[1]
>
> James Surowiecki, The New Yorker, 3/28/2011

[1] Similarly: ""A 1995 earthquake in Kobe, Japan, caused an estimated $100 billion in damage. Within 15 months, manufacturing activity was back at 98 percent of its pre-quake levels, according to a 2000 paper by George Horwich, a professor at Purdue University. 'Destroy any amount of physical capital, but leave behind a critical number of knowledgeable human beings whose brains still house the culture and technology of a dynamic economy, and the physical capital will tend to re-emerge almost spontaneously,' Mr. Horwich wrote in the paper…" (Appelbaum, NY Times, 3/15/2011). Similar statements can be seen in other media, including the Wall Street Journal, The Economist, and the all-pervasive Wikipedia (accessed 1/17/2012).

Immediately after a previous catastrophic event, the 2004 tsunami in South-East Asia, Nobel Prize winner Gary Becker similarly wrote: ""The Kobe earthquake of 1995 killed over 6,000 persons, and destroyed more than 100,000 homes, still the economic recovery not only of Japan but also of the Kobe economy was rapid."

Much of this view can be traced to a paper by George Horwich published in *Economic Development and Cultural Change* that analyzed the Kobe event a few years afterwards. Horwich concluded that the devastation did not have much long-term impact on the Japanese economy, but like Becker later, further claimed that it did not have much impact on Kobe itself beyond the first couple of years.

Here, we re-evaluate the evidence to examine whether indeed the 1995 earthquake in Kobe had no long term economic impact on the Kobe region. Without spoiling too much, we already note that we believe 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. The subject of our investigation here, of course, is not only interesting for Japanese policymakers and the people of Kobe or, currently, Tohoku. The evidence we present is relevant for any assessment of the long term impact of any large exogenous adverse shock. It also informs us about the alternative ways people may respond to these shocks, and how these choices help shape future economic trajectories.

We use a methodological innovation recently formalized in Abadie, Diamond and Hainmueller (2010, henceforth ADH); a paper that investigated tobacco taxes in California. The methodology is based on simulating conditions after an exogenous event (in their case, a change in the tax rate) based on the relationship to a control group (other U.S. states). The ADH methodology presents an estimation technique that allows us to construct a no-disaster counterfactual and thus measure in detail the impact of the disaster itself.

Kobe is worth investigating with the ADH methodology for several reasons: (1) it was one of the largest disasters of the past 50 years, in terms of the monetary value of the direct destruction wreaked, and there is now a wealth of detailed post-disaster economic data that enables our long-horizon investigation; (2) the earthquake was both unexpected and unusually large, and thus clearly an exogenous event; (3) since destruction was limited to a very specific geographical region that is clearly associated with an administrative region, the other Japanese prefectures, which were not impacted at all, provide an ideal control group;[2] and (4) another careful look at Kobe will also provide us some clues about the likely long-term impact of the Tohoku/Sendai tsunami and about the future consequences of natural shocks that are likely to occur in Japan and elsewhere in the developed world.[3]

In the next section, we discuss relevant empirical work regarding the impacts of large disaster events. The interested reader can also consult a more comprehensive recent survey (Cavallo and Noy, 2011). In section 3 we describe the economy of the city of Kobe as well as the earthquake's initial impact. Section 4 details the ADH synthetic control methodology while section 5 describes the data. A results and conclusions section follows.

[2] The nearby city of Osaka was affected by the quake, even if relatively mildly; we do not use Osaka as part of our control group.

[3] There is a significant body of research that finds that disasters affect poorer developing countries much more adversely in the short-run. Thus, we view our findings about Kobe as a lower-bound in terms of the likely long term impact of a catastrophic event on a specific region in a developing/poorer country.

2. Economic consequences of large disasters

Research on disasters and their long-term impact on the economy is sparse with few papers interested in any long term trajectory or systematically examining the long-term dynamics of the economy following disaster events.[4] The difficulty, of course, is to separate developments, even if these involved dramatic shifts, from those that would have occurred even if the disaster had not.

Skidmore and Toya (2002), in a widely mentioned paper, find a positive association between disaster frequency and long-run GDP growth, which they interpret as caused by a creative destruction mechanism that leads to a speeding-up of adoption of new technologies and improvement in infrastructure. On the other hand, Noy and Nualsri (2007) and McDermott et al. (2011), for example, use panel data techniques and find, on average for developing countries, an adverse long-run effect on GDP growth.

One other paper, Cavallo et al. (2012) uses the same ADH methodology to examine the average impact on the national economy of catastrophic natural disasters using a cross-country group of disaster events. They conclude that the evidence (mentioned above) on a long-term adverse effect is driven by a few cases in which disasters were temporally associated, and possibly caused, a dramatic political regime change. The proto-type they identify is the large earthquake in Iran of 1978, which was then quickly followed by the Islamic Revolution of 1979

[4] A large number of papers examine the short-term impact of specific disaster case-studies; and there is some comparative research on the short-term impact of disasters more generally (e.g., Noy, 2009 and Strobl, 2012). All of these say little about any long-term impact.

and the Iran-Iraq war that started in 1980. Beside these events, they fail to find any evidence of a long-term impact of even very large disasters on national incomes (per capita).[5]

A series of papers, initially inspired by Davis and Weinstein (2002), investigated the long-term impact of large-scale war-related destruction using geographically-detailed bombing data from World War II Japan (Davis and Weinstein, 2008), the American-Vietnam War (Miguel and Roland, 2011), and Germany, also during WWII (Bosker et al., 2007). The first two papers failed to find any long term impact of the bombing campaigns on the distribution of economic activity; while the latter identifies evidence of long-term adverse impact of city destruction in Germany on city-size distribution.

To summarize, the literature on the long-term impact of economic shocks is inconclusive, but the weight of the evidence suggests no long-term impact of even catastrophic shocks at the national level. Papers that have examined longer run labor market effects have also failed to find any negative or positive impact beyond the first year. Several papers, however, do point to some potentially long-term impacts at the local/regional level.

On Kobe, as we already pointed out, the received wisdom is that the city recovered very quickly, and that there were no long term impacts of the earthquake on the local economy (except some re-distribution of population and economic activity across city districts; e.g., Aldrich, 2011). Chang (2010), and Beniya (2007) examine the time-series data for Kobe following the disaster, and measure the impact of the event by comparing the Kobe dynamics to what happen to the aggregate national economy (i.e., implicitly assuming the Kobe would

[5] Lack of data on small island states does raise the caveat that for these states disasters are comparatively much larger and therefore may impose long-term costs.

have followed nation-wide average trends without the disaster). Both papers note a long-term adverse effect on gross regional product of the Kobe region (this effect disappears by 2005 in the latter work); but given their methodological approach, the statistical robustness of either papers' findings is not well established.

3. Kobe and the 1995 earthquake – an economic overview

Kobe is located to the northwest of Osaka, the second largest city in Japan. Though it is, to some extent, part of the greater Osaka area, Kobe is a major city in its own right. Prior to the earthquake Kobe had a population of around 1.5 million, just over a quarter of Hyogo Prefecture's 5.47 million inhabitants. The economy of the city was mainly centered on Kobe's Port, which accounted for about 39% of its Gross Industrial Product and was ranked first in Japan and sixth worldwide in terms of cargo throughput (Chang, 2000). Additional prominent industries in 1995 included steel, sake, non-leather shoe manufacturing, tourism and fashion (Olshensky et al., 2005).

On January 17th, 1995, in the early morning, a short but powerful earthquake hit the city (the epicenter was 20 km away from the city). Over 6,400 people lost their lives, 4,571 in Kobe itself; the value of infrastructure and physical capital destroyed was evaluated at US$ 100 Billion; roughly 2.5% of Japanese GDP at the time. The port suffered severe damage from the earthquake, losing nearly all of its container berths. It was not until March 1997, over two years after the earthquake, that its capacity would be fully restored (Chang 2000). None of Kobe's major industries were spared. Many of the large manufacturers suffered damage to their factories, about 80% of non-leather shoes factories were damaged, and half of the sake breweries were severely damaged. Additionally one third of Kobe's shopping districts and one half its markets were heavily damaged. (City of Kobe, 2011)

Today, many of Kobe's important industries prior to the earthquake are still a large part of the city's economy, though many have not fully recovered. Though the port was completely rebuilt by March 1997—back to 98% capacity, as cited above—as of 2009 the number of cargo ships handled had still not returned to pre-earthquake levels, reaching a peak of 87.7% in 2008. Mining and manufacturing was only 81.3% compared to pre-earthquake levels, non-leather shoe production volume was only 60.4% of what it was as of November 2010. In October 2010, Sake breweries shipped less than 50% of what they did prior to the earthquake. Department stores have also not recovered; their sales as of November 2010 were only three quarters of what they were prior to the earthquake. Only tourism has seen any increase, in 2009 incoming tourists to the city were at 123.6% the level they were in 1994 (City of Kobe, 2011). These before-after changes, of course, cannot be confidently attributed to the quake; and could have been caused by other forces.

Using microeconomic household data, Sawada and Shimizutani (2008) show that credit constrained households persistently reduced post-quake consumption. Even if these observed changes were caused by the quake, they do not necessarily imply that the earthquake had any aggregate adverse effect on the local economy. It may well be the case that the quake speeded up the Schumpeterian creative destruction process, and that the declining industries should have been contracting for aggregate efficiency reasons. The received wisdom appears to be that this was indeed the case.

4. Methodology – synthetic control for comparative case studies

Kobe's earthquake occurred a few years after Japan had already entered a prolonged and painful recession—the 'lost decade' that followed the collapse of the real-estate and stock-market bubbles of the late 1980s. To separate the impact of the earthquake from the effect of the Japanese recession and accurately measure the impact of the disaster on Kobe's economy, a counterfactual scenario for Kobe without the earthquake has to be established. We employ the ADH methodology to develop predictions for a 'synthetic' Kobe economy.

One of the ADH algorithm's advantages is the ability to use the synthetic control methodology to estimate unbiased coefficients with a modest amount of information (few pre-event observations). In Abadie et al. (2010), which formalized the validity of the synthetic control methodology, the analysis is conducted with annual data from 1970 to 2000 while the event of interest occurred in 1988. The time-series length (T_0) of pre-event data available for our study of Kobe is very similar to that of Abadie et al. (2010), with 20 years of pre-disaster data.

Another key element of the synthetic control methodology is the presence of an appropriate control group. In comparative case studies that aim to identify the impact of a specific event, the research necessarily relies on a surprising/exogenous event of a relatively large magnitude and the presence of comparative units of observations that do not experience the event. The Kobe earthquake, the most destructive natural disaster in a developed country in many years (barring two later events; hurricane Katrina in 2005 and the Tohoku tsunami of 2011), is clearly a relatively large exogenous event and, as previously discussed, Kobe has natural comparative units of observation. The other Japanese prefectures are both subject to the same external shocks and institutional and legal infrastructures, and have not directly experienced the event. Of course some prefectures are more similar to Kobe than others—the algorithm we employ is exactly aimed at identifying these similarities and differences to construct the synthetic counter-factual.

4.1 Empirical Model

Let Y_{it} be the outcome variable that shall be evaluated based on the earthquake's impact for prefecture *i*, (with *i*=1 for Hyōgo and *i*>1 for the other Japanese prefectures) and time *t* (for time periods *t*=1,….*T₀*,…,*T*; where T_0 is 1995); while Y_{it}^{I} is the outcome variable in the presence of the earthquake and Y_{it}^{N} is the outcome variable had the earthquake not occurred.[6] The model requires the assumption that the event has no effect on the outcome variable before the date of impact T_0 $(Y_{it}^{I} = Y_{it}^{N} \forall t < T_0)$. Although this last assumption is unjustified in cases where disaster impact is frequent and therefore expected, Kobe has not experienced a similar event in a very long time, was widely perceived in Japan as a low-earthquake-risk region, and the Kobe event ended up being the largest earthquake in Japan since the Kanto earthquake of 1923.

The observed outcome is defined by $Y_{it} = Y_{it}^{N} + \alpha_{it} D_{it}$ where α_{it} is the effect of the disaster on the variable of interest $(Y_{it}^{I} - Y_{it}^{N})$ and D_{it} is the binary indicator denoting the event occurrence (D_{it}=1 for $t \geq T_0$ and $i = 1$; and D_{it}=0 otherwise). The aim is to estimate α_{it} for all

[6] This description is a modified version of Abadie *et al.* (2010). To simplify comparison, we follow their notation where *I* denotes intervention (event occurring) and *N* denotes non-intervention (event not occurring).

$t \geq T_0$ for Hyōgo prefecture (*i*=1). The problem is that for all $t \geq T_0$ it is not possible to observe Y_{1t}^N but only Y_{1t}^I.[7]

Although there is no way of accurately predicting the prefecture-specific determinants of Y_{it}, the structure of the economies is fairly similar and the external shocks affecting them (except for the earthquake) are similar as well (except for mean zero iid shocks ε_{it}). In this case, Y_{1t} can be calculated as the weighted average of the Y_{it} (for $i = 2,\ldots,J$) observations from the other prefectures; i.e.,

$$Y_{1t}^N = \delta + \sum_{j=2}^{J} \omega_j Y_{jt}^N + \alpha_{1t} D_{1t} + \varepsilon_{1t} \qquad (1)$$

For pre-impact observations ($t < T_0$) this equation can be estimated to obtain the weights allocated to the different prefecture observations, ω_j.[8] The following estimation equation is used for each variable of interest, based only the pre-impact observations, to obtain estimates for δ and ω_j:

$$Y_{1t}^N = \delta + \sum_{j=2}^{J} \omega_j Y_{jt}^N + \varepsilon_{1t} \qquad (2)$$

Abadie et al. (2010) show that under acceptable assumptions, one can estimate α_{it} for $t \geq T_0$ by calculating

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[7] For all other observations: $D_{it} = 0$, so $Y_{it} = Y_{it}^N$.

[8] The Abadie *et al.* (2010) specifications include another vector of variables that determine the variable of interest but are unaffected by the treatment. We estimate the model with some additional variables; more details are available further down and in the data appendix.

$$\hat{\alpha}_{it} = Y_{it}^{I} - \hat{Y}_{it}^{N} = Y_{it}^{I} - [\hat{\delta} + \sum_{J=2}^{J} \hat{\omega}_j Y_{jt}^{N}] \qquad \text{for } t \geq T_0 \qquad (3)$$

where the second term on the right hand side of the equation is calculated using the weights ($\hat{\omega}_j$) estimated in equation (1) and the post-impact observations for the different prefectures. The estimates of equation (1) are only used for constructing the counterfactual as accurately as possible. Thus, we are not interested in the actual coefficient estimates of these regressions as they have no economic significance or otherwise interpretable meaning.[9]

There are likely to be some feedback loops whereby a decrease in economic activity in one region reduces trade and therefore economic activity in other regions. In this case, should we observe an adverse effect of the disaster on, for example, GDP, we should interpret this as the lower-bound of the actual adverse impact (since without the event the synthetic control would have also been trending higher). In case of zero-sum variables (like population) however, any finding of a reduction in population relative to control should also be interpreted with care, though in this case the procedures identifies the upper-bound of the likely impact. These observations, however, do not detract from the relevance of our findings given the adverse impacts we document.

4.2 Statistical Significance of Results

The usual statistical significance of our reported results, based on regression-based standard errors, is not relevant in this case since the uncertainty regarding the estimate of $\hat{\alpha}_{it}$ does not come from uncertainty about the aggregate data. Uncertainty in comparative case

[9] Regression results are available from the corresponding author upon request.

studies with synthetic control is derived from uncertainty regarding the ability of the post-treatment synthetic control to replicate the counterfactual post-treatment in the treated observations.

Following Abadie et al. (2010), we use permutation tests to examine the statistical significance of our results. We separately assume that every other Japanese prefecture in our sample is hit by a similar (and imaginary) event in the same year. We then produce counterfactual synthetic control for each "placebo disaster." These synthetic controls for the placebos are then used to calculate the impact of the placebo disasters ($\hat{\alpha}_{it}^{P}$) in every year following its (non)-occurrence with the following formula:

$$\hat{\alpha}_{it}^{P} = Y_{it}^{I} - \hat{Y}_{it}^{N} = Y_{it}^{I} - [\hat{\delta} + \sum_{j=2}^{J} \hat{\omega}_j Y_{jt}^{N}] \qquad \text{for } t \geq T_0 \text{ and } j \neq P \tag{4}$$

We plot these placebo impacts together with the actual impact of the Kobe earthquake as calculated in relation to its synthetic counterfactual. These figures (figures 2 & 4) are used to examine the distribution of predictions in cases in which the treatment (the disaster) did not occur relative to the case it did (Kobe). Essentially, we investigate whether the $\hat{\alpha}_{1t}$ we estimated for Kobe are statistically different from the placebo $\hat{\alpha}_{it}^{P}$ for *i*>1[10]

5. The data

The data used in this paper was taken from the Japanese Statistical Yearbook, which is published by the Japanese Government's Statistics Bureau. The data concerning population is

[10] This placebo methodology is extended to multiple treated cases in Cavallo et al. (2012) to calculate the average impact size when there are multiple shocks (treated observations) and multiple controls (un-treated observations).

by prefecture and is available annually and based on both census data (taken every five years) and survey based estimation as of October 1^{st} of each year. For the purpose of this paper the data covering the period 1975 to 2009 was used. In addition to population, we also compiled data from the Statistics Bureau covering prefectural GDP, construction, residential housing prices, and rent. However, these data sets had to be constructed from multiple sources produced by the Statistics Bureau.

The data used for GDP was also collected annually by prefecture. Unlike other data sets, the prefectural GDP data was not available in a single contiguous set. The first set available from the Statistics bureau covered the years 1975 through 1999. The second set covered the years 1990-2003 and was also based at current prices in millions of yen.[11] The remainder of the data was obtained from the Statistical Yearbook for 2011, which covered the years 2005 through 2007, the archived Statistical Yearbook for 2010, which covered the years 2004 through 2006, and the Statistical Yearbooks (2007, 2008, and 2009) accessible via the Internet Archive to fill in the remainder years. Furthermore GDP data was conducted using 'current prices'. Gross Expenditure data for prefectures at constant prices was also available, however the two previous years were not included in the statistical yearbook, and for cases when overlapping data was available it was not consistent from year to year, therefore no reliable growth rate could be obtained.[12] Growth rates were taken from the later sets then combined with the data in the earlier set to create a smoothed out data set.

[11] The current prices in this set are based on the data compiled for the 2007 yearbook.

[12] This can be seen by checking the Japanese Statistical Yearbook by using the Internet Archive (web.archive.org).

The data used for construction was conducted annually by prefecture. Specifically it is the value of construction work completed by original contract. Similar to the GDP set this series was also not in a single contiguous set. The historical set provided by the Statistics bureau covers the time period from 1956 to 2003. Two more sets of data for 2006 and 2007 were available via the Statistical Yearbooks for 2010 and 2011 respectively and the data concerning 2004 and 2005 were accessible via the 2008 and 2009 Statistical yearbooks accessible via the Internet Archive. Furthermore the data available in the Statistical Yearbook is available in six separate pieces that had to be summed to match the historical set.[13]

The data used for Residential Prices was collected annually by prefecture. Specifically it is the average price of housing land by residential site. Similar to both the GDP and Construction sets this series was also not in a single contiguous set. The historical set provided by the Statistics bureau covers the time period from 1980 to 2004. Two more sets of data for 2008 and 2009 were available via the Statistical Yearbooks for 2010 and 2011 respectively and the data concerning 2005 through 2007 were accessible via the 2007, 2008 and 2009 Statistical yearbooks accessible via the Internet Archive.

The data used for Rent was collected every five years by prefecture. Specifically it is the rent per tatami unit (a measure of area in japan) conducted in yen. The historical set provided by the Statistics bureau covers the time period from 1963 to 2003. The most recent data for the year of 2008 was available via the Statistical Yearbook for 2011. The final set that we used covered the period from 1978 to 2008. The data used for Government Expenditure was

[13] Accuracy was checked by using older Statistical Yearbooks accessible via the way back machine to ensure that the values matched the Historical data.

collected annually by prefecture and is conducted in millions of yen. The historical set provided by the Statistics bureau covers the time period from 1947 to 2008. The final set that we used covered the period from 1975 to 2008.

We already noted that we do not use Osaka as part of the control group since it was directly affected by the quake. In addition, we also remove from the sample the data for Tokyo and Kanagawa prefectures since both appear to be outliers, and the explanatory power of our synthetic model does not improve with their inclusion.

6. Findings and conclusions: What did happen?

We start by examining what happened to population, since in some instances (e.g., hurricane Katrina in New Orleans) the most immediate and important effect of the disaster on those who were not directly harmed or killed was to cause people to temporarily relocate. This relocation can then become permanent. In graying Japan, of course, the population trend is not linear, and an accounting of the counter-factual is clearly important. Figure 1 presents the actual population of Hyōgo prefecture (henceforth referred to, inaccurately, as Kobe) and its synthetic counterfactual, constructed as described above. We clearly observe a large movement of people away immediately following the earthquake, but population recovers fairly quickly, and returns to (or even above) trend within 5 years (by 2000). This result is interesting in as much as it contradicts what indeed happened in New Orleans or elsewhere in the U.S. following destructive hurricanes (e.g., Coffman and Noy, 2012, Vigdor, 2008).

Figure 2 presents the statistical significance of our results, by comparing the population gap (the difference between the actual and the counterfactual for Kobe) with the population gap for the placebo disasters in other prefectures. While the initial drop in population is indeed statistically significant, the data beyond the first couple of years does not suggest that population today is any different than it would have been had the earthquake not occurred.

If people returned so quickly, did income recover as well? Generally, in high-mobility environments we expect people to respond to price/wage signals, so that the return to Kobe should have been preceded by an increase in incomes (or at least the return to the pre-disaster equilibrium when compared with other alternative locations/provinces). We do not find that. In figure 3, we observe that while GDP per capita rose immediately after the disaster, partially as a result of the population movements, and partly as a result of the fiscal stimulus for reconstruction, eventually per capita GDP declined. We find that per capita GDP is still much lower 15 years after the earthquake than it would have been had the earthquake not occurred.

Figure 4 presents the per capita GDP gap comparison with the placebo disaster events. Clearly, the decline that we observe in per capita GDP is persistent, long-term, and clearly observable statistically even 15 years after the quake. GDP per capita in 2007 was 500,000 yen per person lower than it would have been had 'Old Kobe' still existed. [14]

Intriguingly, this result is apparent in spite of a massive infusion of fiscal resources into the region. Figure 5 describes government expenditures in the prefecture, and compares it to the counterfactual. While our model enables us to clearly track the pre-earthquake level of expenditures in the region, it breaks down in the aftermath of the earthquake. The region

[14] Corresponding to these impacts on population and per capita incomes, we find that housing rental prices went up after the quake, but eventually declined and are now below the hypothetical (synthetic) no-quake Kobe. These results are not presented but are available upon request.

enjoys a massive fiscal stimulus. As already described, however, this large fiscal stimulus was still unable to provide the boost necessary to bring the region back to its pre-quake potential.[15]

Thus, in a wealthy and developed region and with the backing of a deep-pocket fiscal authority, the disaster we examined still resulted in significant adverse long-term impact with a reduction of 13% in per capita GDP, from which the prefecture has never fully recovered. The presence of a large fiscal stimulus is important, given much recent work that predicts that disasters are more likely to hit poorer countries in the future. Poor developing countries are less likely to be able to adopt counter-cyclical fiscal policies; and this will inevitably make a large disaster's adverse consequences more severe. Haiti, following the January 2010 earthquake, is unlikely to receive its reconstruction needs, in spite of a massive international mobilization and well-publicized donor conferences (see Becerra et al., 2010).

While this analysis provides no specific recommendations on disaster mitigation strategies, it sheds light on the 'true' costs of a disaster event. The long-term impacts of disaster events are, in a sense, 'hidden' when focusing on aggregate national data, and due to the difficulty in attributing them to an event with the passage of time. As this study documents, the long-term dislocations that disasters engender can be substantial and thus should not be ignored when cost-benefit analyses of disaster mitigation and resiliency programs are used to determine policy choices now, and into a future in which disaster patterns are likely to change.

[15] The additional spike in government expenditures in 2005 is a result of the fact that some of the transfers from the central government to Hyōgo prefecture immediately after the quake were classified as 10 year loans. In 2005, the central government assumed these liabilities and that was recorded again (information obtained from personal correspondence with the Ministry of Internal Affairs and Communications).

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Figure 1: Population (# of people)

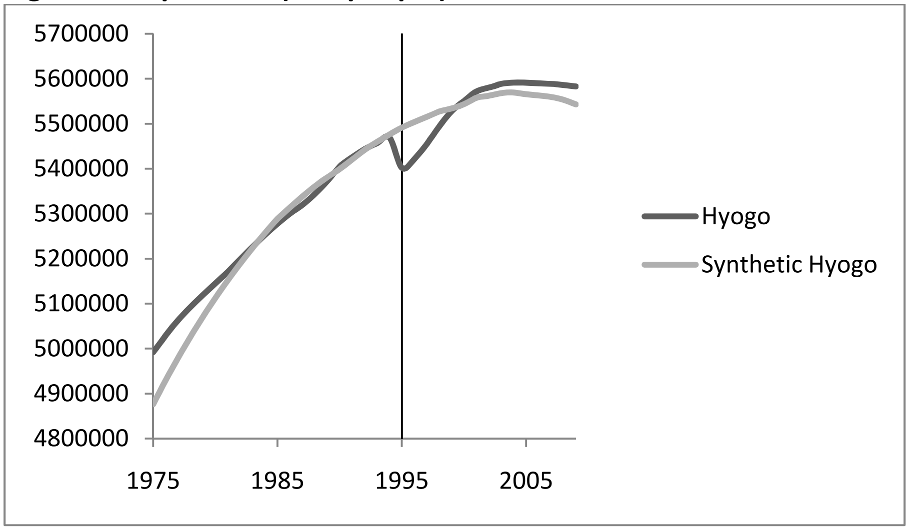


Figure 2: Placebo Population (# of people)

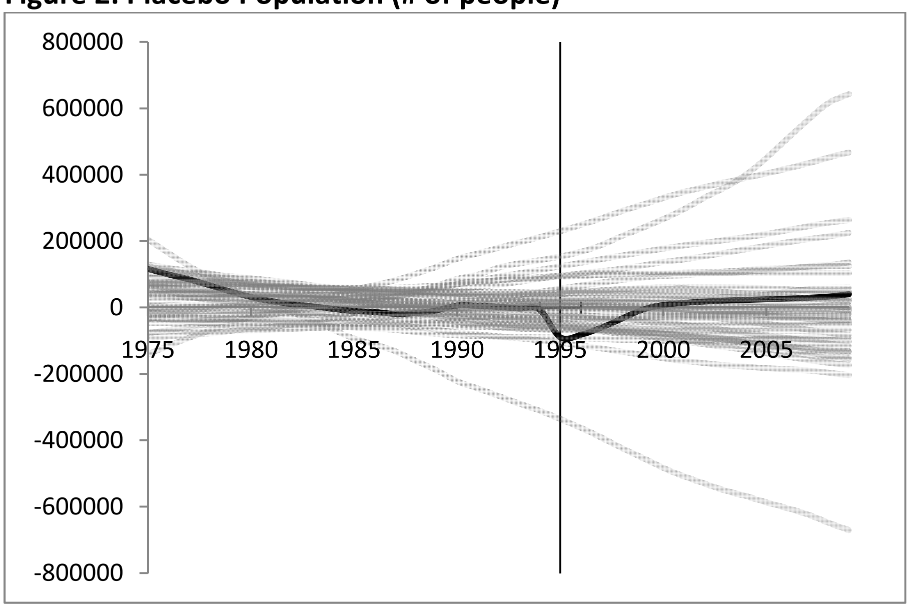


Figure 3: GDP per capita (Millions of Yen per Person)

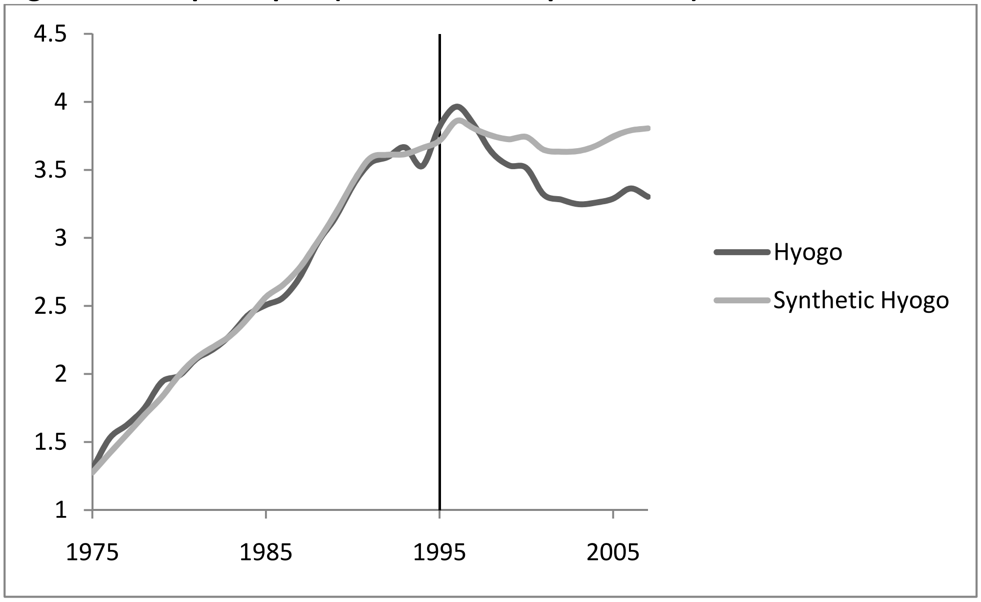


Figure 4: Placebo GDP per capita (Millions of Yen per Person)

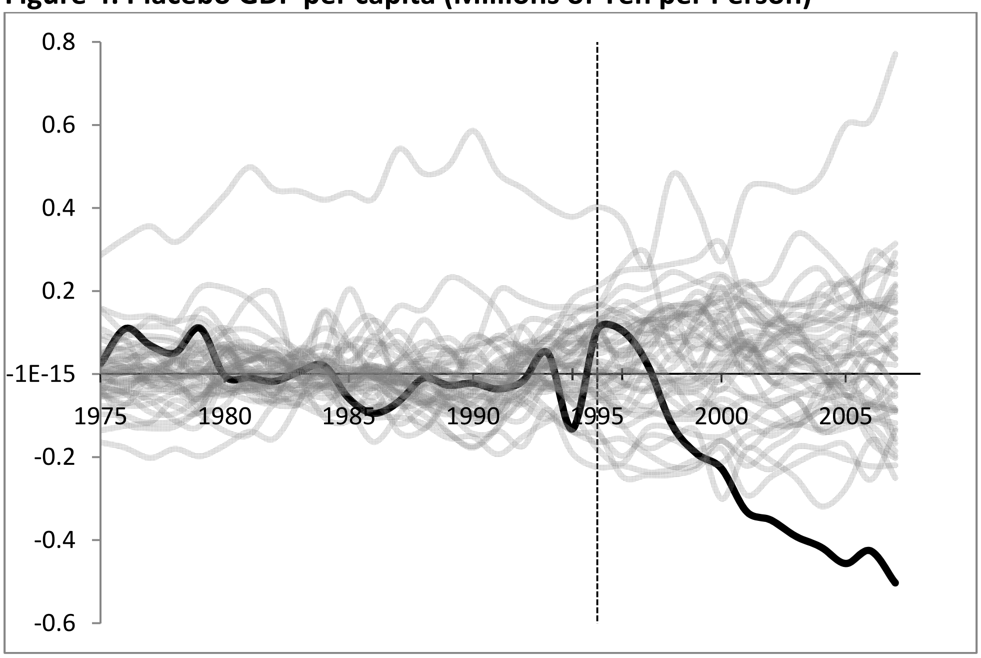
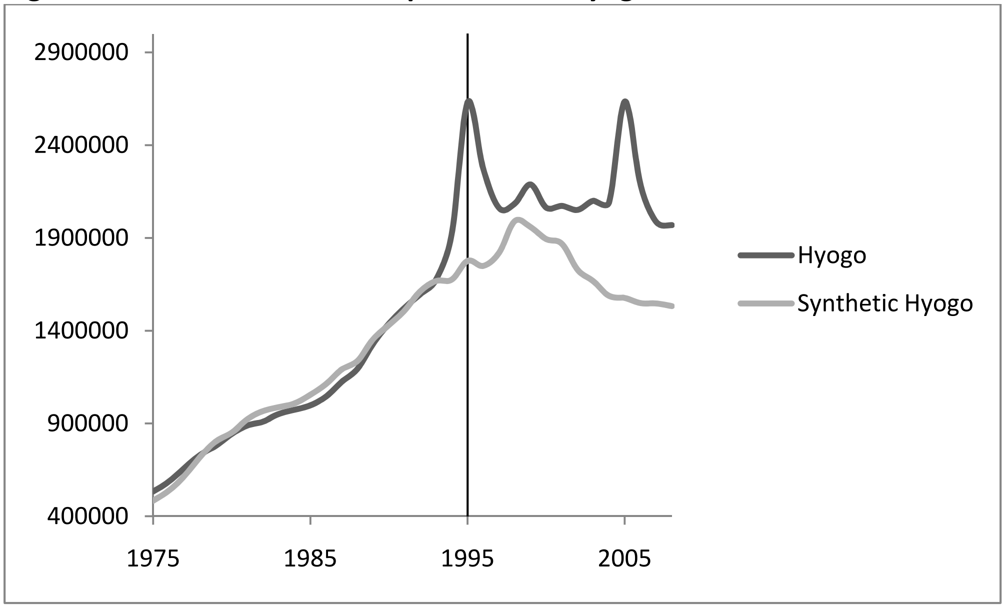


Figure 5: Local Government Expenditures: Hyogo Prefecture



Appendix: Data Table

Type	Source	Chapter	Series	Frequency	Duration	Location	Year
Population	Historical Statistics of Japan	2	5	Annual	1884-2009	Prefecture	2011
GDP	Historical Statistics of Japan	3	37a	Annual	1975-1999	Prefecture	2011
GDP	Historical Statistics of Japan	3	37b	Annual	1990-2003	Prefecture	2011
GDP	Japan Statistical Yearbook	3	14B	Annual	2003-2005	Prefecture	2009
GDP	Japan Statistical Yearbook	3	14B	Annual	2004-2006	Prefecture	2010
GDP	Japan Statistical Yearbook	3	14B	Annual	2005-2007	Prefecture	2011
Construction	Historical Statistics of Japan	9	17	Annual	1956-2003	Prefecture	2011
Construction	Japan Statistical Yearbook	9	10		2004	Prefecture	2008
Construction	Japan Statistical Yearbook	9	10		2005	Prefecture	2009
Construction	Japan Statistical Yearbook	9	10		2006	Prefecture	2010
Construction	Japan Statistical Yearbook	9	10		2007	Prefecture	2011
Residential Price	Historical Statistics of Japan	15	20	Annual	1980-2004	Prefecture	2011
Residential Price	Japan Statistical Yearbook	17	14		2005	Prefecture	2007
Residential Price	Japan Statistical Yearbook	17	14		2006	Prefecture	2008
Residential Price	Japan Statistical Yearbook	17	14		2007	Prefecture	2009
Residential Price	Japan Statistical Yearbook	17	14		2008	Prefecture	2010
Residential Price	Japan Statistical Yearbook	17	14		2009	Prefecture	2011
Rent	Historical Statistics of Japan	15	22	Every 5 Years	1963-2003	Prefecture	2011
Rent	Japan Statistical Yearbook	18	16		2008	Prefecture	2011
Gov. Expenditure	Historical Statistics of Japan	5	12d	Annual	1947-2008	Prefecture	2011