Long-run Effect of a Disaster:
Decomposing Region Specific Structural Change

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Abstract

Okuyama (2010) found that the long-run effects of the Kobe Earthquake, occurred in 1995, appear to be significant, lasting for several years in an increasing manner, based on the time-series analysis of regional economic data, such as GRP. It also suggested that a large part of the economic effects be resulted from structural changes of the Kobe economy caused by the damages of and reconstruction activities after the earthquake. In order to investigate the long-run effects further, this paper aims to analyze the extent and structure of the disaster effects, based on the input-output framework. The structural changes are measured based on time-series of Kobe regional input-output tables. Since 1995 Kobe regional input-output table was not compiled due to the earthquake occurrence, the 1995 table is estimated using the available regional data. Based on these tables, the region specific structural change of the Kobe economy is decomposed using structural decomposition technique and shift-share analysis.

Keywords: natural disaster; structural analysis; regional input-output table; long-run impact

1. Introduction

Since the pioneering work by Dacy and Kunreuther (1969), a generalized framework for the economic analysis of natural disasters had been proposed (for example, Sorkin, 1982; and Albala-Bertrand, 1993). While significant progress has been made in recent years for the economic analysis of natural disasters, especially in the field of economic modeling for disaster impact (for example, Okuyama and Chang, 2004; and an excellent compilation of related papers by Kunreuther and Rose, 2004), the recent advancements have been more toward short-run impact analysis with the strategies for modeling extensions and modifications to fit them to disaster situations rather than toward evaluation of long-run effect of such events. This tendency is due to improved data availability of disaster damages and losses and to increased multidisciplinary research activities about disasters, including sociology, economics, and psychology for more detailed analysis and simulation of the impacts. At the same time, the uniquenesses of each natural hazard and of the distribution of its damages and losses present enormous challenges in economic analysis of disaster impact and effect. In particular, while some research suggests that impact from a catastrophic natural hazard may spill over not only to the surrounding regions but also to the distant regions via tightened interdependency of economic activities (for example, Okuyama et al., 1999), some other researchers claimed that the the impact of even a large disaster ends up "insignificant total impacts" (Albala-Bertrand, 1993).

These arguments should have entertained empirical ex-post investigation of disaster impact and effect; however, few studies have engaged such attempt. Most of those ex-post studies estimated, not measured, the impacts of a particular disaster based on the available damage data and some economic models, like input-output models and so on. It appears considerably entangled to extract disaster impact and effect from empirically available macroeconomic data, because in usual macroeconomic indicators, such as gross domestic products (GDPs) or gross regional products (GRPs), economic impacts of a particular disaster may be potentially hidden within macroeconomic fluctuations and may be more likely cancelled out between negative impacts from damages and positive impacts of recovery and reconstruction activities, and also partly because the disaster statistics are not standardized even among developed countries and are even "somewhat crude measures," (Skidmore and Toya, 2002). Of all these difficulties, empirical measurement of disaster impacts is crucial to understand how a disaster affect economies and to improve the accuracy of impact estimates derived based on economic model.

In this paper, the economic effect of the Great Hanshin-Awaji Earthquake (also known as the Kobe Earthquake) occurred in 1995 are investigated empirically using a time-series of input-output tables and sytuctural analysis methods. Next section briefly summarized the previous studies and findings related to economic impact and effect of natural disasters. Section 3 presents the data for the case study and the methodology fro structural analysis. The results of analysis are illustrated and discussed in Section 4. Section 5 concludes this paper with the discussion of findings and some remarks.

2. Economic Impacts of Natural Disasters

Natural disasters can bring physical destructions to built-environment and infrastructures, such as transportation and lifelines, and can also cause casualties and injuries to human lives. These damages are often called *damages*, and are by economics' definition the damages on stocks, which include physical and human capitals. Then, these damages lead to the interruptions of economic activities, such as production and/or consumption, and the losses from business interruptions are called the (*first-order*) *losses* of a disaster. At the same time, there is another term called *higher-order effects*, which take into account the system-wide impact of flow losses through interindustry relationships. (Rose, 2004). And, *total impacts* are the total of flow impacts, adding (first-order) losses and higher-order effects (Okuyama and Sahin, 2009). While some researchers critique that the higher-order effects of disaster are "more a possibility than a reality" (Albala-Bertrand, 1993, p. 104), the estimation of higher-order effects has been performed to "gauge individual and community vulnerability, evaluate the worthiness of mitigation, determine the appropriate level of disaster assistance, improve recovery decisions, and inform insurers of their potential liability" (Rose, 2004, p. 13).

The economic impact and effect of natural disasters have been studies in various contexts and with a range of time durations. Ex-ante analysis of a hypothetical or potential hazard occurrence is often carried out for the decision-making of preparedness and mitigation strategies; and ex-post analysis of actual hazards and disasters is usually carried out to investigate how the event affected the economy and to examine to what extent the relief efforts by various levels of public sector and by other institutions are needed. Economic analysis of natural disasters can be also divided into two categories: analyses of short-run impact and of long-run effect. Short-run impact analysis of disaster intends to estimate the total (flow) impacts of a hazard, defined above, for the duration of a few years, and usually employs input-output model, social accounting matrix, or computable general equilibrium model of a particular region, regions, or nation. By its nature, short-run impact analysis estimates only flow changes and can distinguish between the negative impacts from losses and the positive impacts of recovery and reconstruction activities, which serve as intense demand injections to the region. Several short-run analyses of disasters were compiled in

Okuyama and Chang (2004) and the methodologies are summarized in Okuyama (2007). On the other hand, long-run analysis of disaster effects aims to measure the effects of damages on stock, which may affect the long-run growth path of the damaged region, resulted from the changes in level of physical and human capital accumulation and technology replacement (Okuyama, 2003). The long-run analysis of disasters usually employs econometric models with time series data; and because of this, they cannot distinguish between negative and positive impacts of a disaster and can only derive net effects. Comparing to short-run impact analysis, long-run analyses of natural disasters have been limited, due mainly to the uniqueness of each disaster and also to the difference in details and extent of damage data gathered over time. Notable examples in the line of study using cross-country data to analyze the tendency between various indices of economic growth and disaster occurrences include Skidmore and Toya (2002), Rasmussen (2004), Cuaresma et al. (2008), and Cavallo et al. (2010). Interestingly, some of these studies provide conflicting or inconclusive results in terms of the relationship between economic growth and disasters. In particular, Cavallo et al. (2010) found that natural disasters, even focusing only on the largest events, do not have any significant effect on subsequent economic growth. Empirical evaluation of a particular disaster's long-run effect has been also limited and include Odell and Weidenmier (2002) for the 1906 San Francisco Earthquake, Hornbeck (2009) for the 1930's American Dust Bowl, and Baade et al. (2007) for the 1992 LA Riot and 1992 Hurricane Andrew among others. Contrary to Cavallo et al. (2010) using country as the unit of analysis, these event specific studies found that a disaster brings some long-run effect, especially to some specific part of economy, such as regional economy (Hornbeck and Baade et al), financial sector (Odell and Weidenmier). The contrast of the results between cross-country studies and regional and event specific studies supports the Albala-Bertrand's (2007) claim that a disaster causes localized damages and losses on capital and activities but may not affect negatively (or positively) the macro-economy, such as national economy, in both short-term and longer-term. At the same time, this claim implies that localized damages and losses may cause localized economic impacts, which may be significant to the local economy hit by the disaster. This paper investigates that how the Kobe earthquake affected the local economy structurally in the long-run, and whether or not the event follows the above studies' conclusion.

3. Data and Methods: Regional Input-output Tables and Structural Decomposition

We employ the Hanshin-Awaji Great Earthquake (hereafter Kobe Earthquake),which occurred in 1995 at Kobe, Japan, as the case study for empirically investigating the structural changes of a regional economy over time resulted from the Kobe Earthquake.

3.1 Recap of the Kobe Earthquake

On January 17, 1995, the worst disaster in the postwar Japan struck the second largest region of Japan—the Kinki region. The City of Kobe and surrounding municipalities experienced massive destruction of houses, buildings, roads, rails, and infrastructure. The magnitude of this event can be shown with the following facts: according to the Hyogo Prefecture Government (2010), the number of casualties was 6,434; the number of injuries was 43,792; the number of evacuees was 316,678 (at its peak); and the number of damaged houses was about 640,000. The direct damages from this Kobe Earthquake were estimated at about 10 trillion yen (US$ 100 billion, as $1=100 yen), equivalent to about 2.1% of Japan's GDP and 11% of Kinki's GRP (Gross Regional Product) at that time. These direct damages were concentrated in the destruction of buildings (including houses and production facilities), transportation facilities, and utilities. Although the damaged area was geographically only 4% of Kinki, it included 15% of the Kinki's population. The damages to capital stocks were estimated about 0.8% of Japan's total (Okuyama et al., 1999).

3.2 Data: Kobe Regional Input-ouput Tables

In Japan, designated large cities with the population greater than 700 thousand, including the City of Kobe, have compiled city's input-output tables every five years. In this study, the Kobe's city input-output tables for 1985, 1990, 2000, and 2005 are employed. Since the Kobe Earthquake occurred in 1995, that year's city input-output table was not constructed due to difficulties in data collection. The lack of 1995 table may create some difficulties in analysis, and they will be discussed in the analysis section below.

Sector classification of each year's Kobe input-output table is slightly different, as the Japanese national tables' sector classification had changed over these years. The number of sectors had changed from 31 for 1985 to 34 for 2005. In order to make a consistent sector classification over the years but not to aggregate to much for losing the details, the sectors are rearranged to become 28 sectors as shown in table A-1 in Appendix.

In addition, these tables are in current price; thus, they need to be in a constant (real) price. Since the Ministry of Internal Affairs and Communications of the Japanese government published the constant price national tables for 1985-90-95 (in 1995 price) and 1995-00-05 (in 2005 price), the

Kobe tables above are transformed to have the constant price (2005 price) based on the sectoral inflators calculated from these two constant price national tables.

3.2 Method of Structural Decomposition

A well-summarized description of structural decomposition methods can be found in Miller and Blair (2009). In this subsection, the method of decomposition employed in this papaer is preseted. The key feature of this decomposition is to identify the factors of regional structural change, potentially resulted from the Kobe earthquake, distingushing the regional specific changes from the macroeconomic trends.

Kobe regional input-output tables are constructed as a competitive import form in the following manner:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} + \mathbf{e} - \mathbf{m} \tag{1}$$

where **x** is a vector of total outputs; **A** is a matrix of input coefficients; **f** is a vector of final demand; **e** is a vector of exports; and **m** is a vector of imports. In order to analyze regional specific changes in technology and demand, the tables need to be transformed to a non-competitive one. This can be done by calculating import coefficients based on (1) as follows:

$$M_i = \frac{m_i}{\sum_j a_{ij} x_j + f_i} \tag{2}$$

Using these import coefficients, the relationship (1) can be transformed:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{f} + \mathbf{e} - \mathbf{M}(\mathbf{Ax} + \mathbf{f}) \tag{3}$$

where **M** is a diagonal matrix with import coefficients. Then, this will become:

$$\mathbf{x} = \left[\mathbf{I} - (\mathbf{I} - \mathbf{M})\mathbf{A}\right]^{-1} \left[(\mathbf{I} - \mathbf{M})\mathbf{f} + \mathbf{e}\right] \tag{4}$$

Suppose **D=I-M**, indicating a diagonal matrix of regional purchase coefficients, (4) can be:

$$\mathbf{x} = (\mathbf{I} - \mathbf{DA})^{-1} (\mathbf{Df} + \mathbf{e}) \tag{5}$$

This, in turn, becomes a decomposition of total ouput into outputs induced by regional final demand and by exports as follows:

$$\mathbf{x} = (\mathbf{I} - \mathbf{DA})^{-1} \mathbf{Df} + (\mathbf{I} - \mathbf{DA})^{-1} \mathbf{e} = \mathbf{x}_\mathbf{r} + \mathbf{x}_\mathbf{e} \tag{6}$$

where $\mathbf{x}_\mathbf{r} = (\mathbf{I} - \mathbf{DA})^{-1} \mathbf{Df}$ and $\mathbf{x}_\mathbf{e} = (\mathbf{I} - \mathbf{DA})^{-1} \mathbf{e}$. Following Miller and Blair above and Hitomi et al. (2000), these two are decomposed but separately.

Decomposition of $\mathbf{x_r}$

For posing a hierarchy in structural decomposition, $\mathbf{x_r}$ can be rewritten as follows:

$$\mathbf{x_r = (I - DA)^{-1} Df = L_r f_r} \tag{7}$$

where $\mathbf{L_r = (I - DA)^{-1}}$ and $\mathbf{f_r = Df}$. Suppose the changes in output induced by regional final demand between periods 0 and 1 can be set as:

$$\mathbf{\Delta x_r = x_r^1 - x_r^0} \tag{8}$$

Then, pluging (7) into (8) and taking the average of two polar decompositions[1] yield:

$$\mathbf{\Delta x_r = L_r^1 f_r^1 - L_r^0 f_r^0 = \Delta L_r \bar{f}_r + \bar{L}_r \Delta f_r} \tag{9}$$

where $\mathbf{\Delta L_r = L_r^1 - L_r^0}$; $\mathbf{\Delta f_r = f_r^1 - f_r^0}$; $\mathbf{\bar{f}_r = \frac{1}{2}(f_r^1 + f_r^0)}$; and $\mathbf{\bar{L}_r = \frac{1}{2}(L_r^1 + L_r^0)}$. This is the decomposition of upper layer. In the lower leyer, $\mathbf{\Delta f_r}$ and $\mathbf{\Delta L_r}$ are further decomposed.

First, since $\mathbf{f_r = Df}$, the changes in $\mathbf{f_r}$ can be decomposed similarly to (9) as follows:

$$\mathbf{\Delta f_r = \Delta D \bar{f} + \bar{D} \Delta f} \tag{10}$$

where $\mathbf{\Delta D = D^1 - D^0}$; $\mathbf{\bar{D} = \frac{1}{2}(D^1 + D^0)}$. The first component of (10) represents the contribution from changes in regional purchase matrix, while the second components shows the contribution from changes in (total) final demand.

Second, according to Akita (1994 and 1999), the changes in Leontief inverse matrix in general can be decomposed as $\mathbf{\Delta(I - A)^{-1} = \Delta L = L^1 \left[(L^0)^{-1} - (L^1)^{-1} \right] L^0}$. Using this notion, $\mathbf{\Delta L_r}$ can be decomposed as follows:

$$\mathbf{\Delta L_r = L_r^1 \left[(L_r^0)^{-1} - (L_r^1)^{-1} \right] L_r^0 = L_r^1 \left[D^1 A^1 - D^0 A^0 \right] L_r^0 = L_r^1 \left[\Delta(DA) \right] L_r^0} \tag{11}$$

In addition, similar to the above, $\mathbf{\Delta(DA) = \Delta D \bar{A} + \bar{D} \Delta A}$. Then, (11) can be rewritten as:

$$\mathbf{\Delta L_r = L_r^1 \left[\Delta D \bar{A} + \bar{D} \Delta A \right] L_r^0 = L_r^1 \Delta D \bar{A} L_r^0 + L_r^1 \bar{D} \Delta A L_r^0} \tag{12}$$

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[1] Dietzenbacher and Los (1998) argued that structural decomposition does not provide a unique solution, having "a multitude of equivalent forms (p.307)", this creates a inconsistency in results among different forms. They recommended to calculate all the possible combinations (if the number of determinants is *n*, the number of equivalent decomposition forms becomes *n!*) and take average or report the range of the results. They also suggested that the average of two polar decompositions can be very close to the *n!* results, and Miller and Blair (2009) concluded that it is "often an acceptable approach (p.595). In addition, as presented in this sub-section the structural decomposition in this paper contains a hierarchical form, while Chen and Wu (2008) claimed "calculating mathematical expectation of *n!* decomposition forms is not possible in hierarchical I-O SDA (p. 887). Hence, in this paper, the average of two polar decompositions is used in the structural decomposition form.

Using (10) and (12), (9) can be rearranged as follows:

$$\Delta\mathbf{x_r} = \Delta\mathbf{L_r}\overline{\mathbf{f}}_\mathbf{r} + \overline{\mathbf{L}}_\mathbf{r}\Delta\mathbf{f_r} = \left[\mathbf{L_r^1}\Delta\mathbf{D}\overline{\mathbf{A}}\mathbf{L_r^0}\overline{\mathbf{f}}_\mathbf{r} + \overline{\mathbf{L}}_\mathbf{r}\Delta\mathbf{D}\overline{\mathbf{f}}\right] + \mathbf{L_r^1}\overline{\mathbf{D}}\Delta\mathbf{A}\mathbf{L_r^0}\overline{\mathbf{f}}_\mathbf{r} + \overline{\mathbf{L}}_\mathbf{r}\overline{\mathbf{D}}\Delta\mathbf{f} \tag{13}$$

in which the first component indicates the contribution from the changes in regional purchase matrix, the second component shows the contribution from the changes in technology, and the third component reporesents the contribution from the changes in fianal demand.

Decomposition of $\mathbf{x_e}$

As above, the output induced by exports can be rearranged to become $\mathbf{x_e} = (\mathbf{I} - \mathbf{DA})^{-1}\mathbf{e} = \mathbf{L_r e}$. Then, again, using the average of polar decompositions, the changes in output induced by exports can be transformed similarly to (13):

$$\Delta\mathbf{x_e} = \Delta\mathbf{L_r}\overline{\mathbf{e}} + \overline{\mathbf{L}}_\mathbf{e}\Delta\mathbf{e} = \mathbf{L_r^1}\Delta\mathbf{D}\overline{\mathbf{A}}\mathbf{L_r^0}\overline{\mathbf{e}} + \mathbf{L_r^1}\overline{\mathbf{D}}\Delta\mathbf{A}\mathbf{L_r^0}\overline{\mathbf{e}} + \overline{\mathbf{L}}_\mathbf{r}\Delta\mathbf{e} \tag{14}$$

where $\Delta\mathbf{e} = \mathbf{e^1} - \mathbf{e^0}$ and $\overline{\mathbf{e}} = \frac{\mathbf{1}}{\mathbf{2}}(\mathbf{e^1} + \mathbf{e^0})$. The first component of (14) indicates the contribution from the changes in regional purchase matrix, the second component shows the portion from the changes in technology, and the third represents the effects from the changes in exports.

Adding (13) and (14) provide the decomposition of the total output as follows:

$$\Delta\mathbf{x} = \left[\mathbf{L_r^1}\Delta\mathbf{D}\overline{\mathbf{A}}\mathbf{L_r^0}\overline{\mathbf{f}}_\mathbf{r} + \overline{\mathbf{L}}_\mathbf{r}\Delta\mathbf{D}\overline{\mathbf{f}} + \mathbf{L_r^1}\Delta\mathbf{D}\overline{\mathbf{A}}\mathbf{L_r^0}\overline{\mathbf{e}}\right] + \left[\mathbf{L_r^1}\overline{\mathbf{D}}\Delta\mathbf{A}\mathbf{L_r^0}\overline{\mathbf{f}}_\mathbf{r} + \mathbf{L_r^1}\overline{\mathbf{D}}\Delta\mathbf{A}\mathbf{L_r^0}\overline{\mathbf{e}}\right] + \overline{\mathbf{L}}_\mathbf{r}\overline{\mathbf{D}}\Delta\mathbf{f} + \overline{\mathbf{L}}_\mathbf{r}\Delta\mathbf{e} \tag{15}$$

This illustrates the decomposition of total output change into 1) the changes in regional purchase matrix, $\Delta\mathbf{D}$; 2) the changes in technology, $\Delta\mathbf{A}$; 3) the changes in final demand, $\Delta\mathbf{f}$; and 4) the changes in exports, $\Delta\mathbf{e}$.

4. Results and Analysis

This section presents and discuss the results from the above structural decomposition. First, the general tendency of Kobe economy before and after the Kobe Earthquake is illustrated. In addition, some ther decomposition scheme, namely shift-share analysis, provides some attempts to specify the Kobe Earthquake's impact on the changes in the Kobe's economic structure.

4-1. General Trends of the Kobe Economy around the Kobe Earthquake

An overview of the trends of per capita gross output of Japan (JPN), Hyogo Prefecture (HYOGO), and City of Kobe (KOBE) are shown in Figure 1[2]. The values are adjusted to year 2000 constant price and are taken logarithm. The Japan's GDP per capita had steadily increased throughout the period (1975-2006), while the rate of growth had slowed down a bit after 1990, when the bubble economy burst, and has regained some upward pace after 2002. Hyogo's GRP per capita is mostly lower than Japan's, and the rate of growth appears to parallel to the Japan's until 1993. The fiscal year 1994, when the Kobe earthquake occurred, shows a small dent, whereas 1995 and 1996 show sharp increases. At the same time, after 1997, the Hyogo's trend looks downward, until it turned to upward after 2004. The Kobe's growth path mirrors the Hyogo's, but the values are generally larger than not only Hyogo's but also Japan's. The dent of 1994 for Kobe is much larger than the Hyogo's, and the increase in 1995 is higher. Unlike Hyogo, however, Kobe seems not to turn the trend upward until 2006. This may be resulted partly from the changes in the Kobe's population after the earthquake. As displayed in Figure 2, after the sharp decline of its population in the fiscal year 1994, Kobe had struggled to regain its population to the pre-earthquake level until 2002, and the population increase has continued afterwards. On the other hand, the Hyogo Prefecture, including the City of Kobe, also lost their population in 1994, but it was not as sever as Kobe did in terms of the rate of change. Hyogo returned to its previous population level in 1998, and after 2003, their population trends appear flat. With these casual observations, the effects of the Kobe Earthquake are apparent: a sharp negative impact in 1994, positive ones in the following few years, and some slumps afterwards until picking up the paces in the mid 2000s. We estimate these trends statistically in the following section to see whether or not this observation is supported statistically.

<< Figures 1 and 2 here>>

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2 The raw data were extracted from Cabinet Office of Japan's web site (http://www.esri.cao.go.jp/jp/sna/toukei.html#kenmin (in Japanese)). And all the years are set in the Japanese fiscal year, starting from April of that year and ending at March of the next year.

Based the Kobe's regional input-output tables, the trends of sectoral output changes are summarized in Table 1. Total output change is the largest for 1985-1990, because in this period Japan's bubble economy was in full swing. In this period, the changes in sectoral outputs are relatively small in percentage and mostly positive, indicating the Kobe's economy was growing as a whole: the largest positive change comes from Construction sector (17) folloed by Public Services sector (24).

This figure changes drastically in the next two periods. While it is a 10-year period, twice longer than other two periods, with the Kobe Erathquke occurred in the mid period, the 1990-2000 period has a negative change of total output, but the volume is much smaller (about 30% of) than the 1985-1990 periods. The changes in sectoral outputs are both positive and negative and the percentages over the total change in this period are rather large, comparing to the previous period. The largest positive change is for Public Services sector (24), followed by Real Estate (21) and Finance and Insurance (20). In the mean time, the largest negative change comes from Construction (17), and Food and Kindred Products (3) and Port Related Transport Services (22) are the second and third, respectively. It can be considered that the first half of this period (1990-1995) should be the aftermath of the bubbly economy's burst in which Construction sector had a large debt (or unrecovable credits) leading to the contracted output; on the other hand, in the latter half (1996-2000), the Kobe's Construction sector had a large demand injection for the reconstruction after the Kobe Earthquake in 1995. It is striking that the change in Construction sector's output for the total of first and second halves of this period becomes negative.

Whereas the 2000-2005 period has the smallest and positive change (about 10% of 1985-1990 change), the range between positive and negative changes of sectoral outputs is the widest among the three periods in Table 1. The largest positive change is again for Public Services sector (24) with 155% of the total output change in this period, followed by Electrical Appliances (12) and Commerce (19). Construction sector (17) is again ranked first for the negative change, and Lumberm Wood Products and Furnitures (5) and Business Services (25) follow it.

Based on the above observations, it is evident that the Kobe economy has experienced strucutral changes that until 1990 most sectors in the Kobe economy were growing as the city grows depicted in Figures 1 and 2; however, after 1990, the sectors had become moving differently—some sectors are growing, such as Public Services (24), some other sectors are declining, most notablly Construction (17), and other sectors are fluctuating, for example Business Services (25) and Persoanl Services (26). In the next subsection, these output changes are decomposed to different factors of change as displayed in the previous section.

<<*insert Table 1 here*>>

4-2. Structural Decomposition: Results and Analysis

The changes in sectoral output are decomposed using (15) in order to analyze the sources of structural change. Figure 3 shows the distribution of decomposed output changes during 1985 and 1990. As observed in Table 1, this period has mostly positive changes, and the majority of them come from the changes in final demand ($\Delta\mathbf{f}$) and in export demand ($\Delta\mathbf{e}$). These count 65% and 37% of total output change, respectively[3]. Most of the changes belong to services sectors on the right side of the figure, except Food and Kindred Products (3) and Construction (17). Other Transport Services (23) has an interesting distribution of decomposed changes: final demand and export demand have positive changes, whereas all other changes, such as changes in technology for regional use and for export and changes in regional purchase coefficients for both regional and export uses, are negative. In sum, this sector (23) has a nominal negative change, just 1% decline of the total output change.

<<insert Figure 3 here>>

In the following period, 1990-2000, the distribution of decomposed changes has a much more different shape, as expected from the observation in the previous subsection (see Figure 4). It is evident that there are two distinctive patterns of distribution: mostly negative changes for primary and secondary sectors (1 through 17), and the coexistence of positive and negative changes for services sectors (from 18 to 28). The negative decomposed changes for primary and secondary sectors originate from the changes in export demand ($\Delta\mathbf{e}$), indicating that either Kobe lost the competitive edge of these sectors or the macroeconomic condition during this period caused the contracted demand for these sectors. Only Construction sector (17) experienced the significant decline of final demand ($\Delta\mathbf{f}$), and some minor decline in other components. On the other hand, services sectors have quite different distribution patterns of decomposed changes among them. For instance, Commerce (19) has a large change from the change in export demand ($\Delta\mathbf{e}$), while the changes in regional purchase matrix ($\Delta\mathbf{D}$) for both regional and export uses are relatively negative, almost offsetting the positive changes from other components including $\Delta\mathbf{e}$. At the same time, Public Services (24) has a large positive contribution of final demand change ($\Delta\mathbf{f}$) with moderate negative contribution from the changes in regional purchase matrix ($\Delta\mathbf{D}$) and in export demand ($\Delta\mathbf{e}$). In general, throughout the service sectors, the changes in final demand ($\Delta\mathbf{f}$) contributed positively to the changes in total output, whereas the volumes of contribution appear to have a wide range of differences.

The contribution of the changes in technology ($\Delta\mathbf{A}$) seems concentrated among services sectors with majority being positive. By and large, the contributions from the changes in regional

[3] Since there are some negative decomposed changes, the sum of two can exceed 100% of the total output change.

purchase matrix ($\Delta\mathbf{D}$) are more significant and mostly negative, with a few exceptions, for this period than for the previous period. While the contributions from the changes in final demand ($\Delta\mathbf{f}$) and in export demand ($\Delta\mathbf{e}$) have the larger share, the changes in technology ($\Delta\mathbf{A}$) and in regional purchase matrix ($\Delta\mathbf{D}$) increased their contribution, but in different directions—positively for $\Delta\mathbf{A}$ and negatively for $\Delta\mathbf{D}$. Especially, the increased negative influence from $\Delta\mathbf{D}$ may be considered as a hollowing-out process, a decrease in the level of intraregional intermediation (Hitomi et al., 2000), of this region.

<<insert Figure 4 here>>

Figure 5 illustrates the distribution of decomposed change be sector for the 2000-2005 period. Since the total output change in this period is the smallest among the three periods, the shape of distribution looks not as dramatic as for the previous two periods in volume. Again, the changes in final demand ($\Delta\mathbf{f}$) and in export demand ($\Delta\mathbf{e}$) occupy larger shares to the total output change than other factors do. Construction (17) and Public Services (24) are standout having significant influence to the total output change, similar to the previous two periods. In addition, the changes in regional purchase matrix ($\Delta\mathbf{D}$), especially for regional use, have mostly negative numbers, with a few exceptions. This appear a continuous trend from the previous period (1990-2000), indicating the continuous hollowing-out process. What different from the previous periods, especially from 1990-2000, is that the changes in export demand appear to be mostly positive, with a few exceptions in light industries (2, 4, 5, and 6), indicating that the Kobe economy regained the demand from the outside.

<<insert Figure 5 here>>

All of these analyses can provide useful information for the transformation of the Kobe economy during 1985-2005. Some of the indications, such as continuous hollowing-out process, somehow accelerated during 1990-2000, and the decline (1990-2000) and regain (2000-2005) could be considered as the effects from the 1995 Kobe earthquake. However, this conclusion has to be verified with some further information, which can separate regional specific change from the changes caused by macroeconomic trends. The subsection below presents such an attempt.

4-3. Separation of Regional Specific Effects: Shift-Share Analysis

Shift-share analysis is one of the decomposition techniques to analyze the influence of economic trend of a region through identifying the components of change. In particular, shift-share analysis decomposes the economic change in a particular region into three factors: national (macroeconomic) influence, industry specific influence, and regional specific factor. Using production level (output)[4] as the indicator of economy's performance, these three factors can be defined as follows:

National Share: $NS_i = x_i^0 \left(X^1 / X^0 - 1 \right)$

Industry Mix: $IM_i = x_i^0 \left(X_i^1 / X_i^0 - X^1 / X^0 \right)$

Regional Shift: $RS_i = x_i^0 \left(x_i^1 / x_i^0 - X_i^1 / X_i^0 \right)$

where x_i^0 is the output level of industry *i* in a particular region at the beginning of the period, X_i^1 is the output level of industry *i* in the nation at the end of the period, and X^1 is the total output of the nation at the end of the period. Then:

$$\Delta x_i = x_i^1 - x_i^0 = NS_i + IM_i + RS_i$$

Therefore, the results from this shift-share analysis can be compared with the structural decomposition results above to investigate the regional specific effects.

Figure 6 displays the results of shift-share analysis for 1985-1990. The distribution pattern largely mirrors Figure 3 for structural decomposition results. Major changes specific to Kobe can be seen at Food and Kindred Products (3), Construction (17), Public Services (24) and Business Services (25) for positive change, and Other Transport Services (23) and Personal Services (26) for negative change. These observations are consistent with the results from structural analysis.

<<insert Figure 6 here>>

The results of shift-share analysis for 1990-2000 are shown in Figure 7. With a casual look, the distribution pattern of the results mirrors Figure 4's; however, the careful inspection reveals notable differences. For example, Food and Kindred Products (3) and Construction (17) have the positive value of national share, whereas the results from the structural decomposition for these sectors do not have any positive factors. Another difference of factor distribution can be found in Commerce (19): the range of distribution between positive and negative values is much narrower in shift-share results than in structural decomposition results. At the same time, the interpretation of this sector's results shows some consistency, since regional shift is the negative factor in Figure 7 while the changes in regional purchase matrix ($\Delta \mathbf{D}$) are only the negative contributions in Figure 4. This implies that for this particular sector the hollowing-out process is this region specific. This also applies to the results of Public Services (24).

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[4] Oftentimes, number of employments, rather than output level, is used for shift-share analysis, because it is easier to obtain in a regional context and for regional employment analysis. Shift-share analysis with output level can be found Mayor and López (2008) and Márquez et al. (2009) among others.

However, there are a few sectors with counter-evidence: particularly, Other Transport Services (23) has negative regional shift (and all other factors are positive) in Figure 7, whereas in Figure 4 the contributions of $\Delta\mathbf{D}$ are positive and the change in export demand ($\Delta\mathbf{e}$) is only the negative value. Why? This can be interpreted that by some reason (probably national and this industry specific trend based on the results from shift-share analysis) this sector has changed the technology and intermediate purchasing pattern to emphasize more on regional specific services rather than exporting their service to other regions.

<<insert Figure 7 here>>

Figure 8 illustrates the results of shift-share analysis for 2000-2008. The distribution of results emulates the one in Figure 5, similar to the comparison of 1985-1990 results. The results are mostly consistent between the results of structural decomposition and of shift-share analysis, except Public Services (24). This sector has all the factors having positive values for shift-share results, while the structural decomposition derived the contributions of $\Delta\mathbf{D}$ are negative. How can these inconsistent results between two decomposition schemes be interpreted?

<<insert Figure 8 here>>

5. Conclusions

This study aimed to measure the impact of the Kobe Earthquake on the economic structure using a series of regional input-output tables and the structural decomposition method. Based on the analysis, the significant structural changes are observed in different ways among the periods. Between 1985 and 1990, when the Japanese economy experienced a rapid growth through the so-called bubble economy, the Kobe economy grew as most of the sectors increased the outputs. This tendency, however, changed significantly after 1990 when the bubble economy bursted. During 1990 and 2000, including 1995 when the Kobe earthquake occurred, most sectors' output changes appear a mixture of positive and negative changes. This trend continues to the period of 2000-2005, while the total output change is the smallest among the three periods, the range of changes in percentage is the largest.

In order to separate out the structural change specific to the Kobe region (assuming those would be the Kobe earthquake's impacts after 1995), an additional decomposition of output change was carried out using shift-share analysis. The results reveal that large negative regional shift, implying decline of output specific to regional causes, was observed in many sectors during 1990-2000, except some service sectors having positive regional shift, while other two periods have relatively minor volume of regional shifts. Superimposing the results on shift-share analysis on the strucutural decomposition may indicate the regional specific structural change; however, comparing these results requires some tweaking of derived values, thus in this study it was not done. With a casual observation, it appears that the signs of change for regional purchase matrix ($\Delta\mathbf{D}$) and for regional shift seem consistent each other with a few exceptions. This might implicate that the Kobe earthquake influenced to accelerate the hollowing-out process of the Kobe economy. It is hence quite unfortunate that 1995 Kobe input-output table was not compiled.

The effects of the Kobe earthquake contained in the Kobe regional input-output tables are the net impacts, i.e. the sum of negative and positive impacts. And, these negative and positive impacts may offset each other and may become insignificant. For the further and more detailed analysis of the aftermath and how a disaster affects economy, net impact needs to be disaggregated to negative and positive impacts. This is because negative impact and positive gain affect the economy in many different ways, and because the extent of their effects may differ by its significance and over space. Careful examinations of these disaggregated impacts will provide important and useful information for decision making on preparedness and mitigation strategies for the future catastrophes and on recovery and reconstruction strategies of the next calamity.

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Appendix

Table A-1. Sectoring Scheme of Kobe Input-output Table

Sector Number	Industries
1	Agriculture, Forestry, Fisheries
2	Liquor
3	Food and Kindred Products
4	Apparel and Texitile Products
5	Lumber, Wood Products and Furniture
6	Rubber Products
7	Chemicals and Allied Products
8	Primary Metals Industries
9	Fabricated Metal Products
10	Industrial Machinary and Equipment
11	Heavy Electrical Equipment
12	Electrical Appliances
13	Shipbuilding Industry
14	Other Transport Industry
15	Precision Machinery
16	Miscellaneous Manufacturing Industries
17	Construction
18	Utilities
19	Commerce
20	Finance and Insurance
21	Real Estate
22	Port Related Transport Services
23	Other Transport Services
24	Public Services
25	Business Services
26	Personal Services
27	Government Enterprises
28	Others

Table 1. Trends of Output Change by Sector (2005 million yen)

Sector	1985-1990	(%)	1990-2000	(%)	2000-2005	(%)
1	-2,026	(-0.1%)	-753	(0.1%)	985	(0.5%)
2	-18,528	(-0.9%)	66,167	(-10.0%)	**-62,289**	**(-31.0%)**
3	139,231	(6.6%)	**-389,798**	**(58.7%)**	38,207	(19.0%)
4	12,624	(0.6%)	-28,943	(4.4%)	-16,775	(-8.3%)
5	4,134	(0.2%)	-10,748	(1.6%)	**-89,644**	**(-44.6%)**
6	5,607	(0.3%)	-103,070	(15.5%)	-17,685	(-8.8%)
7	74,162	(3.5%)	542	(-0.1%)	13,543	(6.7%)
8	-26,510	(-1.2%)	**-171,372**	**(25.8%)**	**59,586**	**(29.6%)**
9	26,872	(1.3%)	-23,045	(3.5%)	-31,547	(-15.7%)
10	105,234	(5.0%)	**-256,742**	**(38.7%)**	17,481	(8.7%)
11	64,359	(3.0%)	38,002	(-5.7%)	-500	(-0.2%)
12	51,552	(2.4%)	50,706	(-7.6%)	**131,709**	**(65.5%)**
13	-46,355	(-2.2%)	16,700	(-2.5%)	460	(0.2%)
14	6,126	(0.3%)	-57,827	(8.7%)	**79,257**	**(39.4%)**
15	5,268	(0.2%)	5,347	(-0.8%)	-1,565	(-0.8%)
16	43,860	(2.1%)	-157,876	(23.8%)	11,770	(5.9%)
17	**613,118**	**(28.9%)**	**-467,844**	**(70.5%)**	**-283,848**	**(-141.2%)**
18	30,017	(1.4%)	68,317	(-10.3%)	28,875	(14.4%)
19	241,832	(11.4%)	63,250	(-9.5%)	**83,843**	**(41.7%)**
20	105,724	(5.0%)	**215,092**	**(-32.4%)**	20,186	(10.0%)
21	58,495	(2.8%)	**224,785**	**(-33.9%)**	-39,130	(-19.5%)
22	-49,485	(-2.3%)	**-277,838**	**(41.8%)**	10,622	(5.3%)
23	-22,320	(-1.1%)	-102,064	(15.4%)	12,367	(6.2%)
24	354,165	(16.7%)	**232,696**	**(-35.0%)**	**312,451**	**(155.4%)**
25	267,717	(12.6%)	**174,967**	**(-26.3%)**	**-70,641**	**(-35.1%)**
26	48,763	(2.3%)	**176,563**	**(-26.6%)**	**-60,067**	**(-29.9%)**
27	24,710	(1.2%)	146,064	(-22.0%)	**50,987**	**(25.4%)**
28	5,495	(0.3%)	-95,328	(14.4%)	2,392	(1.2%)
Total	2,123,842	(100%)	-664,050	(100%)	201,032	(100%)

Remark: bold numbers are >= 25% of each period's total change; shaded numbers are >= 20% of total change during 1985-2005 (>=332,165 million yen).

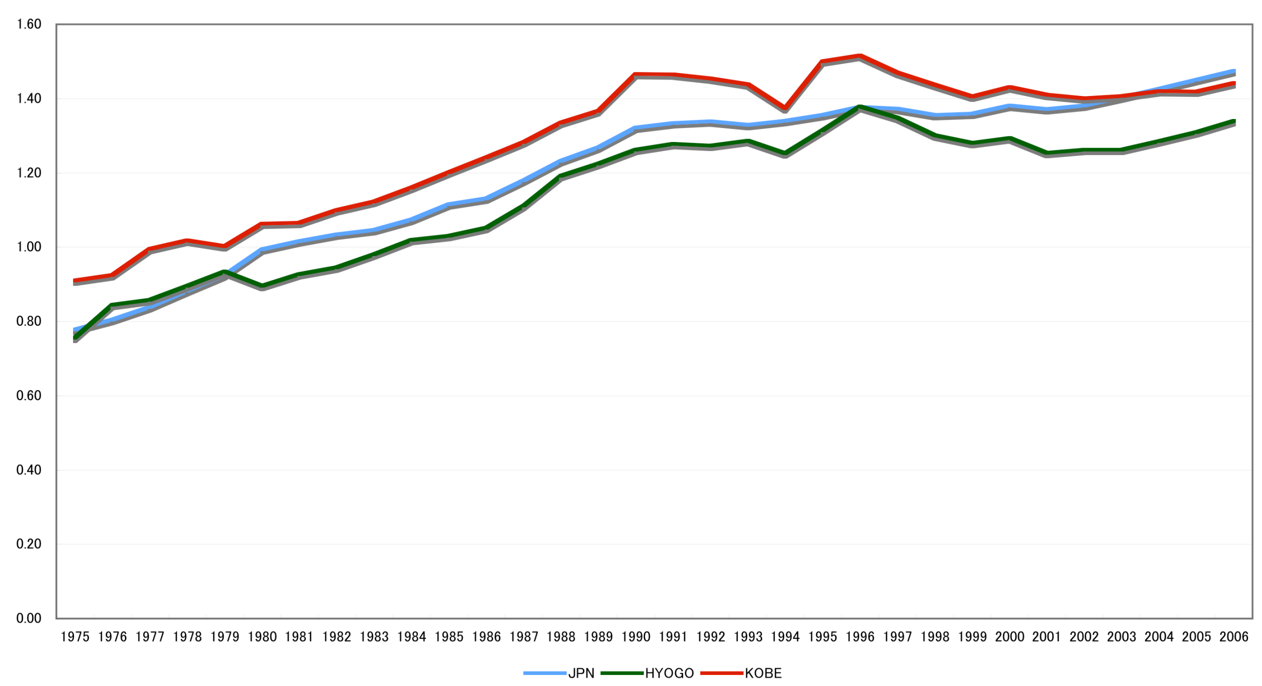

Figure 1. Trends of per capita GDP and GRPs (logarithm):
Japan, Hyogo Prefecture, and City of Kobe (constant price at year 2000)

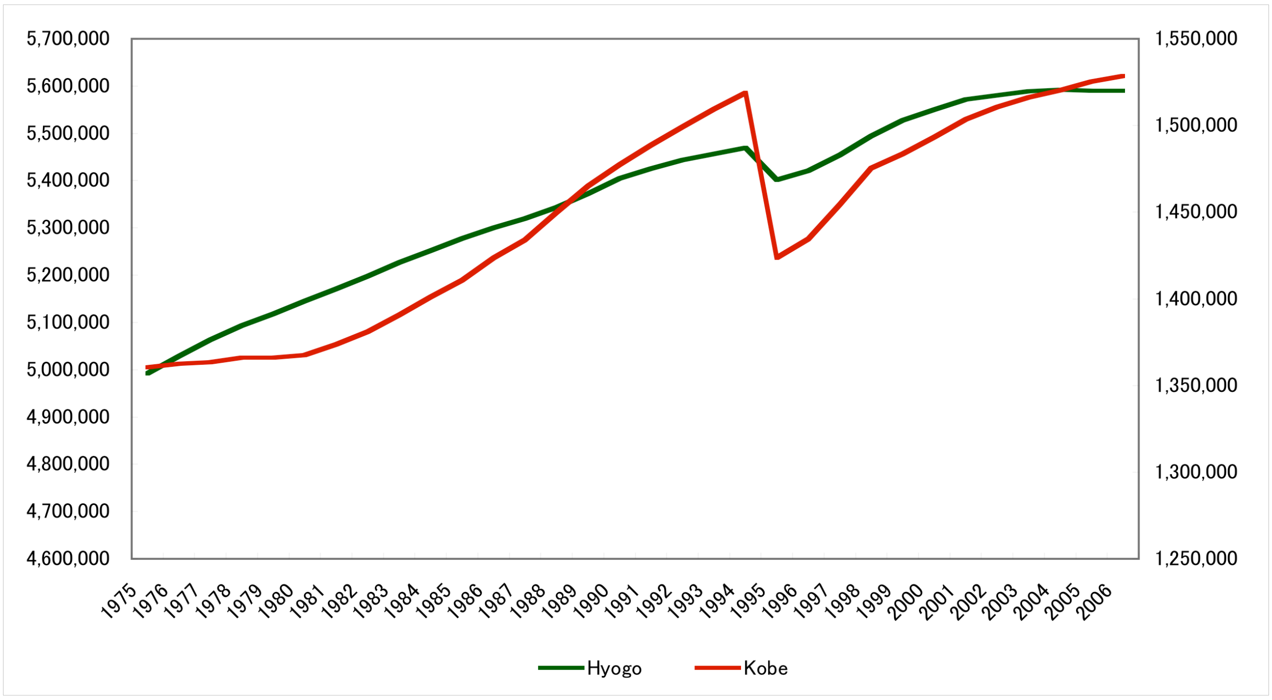

Figure 2. Trends of Population for Hyogo Prefecture and City of Kobe
(right vertical axis for Kobe and left vertical axis for Hyogo)

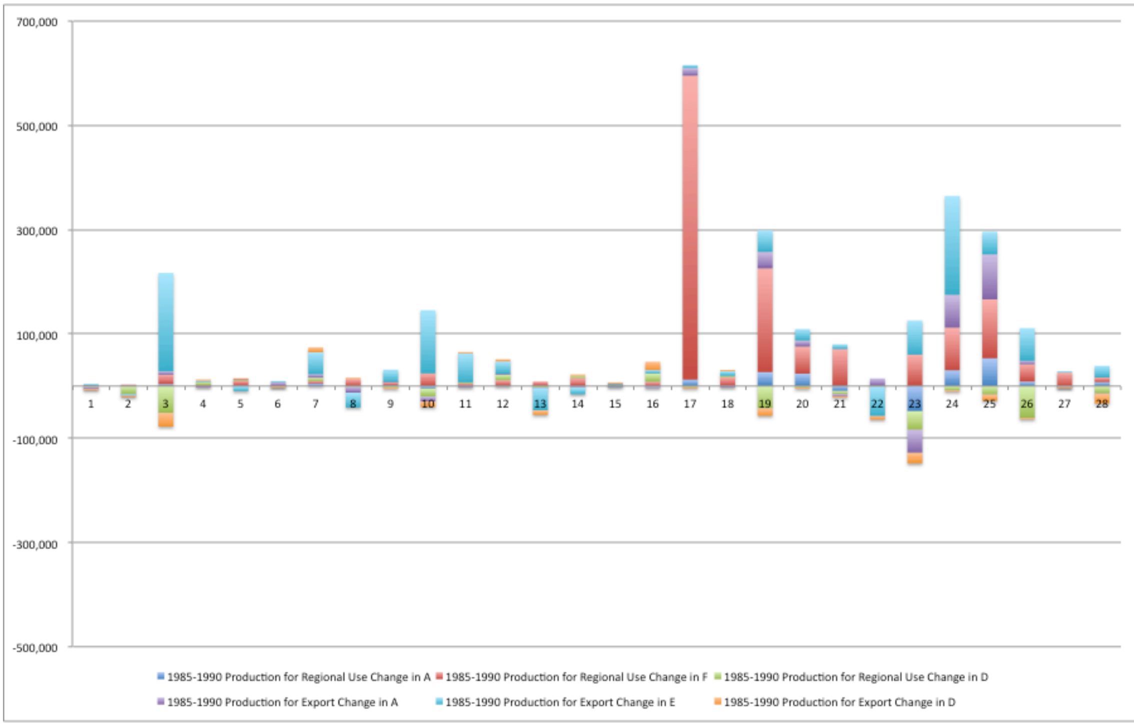

Figure 3. Distribution of Decomposed Factors by Sector: 1985-1990

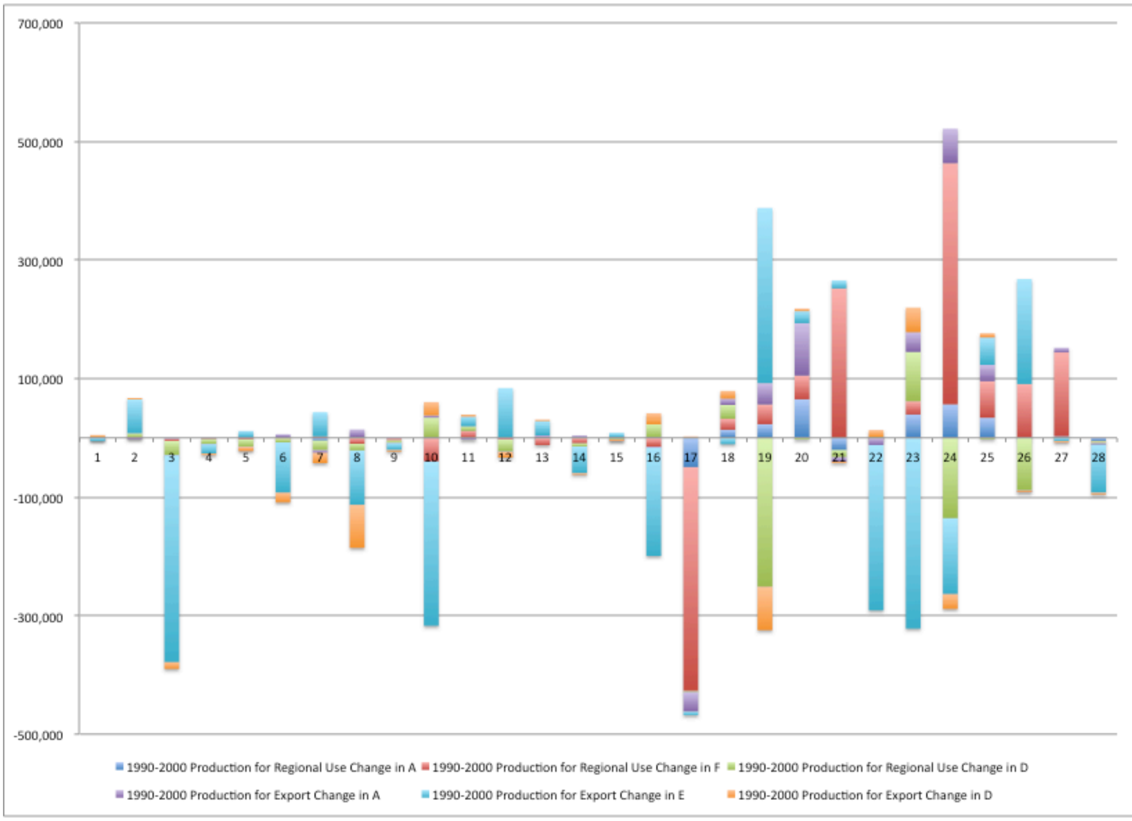

Figure 4. Distribution of Decomposed Factors by Sector: 1990-2000

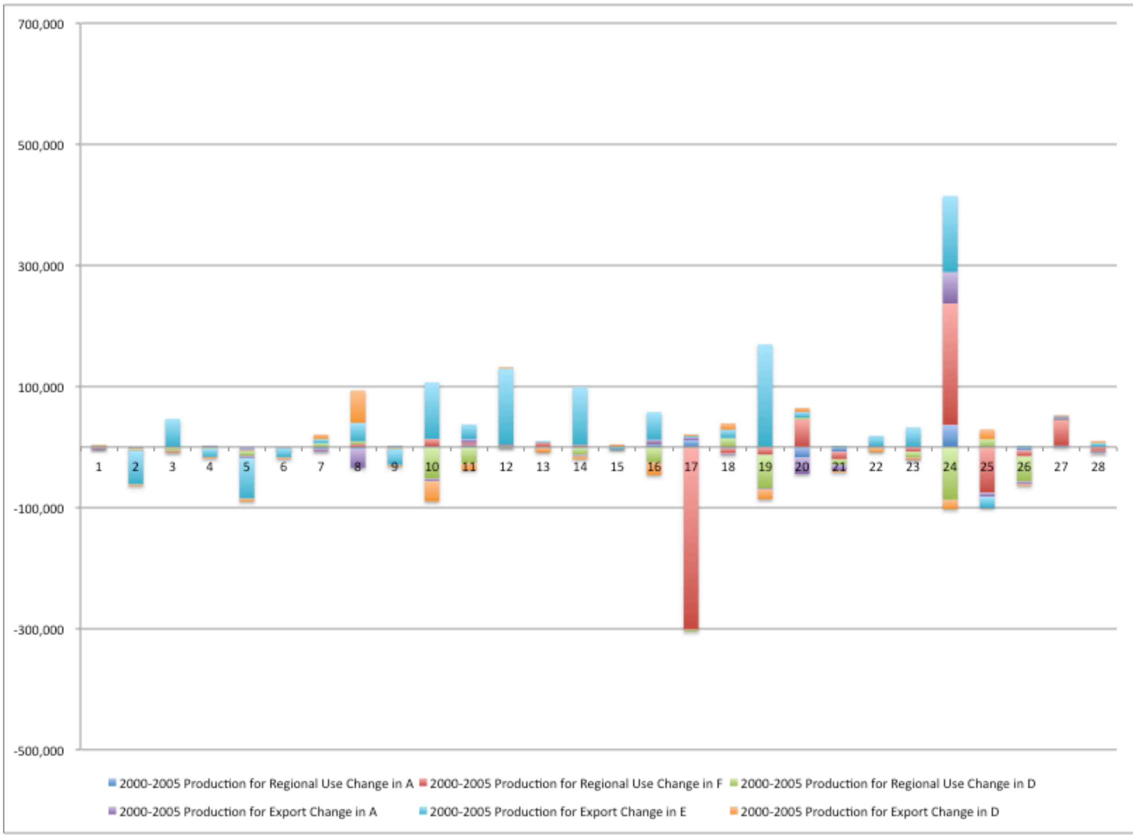

Figure 5. Distribution of Decomposed Factors by Sector: 2000-2005

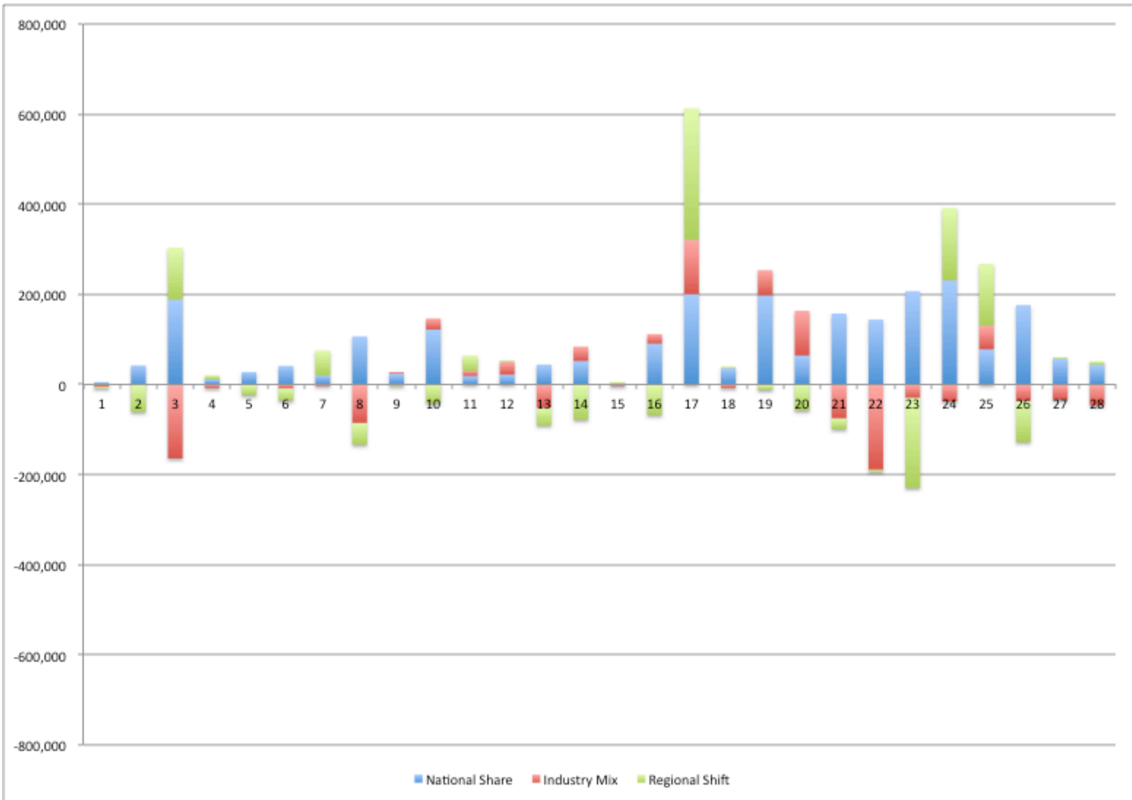

Figure 6. Distribution of Shit-Share Results: 1985-1990

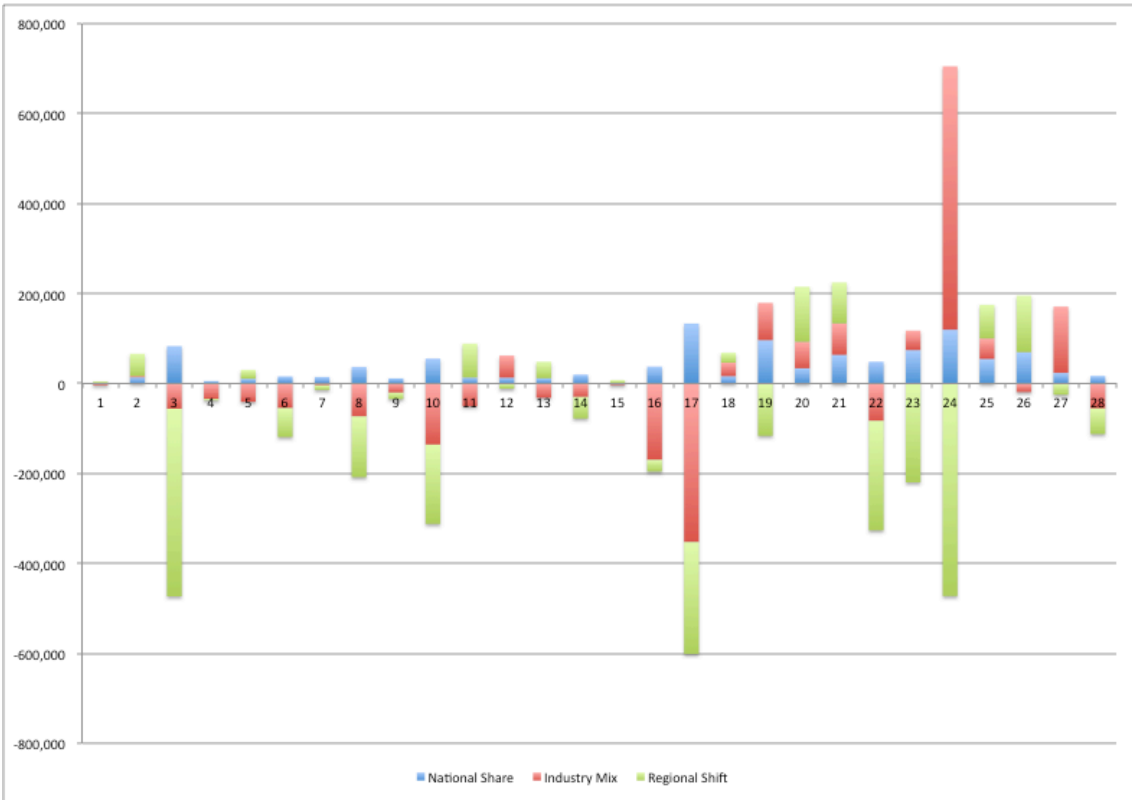

Figure 7. Distribution of Shit-Share Results: 1990-2000

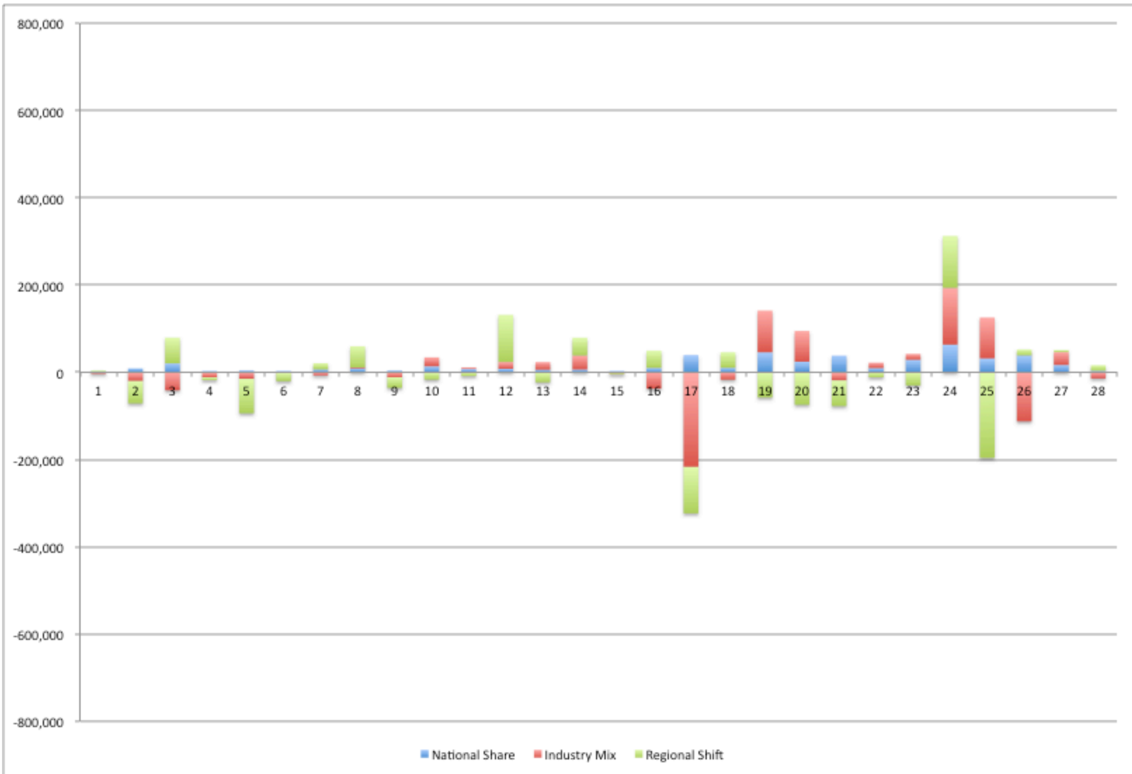

Figure 8. Distribution of Shit-Share Results: 2000-2005