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DOCTORAL DISSERTATION

EMPIRICAL STUDIES ON REGIONAL AND MACROECONOMIC DEVELOPMENTS OF THE JAPANESE ECONOMY

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MASAAKI KAWAGOE

OSAKA SCHOOL OF INTERNATIONAL PUBLIC POLICY

OSAKA UNIVERSITY

Abstract

This dissertation is an empirical study of the regional and macroeconomic issues of the Japanese economy. In addition to Introduction, there are three chapters, the main points of which are summarized below.

Chapter 2 deals with the long-term trends and short-term cyclical aspects of the regional economies in Japan. Barro and Sala-i-Martin's (1992) results of regional convergence in US state and Japanese prefecture data are re-examined using alternative methodologies. As a result, the convergence hypothesis of "catching up" is rejected in Japanese prefectural data, with the distribution across prefectures converging to an almost uniform distribution.

In order to examine labor mobility, VAR models are applied to regional labor market data. A comparison of the results with those of Decressin and Fátas (1995) reveals that labor mobility plays a minor role in Japan and that, overall, the Japanese responses resemble those in Europe.

Chapter 3 examines the personnel costs of local governments, which is an important factor in restricting increases in local government expenditure. Spatial econometrics techniques detect strong spatial autocorrelation, even after adjusting for differences in fiscal and other conditions, in weighting allowance rates, which municipal governments can determine on their own. This is consistent with the hypothesis that a herding mentality occurs among municipal governments in close proximity to each other when setting the rates.

Chapter 4 sheds light on how to measure the long-term performance of the economy. This chapter attempts to quantify the economic value of the mortality reduction between 1970 and 2005 by estimating the willingness-to-pay (WTP) for greater longevity based on Murphy and Topel (2003, 2006). The economic value turns out to be as much as 165 trillion yen per year, as of 2005, or about 30 percent of GDP.

The results are as follows. First, regional developments are by no means deterministic, and initial income levels have limited ability to predict subsequent growth. Regional demand shocks may have long-lasting effects on economic performance of the regions because of the slow labor mobility. Various forces, and their interactions, may drive regional economies, and such complex dynamics are unlikely to be represented by convergence, even in a first approximation. Second, greater longevity may bring enormous benefits. Measuring the WTP for greater longevity is likely to provide additional information about the long-term economic performance of the national and regional economies, thereby contributing to more balanced views of aging.

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Chapter 1

Introduction

This dissertation is an empirical study of the regional and macroeconomic issues of the Japanese economy. The following two underlie this dissertation.

First, I let the data speak, and hear their stories. I utilize model-free and data–driven approaches whenever possible, because unfit models in mind could misguide empirical studies. This is in sharp contrast to the approach of Barro and Sala-i-Martin (1992a, b) in empirical studies of growth theory, for example. If we consider data through the lens of the Solow growth model, it would be natural to begin our analysis by regressing economies' growth rates on their initial income levels in order to detect negative relations between them. However, we may make a mistake called Galton's fallacy. Furthermore, we cannot overlook a small residual in the regression, because a seemingly innocuous growth difference could result in a large difference in relative income levels in the long run, owing to the power of compound rate calculations. It is necessary to carefully examine the data and to refrain from "using econometrics to illustrate the theories which we believe independently" (Gilbert, 1986). Although my dissertation does not concern econometric procedures, it is, in a sense, in the spirit of the general-to-specific approach of econometrics (Hendry, 1993). In addition, new tools are needed for us to fully understand the stories the data tell: Markov chain models are useful to capture the dynamics of regional per capita output distribution over time; and spatial econometrics to incorporate geographic information into analysis of the local public finance situations.

Second, measurement is valuable: it makes things visible. A classic example is that of measuring money stock in Friedman and Schwartz (1963). Today, people seem to worry about the costs, but ignore the benefits, of aging. Aging may be a fruit of economic growth, and should be welcomed in itself. Although this viewpoint is emphasized in a physiological approach to economic growth (e.g., Fogel, 1994), it is often overlooked in policy debates, as in the fiscal consolidation debate in the late

2000s. Measuring the benefits of aging is expected to be a valuable first step towards a better understanding of aging societies.

In addition to this Introduction, the dissertation consists of three chapters, the main points of which are summarized as below.

Chapter 2 discusses the long-term trends and short-term cyclical aspects of the regional economies in Japan. Section 1 re-examines Barro and Sala-i-Martin's (1992) results of regional convergence in US state data and Japanese prefecture data. Cross-section regressions, so-called "Barro regressions," were widely used in world and regional income data to test whether convergence takes place. This section applies alternative theory-free methodologies, namely a time series test and a Markov chain model, to Japanese prefectural data and shows that the convergence hypothesis of "catching up" does not hold. Markov chain models are also shown to be more informative about the evolution of distribution than are cross-section regressions, because the former allow us to model the entire distribution.

Section 2 also takes a model-free approach: it examines how Japanese regional labor markets respond to demand shocks, using VAR models. Comparing the results with those of Decressin and Fátas (1995), I find a smaller role played by labor mobility in Japan than in the United States. Changes in labor participation rate play a major role as an adjustment mechanism in Japan, which is a characteristic shared by Europe.

Chapter 3 turns to a local public finance issue, namely personnel costs of local governments, which is an important factor in increasing their expenditures. Using spatial econometrics models, this chapter investigates whether a herding mentality affects personnel pay, especially weighting allowance rates, which are left to the discretion of municipal governments. Even after adjusting for factors such as the fiscal conditions of municipal governments and living costs differences, strong spatial autocorrelation is detected: the estimated parameter is in the range of 0.7 to 0.9. This result turns out to be robust, as long as the weight matrices used are based on various definitions of proximity between municipalities. Thus, a herding mentality is likely to function among municipal governments in close proximity to one another when setting the rates.

Chapter 4 examines how to measure the long-term performance of the economy. This chapter attempts to quantify the economic value of greater longevity between 1970 and 2005. In particular, it estimates people's willingness-to-pay (WTP) for a decline in mortality rates during that period, based on the work of Murphy and Topel (2003, 2006). The economic value turns out to be as much as 165 trillion yen per year as of 2005, or about 30 percent of the gross domestic product (GDP). Changing the values of the discount rate and utility function parameters shows the possible range of the values obtained for WTP.

Lessons gained here are summarized as follows. First, regional developments are by no means deterministic. Regions' initial states may have some effects, but are unlikely to be crucial to their subsequent developments. In fact, Japanese regions did not converge in the sense of "catching up," and their long-run equilibrium distribution is estimated to be almost uniform. Furthermore, regional demand shocks may have long-lasting effects on the economic performance of the regions because of the slow labor mobility. In addition, a herding mentality of local governments may hinder the convergence by maintaining some "fair pay" with their neighbors. Various forces and their interactions may drive regional economies, and such complex dynamics are unlikely to be represented by convergence, even at a first approximation. These findings will lead us to the second lesson: depending on the data at hand, suitable empirical tools need to be selected carefully.

Third, greater longevity may bring us enormous benefits. Measuring the WTP for greater longevity is likely to provide additional information about the long-term economic performance of the national and regional economies, thereby contributing to more balanced views of aging. Different situations need different measurements, as shown by a history of GDP (Coyle, 2014). Progress in aging might need new societal measures and, from this perspective, paying attention to health could have great potential. Examples in this line of research include the following: two experts in public health re-examined the costs of fiscal consolidation after the Global Financial Crisis in

2008 by realizing damages to health conditions due to cutting healthcare expenditures (Stuckler and Basu, 2014); the UN and other international organizations began publishing new estimates of health and other capital every two years (UNU-IHDP and UNEP, 2012). Such measurements could pave the way for new cost-benefit analysis of aging.

Here, I present a list of sources for each chapter.

- Ch. 2 Section 1: Kawagoe, Masaaki (1999) "Regional Dynamics in Japan: A Re-examination of Barro Regressions," *Journal of Japanese and International Economies*, 13: 61-72.
- Ch. 3 Section 2: Kawagoe, Masaaki (2004) "A Comparative Study of Regional Labour Dynamics in Japan," *JCER Discussion Paper* No.90 September Japan Center for Economic Research.
- Ch. 4: Kawagoe, Masaaki and Katsuyoshi Honjo (2008) "Does Herding Mentality Affect Weighting Allowance Rates Set by Municipal Governments? A Special Econometric Approach," *Policy Analysis Quarterly*. 3:3-14. Network for Policy Analysis (in Japanese).
- Ch. 4 Appendix: Kawagoe, Masaaki and Katsuyoshi Honjo (2006) "How Does Fiscal Discipline Work in Local Governments? An Empirical Study of Weighting Allowance Rates," *ESP* 412: 332-336 (in Japanese).
- Ch. 5: Kawagoe, Masaaki (2009) "What Is the Economic Value of Japanese Longevity? Estimating the Outcome of Economic Growth" *The Japanese Economy*, 36: 28-60 M.E. Sharpe, Inc.
- Ch. 5 Appendix 2: Kawagoe, Masaaki and Yoshimitsu Suzuki (2016) "Healthcare Performance" in Masaaki Honmma, Nariaki Matsuura, Masaaki Kawagoe, and Masahiro Hidaka ed. *Healthcare and Economics*, Osaka University Press (in Japanese).

Chapter 2

Regional Dynamics in Japan

1. Introduction

What kinds of forces drive economies? Do poor regions or countries catch up with richer ones? How is an external shock absorbed or propagated through some adjustment mechanism in economies? How can we obtain such a “law of motion” from the data?

This chapter examines the trends and cyclical aspects of the regional economies in Japan. An underlying motivation is to pursue a model-free and data-driven approach to the data: let the data tell a story, and obtain the implications. This is in sharp contrast to the approach of Barro and Sala-i-Martin (1992a, b), among others.

Their empirical methodologies, namely cross-section regressions, are direct applications of the Solow growth model, a theory-driven approach, and have been widely used with various data. Although a 2 percent convergence per year has been found in many analyses, we should question what the cross-section regressions really have shown. For example, as Breinlich, Ottaviano, and Temple (2014) pointed out, an innocuous small difference in the growth rates of economies with the same initial income level, which could be shown by the difference between points slightly above and below the negative regression line, could result in a large difference in their relative income levels in the long run, owing to the power of compound rate calculations.

This skepticism encourages us to apply alternative methodologies, a time series test and a Markov chain model, to Japanese prefectural data and to re-examine the results of Barro and Sala-i-Martin (1992b). These methodologies will show that the convergence hypothesis of “catching up” does not hold for Japanese prefectural data. Markov chain models are shown to be more informative than cross-section regressions for regional dynamics by comparing the different dynamics between the United States and Japan, and between two periods in Japan.

Once factor mobility is taken into account, the 2 percent convergence is more problematic because factor mobility promotes the convergence of an economy to its steady state. Although the Solow model was originally envisaged for a closed economy, factor mobility cannot be ignored in regional data. Some adjustment mechanism is needed to solve the puzzle. An example is provided by Barro, Mankiw, and Sala-i-Martin (1995), who incorporate capital market imperfection.

Going back to the basics, it is necessary to examine the role played by labor mobility. In this context, we investigate how regional labor markets respond to external shocks, using VAR models, another theory-free methodology. In addition, comparing our results with those of Decressin and Fátas (1995), who analyzed the dynamics of European and US regional labor markets, will reveal characteristics of Japanese regional adjustments.

This chapter is structured as follows. Section 2 re-examines the results of Barro and Sala-i-Martin (1992b) by applying alternative methodologies to Japanese regional output data. Section 3 examines the roles of labor mobility in responses of regional labor markets to an external demand shock. Section 4 concludes the chapter. Note that a feature of this chapter is to always put these analyses into an international perspective by comparing the results for Japan with those for the United States and Europe.

2. A Re-examination of Barro Regressions

Following Barro and Sala-i-Martin (1992a,b), in order to test the convergence hypothesis, cross-section regressions have been widely applied to various data: the world income distribution and regional data for the United States, Europe, and Japan. However, many difficulties using cross-section regressions have been pointed out, as discussed later. This section applies alternative methodologies, namely a time series test and a Markov chain model, to Japanese prefectural data and re-examines the results of Barro and Sala-i-Martin (1992b).

2.1 Convergence and Cross-section Regressions

2.1.1 Convergence as "catching-up"

First of all, convergence needs to be defined. Here, convergence means "catching up:" do poor countries or regions catch up to rich ones? If so, this implies the income distribution collapses to a point over time, without any random disturbances. A formal definition, allowing for random disturbances, is given as follows (Bernard and Durlauf, 1996):

$$\lim_{T\to\infty} E_t(y_{i,t+T} - y_{j,t+T}) = 0, \qquad (2.1)$$

where $y_{i,t}$ is the log of the per capita income of economy i at time t[1].

According to the Solow growth model (Figure 2.1 (1)), the per capita income of each economy will attain the same level, at a steady state, as long as the following assumptions hold: there is a common production function with constant returns to scale and the same savings rate (or time preference). The model also shows that, in the process of transitioning to the steady state, the growth rates of rich economies are lower than those of poor economies because of the diminishing marginal productivity of capital.

(Figure 2.1)

Multiple steady states are easily produced if we relax one of the above conditions (Galor, 1996). Figure 2.1 (2) shows an example of heterogeneous production functions. Such heterogeneity is called a "local" Solow model (Durlauf, Kourtellos, and Minkin, 2001). It is also notable that the same multiplicity is obtained by introducing nonlinearity, such as a production function shown by Eq.(2.2), into the model (see Figure 2.1 (2)). In general, this nonlinearity expresses the indivisible nature of some

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[1] This definition corresponds to "convergence as equality of long-term forecasts at a fixed time" (Definition 2) in Bernard and Durlauf (1996). Their definition of "convergence as catching up" is different from ours.

economic activities. This could be a threshold externality (Azariadis and Drazen, 1990), with the threshold of k_3 in Figure 2.1 (2):

$$\mathrm{y} = \begin{cases} f_2(k) \ if \ k \le k_3 \\ f_1(k) \ if \ k > k_3 \end{cases}. \tag{2.2}$$

Suppose we have per capita income data of various economies over time. In the above setup, a natural question to ask would be how these economies evolve over time. Does the observed distribution at a particular time collapse? In other words, does convergence or catching up take place? It would be possible that some economies attain a high income level, while others reach a lower level, as shown in Figure 2.1 (3). Now, we have convergence clubs (Quah, 1997). How can we extract a law of motion from the data at hand? Unfortunately, as the next subsection shows, conventional analytical tools in growth econometrics are not well suited to answer these questions.

2.1.2 *β*- and *σ*-convergence

A series of empirical studies by Barro and Sala-i-Martin (e.g., Barro and Sala-i-Martin (1992a)) concern the transitional dynamics implied by the Solow model. In their studies, they use so-called Barro regressions, which are regressions of the growth rate of income on its initial level:

$$(y_{i,t+T} - y_{i,t})/T = \alpha - (1 - e^{\beta T})(y^* - y_{i,t})/T + u_{i,t+T}, \tag{2.3}$$

where y^* is the log of the steady-state income. The coefficient β measures the speed of shrinkage of the gap between the steady-state level (y^*) and the initial level ($y_{i,t}$). Positive β implies a negative correlation between the growth rate and the initial level, which Barro and Sala-i-Martin called "β-convergence." Another convergence idea, named "σ-convergence," means the variance of the income dispersion becomes smaller as time passes.

Numerous studies have examined both convergence ideas using various data. These studies found that adding exogenous variables to the right-hand side of Eq.(2.3) turned out to be useful to detecting "true" value of β. That is, a positive β with exogenous variables is called "conditional convergence." These exogenous variables are interpreted to adjust for differences in steady-state per capita income across economies. The empirical studies have produced a long list of exogenous variables, which is featured by the title of Sala-i-Martin's (1997) paper, "I Just Ran Two Million Regressions."

However, the following difficulties in Barro and Sala-i-Martin's studies have been pointed out[2]. The first two are conceptual, and the rest are methodological.

First, "β-convergence" does not imply convergence as catching up, in the sense of Eq.(2.1). A counter-example of Bernard and Durlauf (1996) is the following. Suppose the levels of steady-state income are different. Then, "β-convergence" takes place if economies converging to a lower level of y^* start far below their y^*, while economies converging to the higher level start near their y^*. The situation may correspond to economies of A and D in Figure 2.1 (3).

The second difficulty concerns the idea of "conditional convergence:" the adjustment by exogenous variables itself implies the failure of convergence as catching up. For example, Figure 2.1 (3) shows conditional convergence among four economies $\{A, B, C, D\}$, after controlling for the difference between their steady states, S_1 and S_2. However, no catching up takes place: there remains a difference between the two steady-state per capita income levels. Various techniques, such as using panel data (e.g., Lee, Pesaran, and Smith, 1997), are employed, and may be helpful in cleaning up the β estimate, but are often of little value in overcoming the above conceptual difficulties.

Note that conditional convergence could still be useful in that it gives us information about the production functions. In fact, the unexpectedly slow convergence speed turned economists' attention to broader definitions of capital, including human capital. However, as Quah (1996) argues, "if the researcher's interest lies only in the

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[2] See Quah (1996), Bernard and Durlauf (1996), and Durlauf and Quah (1999), among others. There are extensive literature surveys such as Durlauf, Johnson, and Temple (2005, 2009), Breinlich, Ottaviano, and Temple (2014), and Magrini (2004).

coefficients of a production function, then why not just estimate those directly?” (p.1361).

Third, although various empirical studies show the estimate of β to be about 2%, this may be produced by “unit root in disguise.” Quah (1996) shows if the per capita income of each economy follows a unit root process, the cross-section regressions automatically produce an estimate of about 2% β-coefficient.

Fourth, there is a potential conflict between “β-convergence” and “σ-convergence.” That is, a positive β-coefficient can coexist with distributions with constant variance over time, as the “Galton's Fallacy” argument of Quah (1993b) shows. Galton’s fallacy is an 18th century controversy in France, and was revived by Friedman (1992) in the context of growth. Galton, a statistician, made an erroneous inference: a mean reversion tendency that taller parents, who were likely to be aristocrats at that time, have shorter children, may reduce the height difference between aristocrats and commoners over time, a grave warning to the future military force. His mistake is due to ignoring stochastic disturbances, which could leave the distribution unchanged over time, even with the mean reversion tendency.

Thus, these difficulties suggest that “β-convergence” and “σ-convergence” are of little help in answering the question asked at the beginning of this chapter. A lesson learned from Galton’s fallacy is that it is necessary to model the entire distribution.

2.1.3 Findings of Barro and Sala-i-Martin (1992b)

Let’s summarize Barro and Sala-i-Martin’s (1992b) findings as follows, for later reference:

- **(F1)** their “basic equation,” a modified equation of Eq.(2.3) for an empirical purpose, shows “amazing fit” (adjusted $R^2 = 0.92$) in per capita income across Japanese prefectures from 1930 to 1987, without any exogenous variables;
- **(F2)** by introducing regional dummies to adjust for differences in the steady state per capita income and absorb the fixed effect in the error term, they “confirm that part of the story is convergence across regions and part is convergence across prefectures within regions” (p.322);

(F3) stability of β-coefficient among sub-periods failed in the data;

(F4) in the US-Japan comparison, "the patterns of regional growth are similar for both countries" and the β-coefficient is "0.025 for the United States and slightly higher for Japan" (p.341).

2.2 Data

Our data are annual per capita gross prefectural production (hereafter, per capita output, for simplicity) of 47 Japanese prefectures from 1955 to 1991. Barro and Sala-i-Martin (1992b) used a national CPI as a deflator and ignored the difference in the price level among prefectures. Here, we adopt a national GNP deflator and ignore the price level difference, to keep consistency with Barro and Sala-i-Martin (1992b).

Figure 2.2 shows the evolution of the distribution of $z_{i,N,t} \equiv y_{i,t} - y_{N,t}$ over the sample period. The distributions do not seem to collapse toward a point over time.

(Figure 2.2)

2.3 Time Series Tests

2.3.1 Empirical Methodologies

The first alternative is a variant of Bernard and Durlauf's (1995) test. Suppose Y_t is a vector of per capita income of country 1 to n, $\{y_{1,t},...,y_{n,t}\}'$. Our definition of convergence shown by Eq.(1) requires the following should hold:

$$\begin{bmatrix} 1 & 0 & \cdots & 0 & -1 \\ 0 & 1 & 0 & \vdots & -1 \\ \vdots & \vdots & \ddots & 0 & \vdots \\ 0 & 0 & \cdots & 1 & -1 \end{bmatrix} \begin{bmatrix} y_{1,t} \\ y_{2,t} \\ \vdots \\ y_{n-1,t} \\ y_{n,t} \end{bmatrix} = \begin{bmatrix} z_{1,n,t} \\ z_{2,n,t} \\ \vdots \\ z_{n-1,n,t} \end{bmatrix} = \begin{bmatrix} \mu_{1,n} \\ \mu_{2,n} \\ \vdots \\ \mu_{n-1,n} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1,n,t} \\ \varepsilon_{2,n,t} \\ \vdots \\ \varepsilon_{n-1,n,t} \end{bmatrix} \sim I(0), \qquad (2.4)$$

and the intercept $\mu_{i,n}$ should be zero (i = 1, ..., n-1). Otherwise, the gap between region i and j, $y_{i,t}$ - $y_{j,t}$, will either diverge without bounds or converge to some non-zero constant. Neither case implies that convergence as catching up holds.

Bernard and Durlauf (1995) find each $y_{i,t}$ follows an *I(1)* process, and then estimate a cointegration vector (c, -1): convergence holds if c is one; and, if not, a "common trend" holds. They reject convergence, but find a "common trend" across European and OECD countries. However, as only convergence is our concern, neither the unit root test nor the estimation of the cointegration vector is needed. Whether Eq.(2.4) holds or not is independent of the order of integration of $y_{i,t}$. It is enough to test the following necessary conditions of Eq.(2.4) for each i: the difference between prefecture i and the arbitrarily chosen prefecture j, $z_{i,j,t} \equiv y_{i,t} - y_{j,t} = \mu_{i,t} + \varepsilon_{j,t}$ should be *I(0)*; and the intercept $\mu_{i,t}$ should be zero.

A remark is in order. Although we need to test the null that $z_{i,j,t}$ is *I(0)*, the DF/ADF test, and many others, deal with the null of *I(1)*, not *I(0)*. The test of Kwiatkowski *et al*. (1992) is an exception and is employed here[3]. Their test statistic is:

$$\eta_{\mu} = T^{-2}\sum S_t^{\,2} / s^2(l), \tag{2.5}$$

where :

$$\begin{aligned}
S_t &= \sum_{i=1}^{t} e_i \\
e_t &= z_{i,j,t} - \bar{z}_{i,j.} \\
s^2(l) &= T^{-1}\sum_{t=1}^{T} e_t^{\,2} + 2T^{-1}\sum_{s=1}^{l} w(s,l) \sum_{t=s+1}^{T} e_t e_{t-s} \\
w(s,l) &= 1 - s/(l+1).
\end{aligned}$$

2.3.2 Convergence across 47 Prefectures

We choose $y_{14,t}$, the output of Tokyo[4], as the base prefecture, and then test, following

[3] The approach of Kwiatkowski *et al*. (1992) is explained as follows. Assume that $z_{i,j,t}$ can be decomposed into a random walk ($\theta_{i,j,t}$) and a stationary error ($\varepsilon_{i,j,t}$):

$$z_{i,j,t} = \theta_{i,j,t} + \varepsilon_{i,j,t} = \theta_{i,j,t-1} + u_{i,j,t} + \varepsilon_{i,j,t}.$$

They test $\sigma_u^2 = 0$ under the weak distributional condition of $u_{i,j,t}$.

[4] See Appendix 2.B for district and prefecture codes.

Kwiatkowski *et al.*(1992), whether $z_{i,14,t} \equiv y_{i,t} - y_{14,t}$ is *I(0)* or not. The results are reported in the first part of Table 2.1. Although the values of the test statistic depend on l, the lag order, they seem to settle at l = 7 or 8. We reject the null in two prefectures, Yamanashi and Hyogo, at the 5% significance level and l = 8. For the other prefectures, we proceed to test the null of $\mu_{i,j} = 0$ and find rejections in all cases[5].

Therefore, we find the failure of convergence as catching up across all 47 prefectures, contrary to (F1) of Barro and Sala-i-Martin (1992b).

(Table 2.1)

2.3.3 Convergence within Regions

We now turn to test the convergence within regions, based on the same regional classification as Barro and Sala-i-Martin (1992b) (see Appendix 2.B). The previous procedures are repeated to test the hypothesis in each district. We find rejections of the null that $z_{i,j,t}$ is *I(0)* in five out of seven districts at the 5% significance level and l = 8 (Table 2.1). Furthermore, even if $z_{i,j,t}$ follows an *I(0)* process, the null of the intercept being zero is rejected in almost all cases: an only exception is Niigata in District 1[6].

Consequently, β-convergence across prefectures within regions, (F2) of Barro and Sala-i-Martin (1992b), does not mean the same regional steady-state level of income is shared.

The above two analyses show that (F1) and (F2) of Barro and Sala-i-Martin (1992b) do not imply convergence as catching up. The rejections of convergence as catching up may be noteworthy, because the assumptions of homogeneous technology and preference and perfect capital mobility seem reasonable in regional data.

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[5] Alternatively, we also conduct the DF/ADF test of $z_{i,14,t}$ with the null of $z_{i,14,t}$ being *I(1)*. We fail to reject the null in all cases, except one prefecture, Chiba. However, for Chiba, the intercept, $\mu_{13,14}$, is significantly different from zero.

[6] By the DF/ADF test, the hypothesis that $z_{i,j,t}$ is *I(1)* can be rejected four times: twice in District 1, and once in Districts 2 and 4. However, the null of the intercept being zero is rejected in the four cases.

2.4 Markov Chain Models

2.4.1 Empirical Methodologies

The second alternative methodology is an application of Markov chain models, which is pursued in a series of studies by Quah.

Define $Q(t)$ as the distribution of per capita income across economies at time t, and model its dynamics as follows:

$$Q(t+1) = P(t) \cdot Q(t). \tag{2.6}$$

Here, $P(t)$ maps $Q(t)$ onto $Q(t+1)$: $P(t)$ captures changes in the external shape of the distribution and tracks intra-distributional dynamics, namely where in $Q(t+1)$ each point in $Q(t)$ maps to.

The simple way to proceed is to discretize $Q(t)$ into n states, $\{q_1,\ldots,q_n\}$, and assume time-invariance of P. Thus, we approximate the dynamics of the distribution by a discrete-state, discrete-time Markov chain model, where P is an $n \times n$ transition probability matrix. The (i,j) element of P, p_{ij}, represents the probability that an economy belonging to q_i transits to q_j in the next period.

Iterating Eq.(2.6) leads to the following predictor of the future distribution at $t+T$:

$$Q(t+T) = P^T \cdot Q(t).$$

As T tends to infinity, there exists a $1 \times n$ limiting vector π, such that

$$\pi = P \cdot \pi.$$

The vector π is the ergodic probability vector to which each row of P^T tends as T tends to infinity. Moreover, the vector π, $(\pi_1,\ldots,\pi_n)$, can be interpreted as the long-run equilibrium distribution, where π_j shows the probability that an economy belongs to state j in the infinite future.

Convergence as catching up should appear as a mass at a state of an ergodic distribution. However, Quah (1993a) finds π to be a bimodal distribution, based on world income data, which means countries will be divided into a rich and a poor group in the long run[7].

In our data, let *Q(t)* be the distribution of $z_{i,N,t}$ (i = 1, …, 47; t = 1955, …, 1991). Then, *Q(t)* is discretized into five states, $\{q_1,\ldots,q_5\}$, where q_1 is the lowest and q_5 is the highest per capita output group. The grids are chosen so that they give a uniform distribution over the whole sample period. These processes make it possible to compare our Japanese results with Quah's (1996) US results. It is notable that discretization may distort the dynamics[8] (see Appendix 2.A for further discussion).

The stationarity assumption enables us to easily estimate P: p_{ij} is estimated by calculating the ratio of the number of transitions from i to j to the total number of transitions from i. The estimated matrix P in the upper part of Table 2.2 shows persistence: the diagonal elements, (p_{11}, …, p_{55}), are large. However, this implies high mobility in the long run: the estimated 36-year transition matrix from 1955 to 1991, P^{36}, shows small diagonal elements[9].

The ergodic distribution π, shown in the table, is close to a uniform distribution. This is further evidence against the hypothesis of convergence as catching up in Japan.

(Table 2.2)

2.4.2 Comparison with US Data

We now compare our results with those in Quah's (1996) Table 3 (p.1373), which deals with US regional data. Because the US ergodic distribution is (0.19, 0.22, 0.23, 0.20, 0.16), it is worth noting that the Japanese distribution has a fat upper-side tail. This suggests there are forces pushing regions to the upper end over time in Japan,

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7 Quah (1997) finds a "twin-peaks property" in a stochastic kernel, a transition matrix with continuum states, derived from world income data.

8 That is why I tried four and six state discretization. Neither affected the subsequent discussion.

9 The 36 iterations produce the diagonal elements of (0.24, 0.23, 0.21, 0.26, 0.29). This overestimates the mobility: the diagonal elements derived directly from comparing Q(1955) with Q(1991) are (0.22, 0.43, 0.11, 0.67, 0.56).

which are absent in US.

Moreover, diagonal elements seem to show higher mobility in Japan. This will be examined in two ways. The first tests statistically whether these elements are the same between both countries: H_0 : $p^j_{ii} = p^u_{ii}$, against H_1: $p^j_{ii} \neq p^u_{ii}$. The left column of Table 2.3 (1) shows only those of p_{55} are significantly different.

The second calculates mobility indices (e.g., Geweke, Marshall, and Zarkin (1986)). The following indices are calculated:

$$M_p(P) = (n - tr(P))/(n-1)$$
$$M_b(P) = \sum_i \pi_i \sum_j p_{ij}|i-j|$$
$$M_u(P) = n\sum_i \pi_i (1-p_{ii})/(n-1)$$
$$M_e(P) = (n - \sum_i |\lambda_i|)/(n-1)$$
$$M_d(P) = 1 - |\det(P)|$$
$$M_2(P) = 1 - |\lambda_2|,$$

where λ_i is an eigenvalue of the matrix and $|\lambda_1| \geqq |\lambda_2| ... \geqq |\lambda_n|$. Loosely speaking, the first three indices are based on persistence and the second three on the convergence speed to the ergodic distribution[10]. All the indices suggest greater mobility in Japan (the left part of Table 2.3 (2)). Note that the results of the second three indices are consistent with (F4) of Barro and Sala-i-Martin (1992b). Furthermore, a statistical test is available for an index, $M_p(P)$ (Schulter, 1998). Assuming the rows of P to be independent, the estimator is asymptotically normally distributed:

$$M_p(\hat{P}) \to N\left(\frac{n - \sum_{i=1}^{n} p_{ii}}{n-1}, \frac{1}{(n-1)^2}\sum_{i=1}^{n}\frac{p_{ii}(1-p_{ii})}{n_i}\right).$$

The measured difference of $M_p(P)$ is statistically significant at the 5% level.

(Table 2.3)

[10] Although there can be inconsistency between persistence criteria (first three indices) and convergence criteria (second three) (Shorrocks, 1976), this is avoided here because the transition probability matrices under consideration have real non-negative eigenvalues (Theorem 1 in Geweke, Marshall, and Zarkin (1986, p.1410)). In our data, two indices, $M_p(P)$ and $M_e(P)$, are equal because of this characteristic.

2.4.3 Comparison between Sub-periods

Now, we examine the assumption of stationarity we have so far maintained. I divided the sample period into two sub-periods, 1955-1975 and 1975-1991, and analyzed the data in the same way as before.

The results in the middle and bottom part of Table 2.2 show very different dynamics are at work between the two periods. In the first period, a prefecture is more likely to move down than move up, and high persistence is observed in the (1,1) element. The opposite is true for the second period, with the (5,5) element showing high persistence. The ergodic distributions confirm this conjecture. Moreover, the difference in mobility can be tested statistically: four diagonal elements, except those of p_{55}, are significantly different, as shown in the right column of Table 2.3 (1). All the mobility indices reported in Table 2.3 (2) suggest lower mobility in the second sub-period than in the first, and the difference in $M_p(P)$ is statistically significant at the 5% level.

Therefore, the stationarity does not hold over the whole sample period, which is consistent with (F3) of Barro and Sala-i-Martin (1992b). This result may reflect changes in policies, such as the regional allocation of public investment and the fiscal transfer from the central to local governments. It is beyond the scope of this chapter to examine how the public policies affect the transition probability matrix.

The above two comparisons show how useful Markov chain models are when analyzing regional dynamics. Not only do they confirm (F3) and (F4), but they also uncover different dynamics between countries and sub-periods, which Barro and Sala-i-Martin (1992b) failed to detect. This advantage stems from the fact that Markov chain models directly analyze the dynamics of the whole distribution, rather than some moment of the dynamics of the distribution, such as the mean growth rate (β-convergence) or cross-sectional variance at a certain time (σ-convergence).

2.5 Summary

This section has applied a time series test and a Markov chain model to Japanese prefectural data and re-examined the results of Barro and Sala-i-Martin (1992b). The former shows the failure of convergence as “catching up” across 47 prefectures and even within a district. This is consistent with the almost uniform ergodic distribution obtained by the latter. However, neither “β-convergence” nor “σ–convergence” can answer the question of whether poor regions or countries catch up with richer ones.

Markov chain models can provide plentiful information about the dynamics of cross-section data. The results concerning mobility are also consistent with the findings of different β-coefficients between countries and periods by Barro and Sala-i-Martin (1992b). The merit of Markov chain models is that they analyze entire distributions. Considering that time-series techniques often face limited periods of data, Markov chain models are quite flexible and are expected to be studied further.

3. A Re-examination of Regional Labor Dynamics

Factor mobility is worth careful consideration in analyzing regional data. Because the Solow model was originally envisaged for a closed economy, factor mobility was ignored, which may be allowed in aggregate macro data, but not in disaggregate regional data.

Factor mobility promotes the convergence of an economy to its steady state. Perfect capital mobility, for example, pegs a domestic real interest rate to the world interest rate, resulting in instantaneous convergence. This prediction contradicts the empirical finding of slow convergence of 2 percent per annum. Some adjustment mechanism is needed to save the open economy version of the Solow model from this difficulty. Barro, Mankiw, and Sala-i-Martin (1995) argued that the extended model is consistent if a part of capital, such as human capital, cannot be financed by borrowing from the world market and has to be financed domestically[11]. On an empirical front, unfortunately, a focus was placed on whether the extension into an open economy affects the estimate of beta, despite its uninformative nature, as discussed in Section 2.

An alternative regional model is provided by Blanchard (1991), in his comment on Barro and Sala-i-Martin (1991). As a follow-up, Blanchard and Katz (1992) extended Blanchard (1991) into a three-variable VAR model to capture the dynamics in the US regional labor market. This stimulated comparative studies of how regional labor markets respond to external shocks. For instance, Decressin and Fátas (1995) and Fátas (2000) analyzed the dynamics of European regional labor markets, comparing the results between Europe and the United States. Jimeo and Bentolila (1998) examined Spanish regions, comparing them with European and US regions.

This section adopts a similar methodology to examine the dynamics of Japanese regional labor markets in comparison with their results. Here, "dynamics" means the response of regional labor markets to external shocks. Two kinds of shocks are under consideration: "macro" shocks, common to all regions in a country, and "idiosyncratic" shocks, specific to a region. Differences in the roles of labor mobility will be detected among Japanese, US, and European regions.

3.1 Data

We will use 10-region[12] annual data obtained from the Ministry of General Affairs, Labor Force Survey for the period 1983 to 2003. Decressin and Fátas (1995) studied 51 regions in the United States and Europe[13] for the period 1970 to 1990 and 1966 to 1987, respectively. Our data, thus, have about the same length, but have fewer regions

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11 Another friction used is to introduce adjustment costs of changing capital stock, such as those in Hayashi (1982). This strategy was pursued in Rappaport (2005). Rappaport (2005) also pointed out a possibility that factor mobility could reduce convergence speed. A labor outflow from poor regions may increase the capital-labor ratio, thereby raising per capita income. However, this outflow may also cut the return to capital, thereby discouraging capital investment.

12 See Appendix 2.B for district classification.

13 The following 11 countries are included: France, Germany, Italy, Spain, UK, Belgium, Greece, Ireland, Netherlands, and Portugal.

than in Decressin and Fátas (1995). In order to apply the panel time series methodology, we prefer the Labor Force Survey with the longer time-series to the National Census available every five years, despite the latter having more detailed regional information[14]. Although the Labor Force Survey provides quarterly data throughout the sample period, we use the annual data, placing a priority on consistency with Decressin and Fátas (1995).

The size of a "region" could pose a problem when comparing results among different countries. Indeed, prefectural and municipal data are likely to tell different stories, even in Japan. It seems reasonable that a larger size may imply a greater relative importance of macro shocks due to additional offsets among idiosyncratic shocks and, thus, more disaggregation may imply a greater importance of idiosyncratic shocks. On average, our regions are larger than those of Europe and the United States (see Table 2.4). For example, the value added and populations in our regions are twice as large as those of Europe and the United States. The area of the US regions is very large compared to their European and Japanese counterparts, the former of which is about 1.2 times as large as the latter.

(Table 2.4)

3.2 Analytical Framework

Let the labor force, employment rate, and unemployment rate be LF_{it}, $E_{it}(\equiv N_{it}/LF_{it})$, and U_{it}, respectively. Then, the relationship between the last two is expressed by an identity, $log(E_{it})= log(1-U_{it}) \approx -U_{it}$. Define the population and participation rate as POP_{it} and P_{it} ($\equiv LF_{it}/POP_{it}$), respectively. An identity, $N_{it}= POP_{it}\times P_{it}\times E_{it}$, leads to the following:

$$g(N_{it})=g(POP_{it})+ g(P_{it})+ g(E_{it}). \tag{2.7}$$

14 While the Labor Force Survey has published prefectural data since 1997 on a trial basis, the data is not sufficiently long for panel time series.

where the function, g, expresses the growth rate. That is, a change in employment in a region is decomposed into changes in three factors, ex post: population (mainly due to mobility), participation rate, and employment rate.

Now let's calculate the macro and specific shocks, in accordance with Decressin and Fátas (1995). First, estimate to what extent the labor variables in each region are explained by macro variables. For employment (N_{it}), the unemployment rate (U_{it}), and the participation rate (P_{it}) in each region, the following regressions are estimated. Note that subscript *i* and *J* show a regional disaggregate variable (*i* = 1, 2, …, 10) and a national aggregate variable, respectively.

$$\Delta \log(N_{it}) = \alpha_{1i} + \beta_{1i}\Delta\log(N_{Jt}) + \eta_{1it} \tag{2.8}$$

$$U_{it} = \alpha_{2i} + \beta_{2i}U_{Jt} + \eta_{2it} \tag{2.9}$$

$$\log(P_{it}) = \alpha_{3i} + \beta_{3i}\log P_{Jt} + \eta_{3it}\,. \tag{2.10}$$

Table 2.5 shows the results for each region, as well as their averages and standard deviations[15]. For comparison, the average and standard deviation of European regions are also calculated, from the Appendix of Decressin and Fátas (1995). The table shows that Japanese regions are more homogenous than are European regions. For US regions, a similar comparison is unavailable because Decressin and Fátas (1995) do not carry detailed results for the United States. However, judging from the US average $\bar{R}^2$ of Eq. (2.8) equal to 0.60, the regional heterogeneity is almost comparable between Japan and the United States.

(Table 2.5)

Second, utilizing the results of Eqs.(2.8) to (2.10), idiosyncratic shocks to each

[15] Note that the average in the table is the arithmetic mean, while the relation between regional and macro variables implies a weighted average of the estimates β_{ki} (k= 1,2,3) should be equal to one.

region are calculated as below:

$$n_{it} = \log(N_{it}) - \beta_{1i} \log(N_{Jt}) \qquad (2.11)$$

$$e_{it} = \log(E_{it}) - \beta_{2i} \log(E_{Jt}) \qquad (2.12)$$

$$p_{it} = \log(P_{it}) - \beta_{3i} \log(P_{Jt}). \qquad (2.13)$$

Here, ADF tests are applied to the above three kinds of idiosyncratic shocks in 10 regions, so 30 times in total. We assume n_{it} to be *I(1)* and e_{it} and p_{it} to be *I(0)*, although non-stationarity cannot be rejected in most cases for the last two variables, in order to keep consistency with Decressin and Fátas (1995).

3.3 Results of the Univariate Analysis

This section estimates an autoregressive model for each of the three shocks (n_{it}, u_{it}, and p_{it}) defined in the previous section, and examines their characteristics. The following fixed-effect models with two lags are applied to the panel data with 10 regions and the period 1986 to 2003:

$$\Delta n_{it} = \gamma_{0i} + \textstyle\sum_{j=1}^{2} \gamma_j \, \Delta n_{it-j} + \upsilon_{it}, \qquad (2.14)$$

$$u_{it} = \theta_{0i} + \textstyle\sum_{j=1}^{2} \theta_j \, u_{it-j} + \zeta_{it}, \qquad (2.15)$$

$$p_{it} = \phi_{0i} + \textstyle\sum_{j=1}^{2} \phi_j \, p_{it-j} + \rho_{it}. \qquad (2.16)$$

According to the literature on dynamic panels, in the data with $N \times T$, the obtained estimator may not meet consistency for fixed T, even as $N \to \infty$, while it does for fixed N as $T \to \infty$ (Smith and Fuertes, 2004)[16]. Note that Decressin and Fátas (1995) do not correct possible biases owing to the short time dimension. Here, no corrections are added to the small sample biases either in order to ensure comparability with the

[16] In this paragraph, N expresses the number of individuals, not employment, according to usual panel data econometric usage.

results of Decressin and Fátas (1995).

Table 2.6 summarizes the estimation results, along with those for the United States and Europe taken from Decressin and Fátas (1995). Figures 2.3 to 2.5 show the impulse response functions for Japanese, US, and European regions. Note that the initial shocks are normalized to unity at t = 1 in all three cases because the size of shocks might be related to the degree of regional disaggregation.

(Table 2.6)

First, consider the US and European results as benchmarks. An idiosyncratic shock to employment causes larger effects in the United States than in Europe (Figure 2.3). Unlike in Europe, the initial shock is amplified more than twice, until it stabilizes in the seventh year in the United States. Decressin and Fátas (1995) argue that the magnification in the United States may be brought about by larger labor mobility, or more fundamentally, more specialization of production, among regions. With regard to the unemployment rate, the idiosyncratic shock exerts longer lasting effects in the United States than in Europe (Figure 2.4). Note that when Eq. (2.15) is applied to a regional unemployment rate itself, U_{it}, its effects are more persistent in Europe than in the United States (Figure 2.5). Decressin and Fátas (1995) thus argue that the persistent unemployment rate in Europe is caused by macro shocks.

(Figure 2.3 to 2.5)

Superimposing the impulse response function for Japan on those for Europe and the United States in Figures 2.3 to 2.5 reveals the following two points. First, the Japanese impulse response function for employment is more similar to its European than its US counterparts. The initial shock is not magnified, but dampened, rather surprisingly. Because border matters in transactions, as shown in McCallum (1995), the inter-regional trade volume should be much larger in Japan than in Europe (i.e., across several borders), and could be comparable to that in the United States. Therefore, the perception that more “division of labor” of production could be developed in Japan may pose the following question: why is the impulse response function for Japan nonetheless not much different from that in Europe?

Second, the macro shock to the unemployment rate is more important than the idiosyncratic shock in Japan, exerting permanent effects on it. This is a feature shared by the European case. Because the sum of the coefficients on the lagged regional unemployment rate is close to unity for Japan and Europe, as shown in Table 2.6, the regional unemployment rate follows an *I(1)* process in both countries[17]. Figure 2.5 also suggests that the US regional unemployment rate is rather close to an *I(0)* process. Moreover, for the idiosyncratic shock, the effects are as persistent in Japan as they are in the United States. Thus, the “stickiness” of changes in the Japanese regional unemployment rate is outstanding, compared to Europe and US cases.

3.4 Results of the Trivariate VAR Model

This section examines the panel data of 10 regions over 18 years (1986-2003) using a three-variable VAR model, with each variable being an idiosyncratic shock to employment changes, the employment rate, and the participation rate, respectively. Allowing for a fixed-effect for each region and two lags, we estimate the following:

$$\boldsymbol{X}_{\mathrm{it}} = \boldsymbol{A}_{\mathrm{i0}} + \boldsymbol{A}_1\boldsymbol{X}_{\mathrm{it-1}} + \boldsymbol{A}_2\boldsymbol{X}_{\mathrm{it-2}} + \boldsymbol{\varepsilon}_{\mathrm{it}}. \tag{2.17}$$

Here, $\boldsymbol{X}_{\mathrm{it}}$ is defined as $[\Delta n_{it}\ e_{it}\ p_{it}]'$, and $\boldsymbol{A}_{\mathrm{i0}}$ and $\boldsymbol{A}_{\mathrm{j}}$ (j = 1,2) are three-by-one and three-by-three coefficient matrices, respectively. The fixed-effect, $\boldsymbol{A}_{\mathrm{i0}}$, represents steady forces driving the economies toward their steady state, for example, population mobility that offsets income disparity. Identification restrictions assume a shock to Δn_{it} to be a labor demand shock, thereby affecting e_{it} and p_{it} simultaneously, but not vice versa. Likewise, a shock to e_{it} is assumed to affect p_{it} simultaneously, but not vice versa.

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17 Strictly speaking, in Japan, the sum is slightly larger than unity, and therefore, the shock tends to grow as time passes, as observed in Figure 2.5. Note, however, the sum is not significantly different from unity. For Europe, because the sum is less than unity, the shock tends to die down gradually.

The obtained estimation results imply the impulse responses to a unit labor demand shock in Figure 2.6. Comparing this figure with those showing the European and US cases, Fig.10 and 11 of Decressin and Fátas (1995), respectively, clarifies the following points. First, the low explanatory power of the employment rate, e_{it}, which is shared by European and US regions in Decressin and Fátas (1995), is also true of Japanese regions. Second, for the participation rate, p_{it}, Japan belongs to the European camp: the labor participation rate mainly absorbs the effects of labor demand shocks, especially in the early stages. Third, a close look at the response of the labor participation rate indicates that it is more persistent in Japan than in Europe. While the rate loses explanatory power in the third year in Europe, it still accounts for more than 20 percent of the initial shock in the fifth year in Japan[18]. Fourth, the residual not accounted for by either e_{it} or p_{it}, that is, the role played by labor mobility (see Eq. (2.7)), is quite large in the United States, even in the early stages. In Europe, it can explain nearly 100 percent of the effects after the third year. However, in Japan, because of long-lasting effects due to changes in the labor participation rate, the effects of labor mobility are delayed in comparison with the Unite States and Europe.

(Figure 2.6)

In summary, Japan's response to the labor demand shock resembles that of Europe in that the labor participation rate mainly absorbs the shock, especially in the early stages. Furthermore, the labor participation rate plays a larger role in Japan than it does in Europe: the other side of the same coin, given the limited role of unemployment rate, is that labor mobility plays a smaller role in Japan. This is rather surprising, because the adjustment through labor mobility seems to work better within a country than it does across borders.

Two remarks are in order regarding the role of labor mobility. First, the result might be influenced by the degree of disaggregation of the Japanese regional data, as noted in Section 3.1. In order to investigate this effect, it is necessary to use more disaggregate

[18] This is calculated as 0.14/0.67 in t = 5, as read from Figure 4a.

regional data. Second, the small labor mobility in Japan might reflect a degree of employment security, although the relationship may not be simple. While the effect needs to be large enough to overwhelm the “border effects” in Europe to provide a coherent picture, a small number of workers enjoy such security, and may have to accept frequent reallocation in exchange for such security.

3.5 Summary

This section applies Decressin and Fátas’s (1995) methodology to Japanese regional labor markets to investigate how they respond to external shocks, and compares the results with US and European cases. The trivariate VAR model, which consists of employment growth, unemployment rate, and labor participation rate, is estimated. Taking advantage of the identity among these variables, we interpreted the difference between the shock given to first variable and the portion absorbed by the other two as being attributable to labor mobility.

We found different roles played by labor mobility: a large role in the United States, but a small role in Japan. A larger role in Europe than in Japan is rather surprising because “border effects” (McCallum, 1995) may still be working in Europe, thereby limiting labor and goods flows across borders. Note, however, more finely disaggregated Japanese regional data could affect our results.

Overall, the Japanese response to a shock resembles that of Europe rather than that of the United States. An outstanding feature of Japan is the large role of a change in the labor participation rate in absorbing shocks, which is also observed in Europe, but on a smaller scale. A change in the unemployment rate plays a small role in the adjustment, not only in Japan, but also in Europe and the United States.

4 Conclusion

This chapter employed theory-free approaches to investigate the regional dynamics in per capita output and labor markets. We found per capita output dynamics converge to an almost uniform distribution and there is a rather minor part played by labor mobility in the responses of regional labor markets to an external shock. The small labor mobility may contribute to the law of motion of converging to the almost uniform ergodic distribution in Japan.

In recent years, various empirical tools other than Barro regressions have been put into practice. For example, Shibamoto, Tsutsui, and Yamane (2011) employed time series techniques for Japanese regional data, and Togo (2002) applied a Markov chain model to the dynamics of labor productivities in Japanese manufacturing industries[19]. Seya, Tsutsumi, and Yamagata (2012) examined regional convergence in Japan in a spatial econometrics framework[20].

The findings obtained in this chapter are confirmed by recent studies. Kakamu, Wago, and Otsuka (2011) used spatial models and Markov chain models, finding a unimodal ergodic distribution, thereby confirming the result of Section 1. A follow-up study is available in Yugami (2009), who surveyed major regional labor market studies up to the mid-2000s. He examined whether there occurred any changes in the adjustment mechanism in the bubble era since 1991, and found a smaller role played by labor participation rate, although its statistical significance is not confirmed.

Some interesting questions remain. For example, how do the responses of regional labor markets to shocks affect evolutions of the distribution of per capita output across regions over time? Economies with low mobility could suffer from a prolonged stagnant period, resulting in a wider dispersion of the distribution. In order to fully examine this point, we may need a general equilibrium model such as Rappaport (2005). In particular, it may be interesting to study how these labor market characteristics and government policies affect the transitional probability matrix in the Markov chain models.

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19 A detailed productivity database by prefecture was developed by a study group at the RIETI (Tokui, Makino, Fukao, Miyagawa, Arai, Inui, Kawasaki, Kodama, Noguchi, 2013), and is likely to encourage studies of regional dynamics.

20 The spatial technique is not covered in this chapter, but is employed to examine local governments' behaviors in Chapter 3.

Table 2.1 Results of the Kwiatkowski *et al*. (1992) Test

Number of Rejections of H_0: $z_{i,j}(=y_i-y_j)$ $\sim I(0)$

	Lag Order							
	5	6	7	8	5	6	7	8
	All: *i*=1-47, *j*=14				District 4: *i*=25-30, *j*=27			
5%[a]	14	8	2	2	1	1	1	0
10%[a]	13	18	17	13	0	0	0	1
	District 1: *i*=1-8, *j*=4				District 5: *i*=31-35, *j*=34			
5%[a]	4	4	3	2	4	1	1	1
10%[a]	3	2	3	3	0	3	3	3
	District 2: *i*=9-17, *j*=14				District 6: *i*=36-39, *j*=37			
5%[a]	4	3	1	1	3	3	3	2
10%[a]	4	5	5	4	0	0	0	1
	District 3: *i*=18-24, *j*=22				District 7: *i*=40-47, *j*=40			
5%[a]	2	2	1	0	7	7	7	6
10%[a]	1	1	2	2	0	0	0	1

a. significance level

Table 2.2 Results of Markov Chain Models

(Number) [a]	Upper Endpoint[b]				
	[-0.311]	[-0.199]	[-0.102]	[-0.012]	[0.548]
A.1955-1991					
(345)	0.91	0.09			
(336)	0.07	0.82	0.11		
(341)		0.1	0.8	0.1	
(336)			0.09	0.81	0.1
(334)				0.11	0.89
Ergodic	0.15	0.19	0.2	0.23	0.22
B.1955-1975					
(304)	0.92	0.08			
(162)	0.11	0.73	0.15		
(171)		0.14	0.75	0.11	
(117)			0.17	0.71	0.12
(186)				0.12	0.88
Ergodic	0.30	0.20	0.22	0.14	0.14
C.1975-1991					
(41)	0.78	0.22			
(174)	0.04	0.89	0.07		
(170)		0.06	0.85	0.09	
(219)			0.05	0.86	0.09
(148)				0.09	0.91
Ergodic	0.03	0.16	0.17	0.32	0.33

Note a. The Number indicates the total number of transitions starting from each income group.

b. Grid is chosen to give a uniform distribution over the whole sample period of 1955 to 1991.

Table 2.3 Comparing Transitional Matrices

(1) Testing the Equality of Diagonal Elements

	Japan and US	1955-75 and 1975-91
p_{11}	-0.496	3.438*
p_{22}	-0.730	-3.689*
p_{33}	-0.347	-2.264*
p_{44}	-1.464	-3.416*
p_{55}	-2.485*	-1.049

Note * shows significance at the 5% level.

(2) Mobility Indices

	Japan and US		1955-75 and 1975-91	
Index	Japan	USA	1955-75	1975-91
$M_p(P)$	0.193*	0.160*	0.252*	0.177*
$M_b(P)$	0.156	0.129	0.190	0.121
$M_u(P)$	0.195	0.167	0.238	0.152
$M_e(P)$	0.193	0.160	0.253	0.178
$M_d(P)$	0.503	0.518	0.719	0.554
$M_2(P)$	0.041	0.039	0.049	0.039

Note The differences of values of $M_p(P)$ are significant at the 5% level.

Table 2.4 Comparison of Size of Regions

	Number of Regions	Area 000 km^2	Population 2001, 000s	Value added 2002, billion $
Japan	10	37.8	12,729.1	399.3
US	51	183.8	5,598.9	203.6
Europe	51	46.4	6,944.4	157.4
Memorandum item				
Japanese prefectures	47	8.0	2,708.3	85.0

Note： Value added in dollars is calculated using market exchange rate.
Calculated from OECD, *OECD in Figures*, 2003 edition.

Table 2.5 Estimation results of Eq.(2.8) to (2.10)

	Eq.(2.8)		Eq.(2.9)		Eq.(2.10)	
	$\beta 1$	adj-R^2	$\beta 2$	adj-R^2	$\beta 3$	adj-R^2
Hokkaido	0.940	0.434	0.910	0.780	0.720	0.574
Tohoku	0.974	0.682	1.079	0.946	1.206	0.555
South Kanto	1.012	0.811	1.009	0.953	0.639	0.268
North Kanto and Kosin	1.136	0.787	0.955	0.976	1.328	0.598
Hokuriku	0.925	0.520	0.815	0.971	1.432	0.803
Tokai	0.939	0.712	0.838	0.977	1.218	0.828
Kinki	1.336	0.864	1.294	0.991	1.186	0.717
Chugoku	0.955	0.591	0.775	0.957	1.369	0.663
Shikoku	0.601	0.315	0.800	0.898	1.439	0.408
Kyushu	0.768	0.605	0.961	0.927	0.617	0.524
Japanese 10 regions						
average	0.958	0.632	0.944	0.938	1.115	0.594
standard deviation	0.195	0.174	0.158	0.062	0.328	0.172
EU 51 regions						
average	1.070	0.198	1.085	0.893	1.569	0.269
standard deviation	0.769	0.175	0.646	0.114	2.334	0.288

Note: Values for EU 51 regions are calculated from Decressin and Fátas’s (1995) Appendix Table A.1.

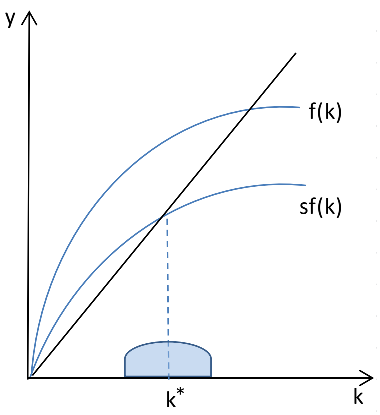
Table 2.6 Estimation Results of Univariate Models

		Japan (10 regions) (1986-2003)		EEC (51 regions) (1966-1987)		US (51 regions) (1970-1990)	
	Lag	estimate	standard errors	estimate	standard errors	estimate	standard errors
Δn(it)	1	-0.0417	0.0719	-0.0017	0.0371	0.6481	0.0333
	2	-0.1817	0.0551	0.0466	0.0372	-0.0845	0.0354
u(it)	1	0.4660	0.0903	0.9787	0.0337	0.8770	0.0322
(idiosyncratic shocks to unemployment rate)	2	0.2039	0.0679	-0.4858	0.0331	-0.1630	0.0320
U(it)	1	1.1767	0.0555	1.305	0.034	0.922	0.032
(regional unemployment rate)	2	-0.1576	0.0652	-0.374	0.034	-0.263	0.032
p(it)	1	0.7739	0.0750	0.476	0.054	0.665	0.040
	2	-0.0253	0.0702	-0.015	0.047	-0.197	0.040

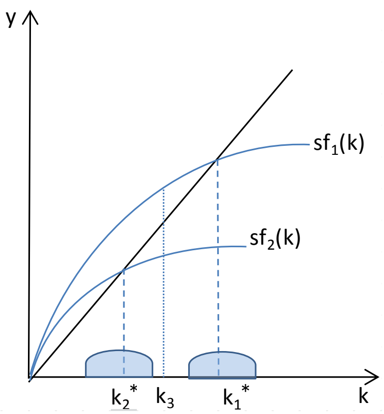
Note: Results for Europe and US are taken from Decressin and Fatas (1995).

Figure 2.1 Variants of the Solow Model

(1) Basic Model



(2) Heterogeneous Production Functions



(3)A Growth Path Example

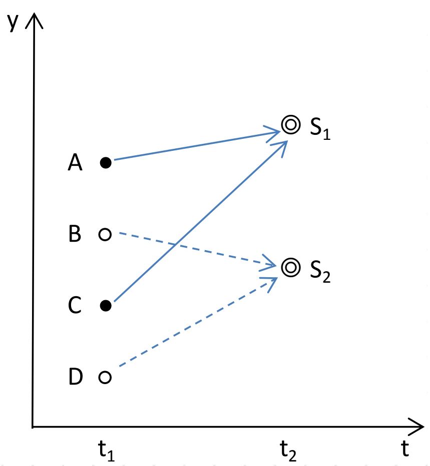


Figure 2.2 Distribution of Per Capita Output

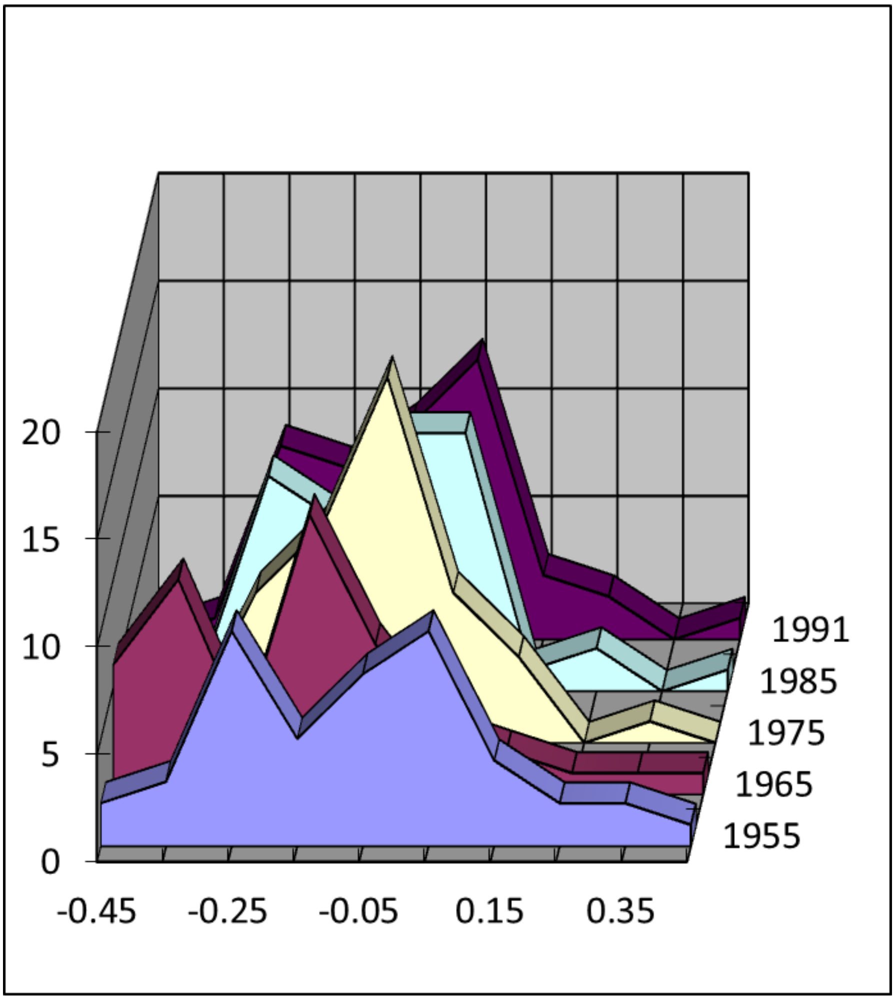


Figure 2.3 Responses to an Idiosyncratic Shock to Employment

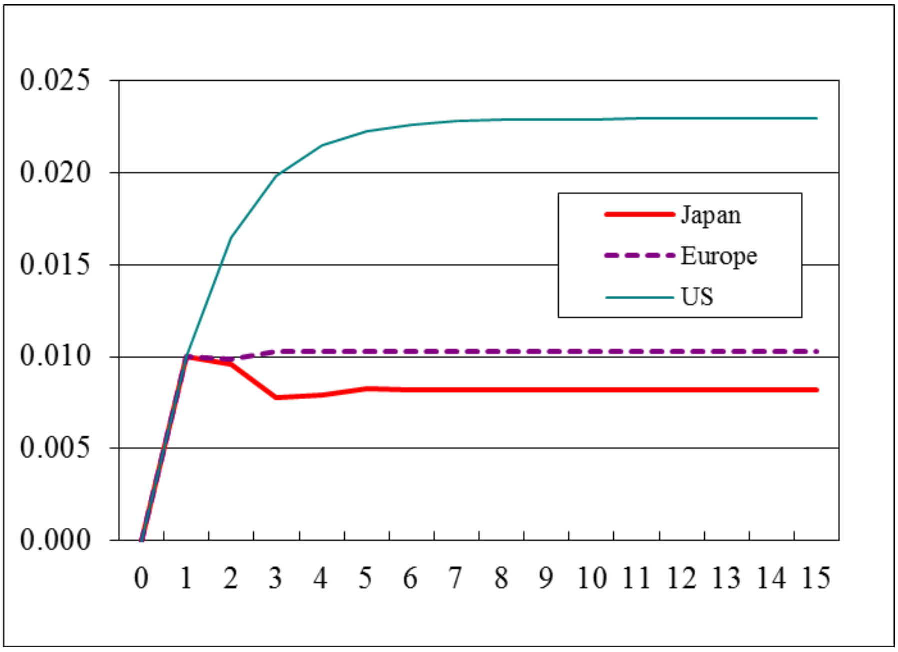


Figure 2.4 Rensponses to an Idiosyncratic Shock to the Unemployment Rate

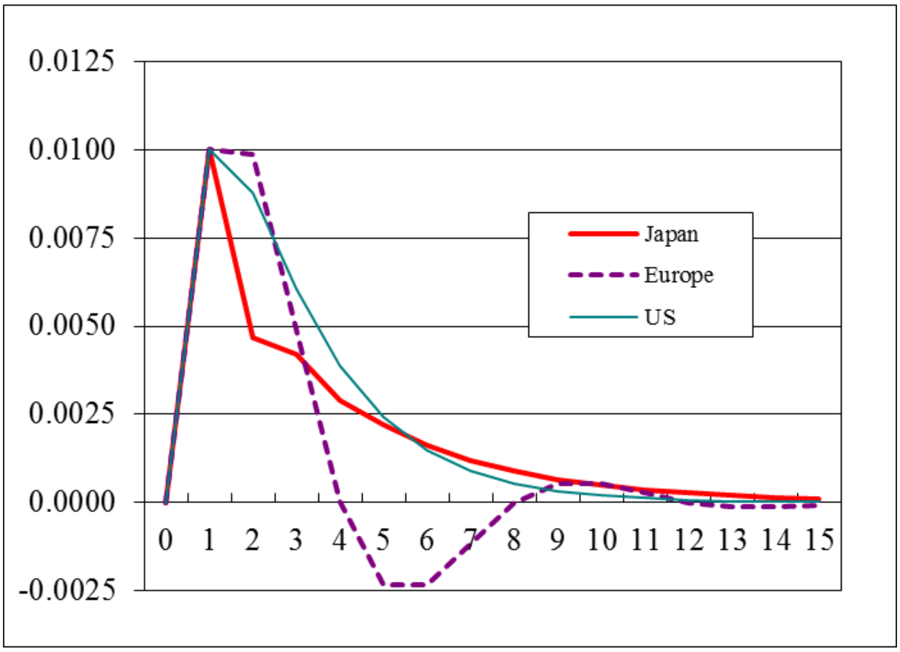


Figure 2.5 Responses to a Shock to the Unemployment Rate

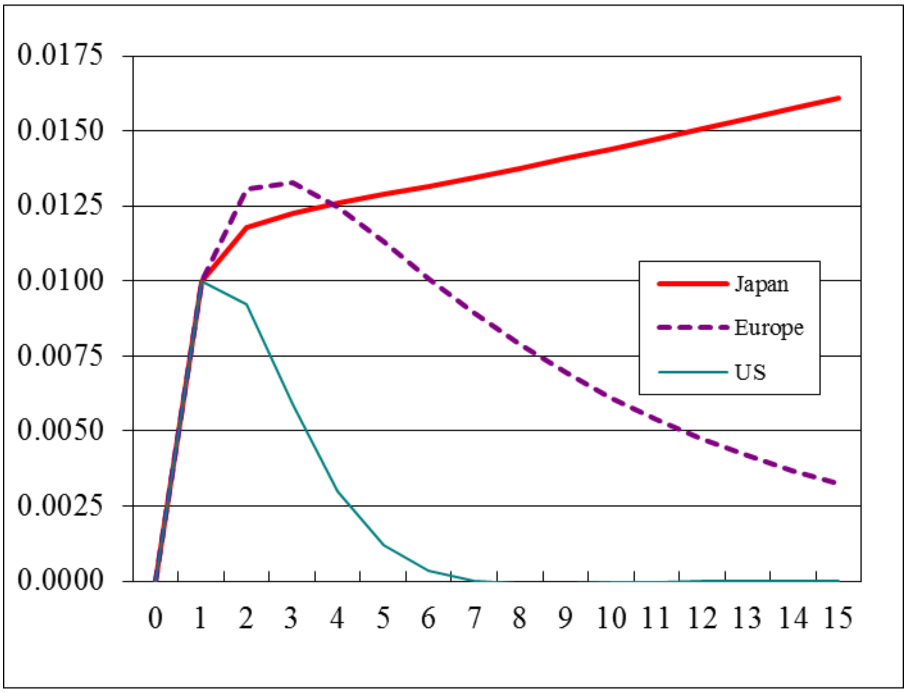
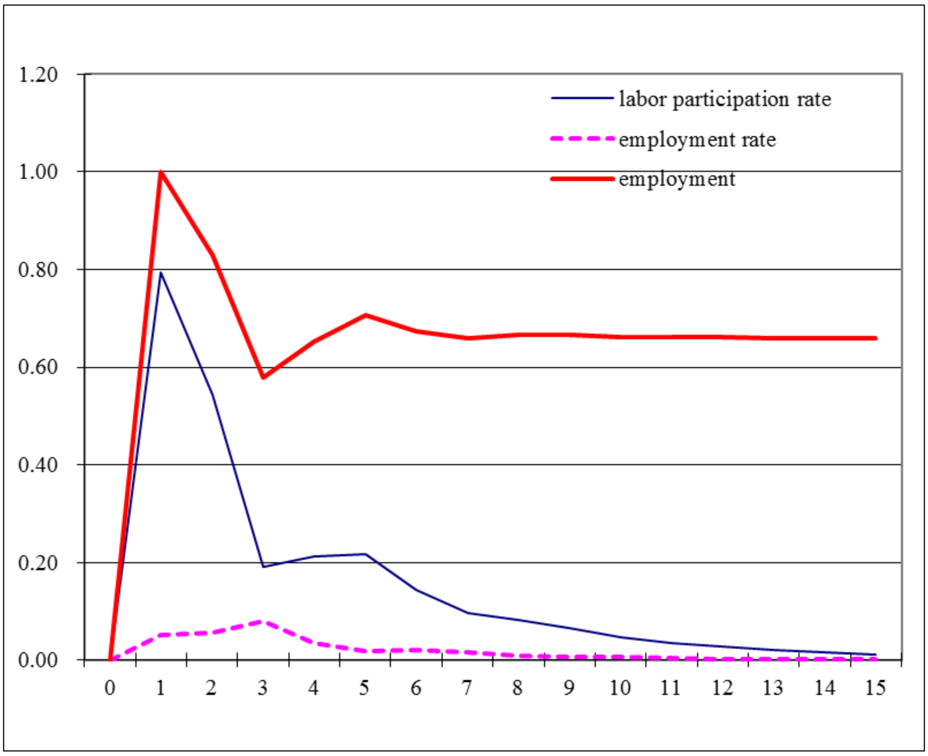


Figure 2.6 Responses of Japanese Regions to a Labor Demand Shock



Appendix 2.A

Continuous-State Markov Chain Model

In Section 2.4, we discretize *Q(t)*, the distribution of per capita income of the economies, into five states, thereby estimating the discrete-state, discrete-time Markov chain model. Because this discretization may distort the dynamics, a continuous-state model is preferred.

The extension into the continuous-state model is easily shown, as follows. Define $f_t(y)$ as a density function of variable y, per capita income at time t, and $g_j(z|y)$ as a j-period-ahead density of z-conditional on y. The density of variable z at time $t+j$ is expressed as follows:

$$f_{t+j}(z) = \int_0^\infty g_j(z|y)\, f_t(y)\, dy.$$

In the above setting, the ergodic density can be found as the solution to the following:

$$f_\infty(z) = \int_0^\infty g_j(z|y)\, f_\infty(y)\, dy.$$

Johnson found the ergodic distribution of per capita income to be unimodal in US state data (Johnson, 2000), using $g_{15}(z|y)$, and bimodal in international data (Johnson, 2005), using $g_1(z|y)$. The latter study also obtained the ergodic distribution of the capital-output ratio, human capital per worker, and TFP (z = k/y, h, TFP).

Appendix 2.B

Table 2.B.1 Classification of District and Prefecture Code Number

Prefecture		District Sec. 2	District Sec. 3	Prefecture		District Sec. 2	District Sec. 3
1	Hokkaido	1 Hokkaido-Tohoku	1 Hokkaido	25	Shiga	4 Kinki	7 Kinki
2	Aomori		2 Tohoku	26	Kyoto		
3	Iwate			27	Osaka		
4	Miyagi			28	Hyogo		
5	Akita			29	Nara		
6	Yamagata			30	Wakayama		
7	Fukushima			31	Tottori	5 Chugoku	8 Chugoku
8	Niigata		5 Hokuriku	32	Shimane		
9	Ibaraki	2 Kanto-Koshin	4 North Kanto	33	Okayama		
10	Tochigi			34	Hiroshima		
11	Gunma			35	Yamaguchi		
12	Saitama		3 South Kanto	36	Tokushima	6 Shikoku	9 Shikoku
13	Chiba			37	Kagawa		
14	Tokyo			38	Ehime		
15	Kanagawa			39	Kochi		
16	Yamanashi		4	40	Fukuoka	7 Kyushu	10 Kyushu
17	Nagano			41	Saga		
18	Shizuoka	3 Chubu	6 Tokai	42	Nagasaki		
19	Toyama		5	43	Kumamoto		
20	Ishikawa			44	Oita		
21	Gifu		6	45	Miyazaki		
22	Aichi			46	Kagoshima		
23	Mie			47	Okinawa		
24	Fukui		5				

Chapter 3

Herding in Municipal Government Officials' Pay:

A Spatial Econometric Approach

1 Introduction

The government undertook public expenditure and revenue structure reforms along with *the Basic Policy Stance 2006* (formally, *Basic Policies for Economic and Fiscal Management and Structural Reform 2006* (Cabinet Decision, July 7, 2006)), aiming to realize a primary surplus on a central and local government basis, which ended in failure after the Great Recession. A Reform of total personnel expenses was an important ingredient and, furthermore, local governments were expected to play a major role because they accounted for about three-fourths of the total expenses, worth about 30 trillion yen. The ceilings on the number of local government employees are to be cut gradually to almost the same extent as their national government counterparts, which are to be reduced by 5.7 percent over five years. Now that one can see the direction of the reform on the front of the number of government employees, one is naturally interested in changing ways to set their salaries.

This chapter[1] focuses on part of local government officials' pay, namely weighting allowance rate. This rate is entirely up to each local government's discretion, and, therefore, is likely to reflect their preference. We examine whether fiscal conditions affected the rate, through fiscal consolidation efforts. We also pay special attention to herd behaviors, as emphasized by Uemura (2005). He showed many cities in Chiba prefecture raised their weighting allowance rate from 3 percent in the late 1960s to 10 percent in 2005, with few exceptions, arguing that these increases were evidence of herding behavior (Table 3.1).

(Table 3.1)

[1] This chapter is an extended version of Kawagoe and Honjo (2008).

How are such herding behaviors modeled for an empirical sturdy? This chapter tries to express such behaviors using spatial autoregression in spatial econometrics. More specifically, this chapter examines whether spatial autoregression is statistically significant, even after controlling for various possible determinants in the data of weighting allowance rates across all municipalities in 2003. This application of the spatial econometric methodology is one of the contributions of this chapter.

This chapter is structured as follows. The next section provides an overview of the pay system of local government officials. Section 3 surveys the literature on herd behaviors. Section 4 briefly explains the spatial econometric methodology employed. Section 5 explains the data used, applies the methodology to them, and shows the results. Section 6 concludes the chapter.

2 Institutional Background

2.1 Overview of the Local Government Officials' Pay System

The compensation of local government employees has to meet the principles stipulated by the Law of Local Public Employees. What matters most is "a principle of equity,"[2] which is stipulated as follows: "Salary of employees has to be determined, taking account of living costs, salaries of the employed by central and other local governments as well as by private sector, and other necessary conditions" (third clause of Article 24). This principle is put into practice by setting local government employees' salary levels in terms of their central government counterparts, which is called the "national government reference" (or "Kokko junkyo," in Japanese).

To be more precise, according to Inatsugu (2000), many local governments use the same salary tables as the national government does, and place jobs at lower ranks than those of their national government counterparts. Exceptions are the big cities: Tokyo and other ordinance-designated cities tend to adopt their own salary tables.

Kawasaki and Nagashima (2007) compared the average compensations among

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[2] See the Ministry of General Affairs (2006) for an exposition of local government employees' pay systems.

central and local governments and the private sector. They showed that the high positive correlation between the first two was maintained during the period 1971 to 2005, but that the correlation between the last two was lost during the last 10 years of the sample period. Parallel movement between the first and the third is ensured, as long as the central government fully implements the National Personnel Authority's annual salary recommendation. Note that the annual recommendation is based on the national average of the salaries of private companies surveyed by the National Personnel Authority, and the national average tends to reflect developments in metropolitan areas because of their large share of the number of companies. As a result, divergent private sector salary developments in rural areas in relation to metropolitan counterparts weakened the correlation between public and private salaries in rural areas.

Relatively high public salaries in rural areas encouraged the Ministry of General Affairs to review the local government officials’ pay system. The Ministry’s study group compiled a report that proposed modifying the current practice of “national government reference” and paying closer attention to private salaries in each area (Ministry of General Affairs, 2006).

Overall, local governments’ voluntary efforts, together with the Ministry’s guidance, contributed to lowering local governments’ salary levels, according to Ohta (2013). Using municipal data in 2011, Ohta (2013) detected a negative effect of fiscal situations on the compensation levels of local government officials, after controlling for differences in industry structures and other exogenous factors. This is consistent with Kawagoe and Honjo (2006), who studied the extent to which fiscal discipline affects changes in weighting allowance rates. They found low explanatory power of fiscal situations of each municipality in the overall sample period of FY1996 to 2003, but significant power in the 2000s. Their results are summarized in Appendix 3.A.

2.2 Weighting Allowance Rates

Here, we focus on the weighting allowance rates added to local government officials’ salaries. For the national government, whose employees work at many places around the nation, the rates are set to fill the gap between the uniform wage schedule applied to all employees and the different living costs, depending on the work sites. However, such a justification may be invalid for each local government because their employees usually work in small areas. The components of public officials' salaries are shown below:

$$\text{basic pay} = \text{monthly salary} + \text{dependent allowance} + \text{weighting allowance}, \tag{3.1}$$

$$\begin{aligned}\text{weighting allowance} \\ &= (\text{monthly salary} + \text{dependent allowance} + \text{management allowance}) \\ &\quad \times \text{weighting allowance rate}.\end{aligned} \tag{3.2}$$

Therefore, the weighting allowance rate can be computed as below, at least for each city, using *the Survey of Local Governments' Settlement Situations* (Shichoson-betsu Kessan Jokyo Shirabe) edited by the Institute of Local Finance (Chiho Zaimu Kyokai), although the data are unfortunately unavailable for towns and villages.

$$\begin{aligned}\text{weighting allowance rate} &= \text{weighting allowance} \\ &\div (\text{basic pay} - \text{weighting allowance} + \text{management allowance})\end{aligned} \tag{3.3}$$

Note that the weighting allowance accounts for only a small portion of personnel expenses. In FY 2003, personnel expenses amounted to 7.5 trillion yen for all the cities. These expenses were reduced to 5.3 trillion yen, if compensations of city council members and high-ranking officials are excluded. The basic pay amounted to 3.4 trillion yen, only 0.2 of which was accounted for by the weighting allowance.

Why do we examine such a small amount of expenditure? This expenditure concerns the difference between two definitions of remunerations, pay (or "Kyuyo" in Japanese) and salary (or "Kyuryo" in Japanese), and is likely to be of significant importance in judging the level of remuneration. The former includes various allowances, while the latter corresponds to the figures in the salary table, without any allowances. The National Personnel Authority compares the remunerations of national government officials with those of private companies' employees on a pay basis (however, without overtime payments and management allowance). The Ministry of General Affairs conducts a comparison of national and local government employees' salaries, and reported in December 2004 that the latter is 2.1 percent lower than the former, if measured by the Laspeyre index. However, Uemura (2005, p.2) pointed to the misuse of the definitions and criticized this result[3].

3 A Literature Review of Herd Behaviors

3.1 Outcomes of Markets or Regulations

Herd behaviors (or "yoko narabi" in Japanese) are phenomena in which people's behaviors are affected by others'. Although they are sometimes regarded as pathological outcomes, they are not always so, as exemplified by the book title, *Rational Herds* (Chamley, 2004). Indeed, herd behavior can result from rational Bayesian learning (Bikhchandani, Hirshleifer, and Welch, 1998). It is also notable that similar actions could be taken independently and simultaneously. For example, although many firms may cut (or increase) their work force in a recession (or boom), these are not herd behaviors, but responses to changes in market conditions.

Herd behaviors are closely linked to uncertainty. The literature often sets up an economy where Bayesian individuals make once-in-a-lifetime decisions under incomplete and asymmetric information. The usual conclusion is that, eventually, every individual imitates her predecessor, even though she would have chosen differently if she had acted on her private information alone. In other words, individuals rationally ignore their own information and follow the herd. Thus, herd behaviors can be generated endogenously within markets, without any government interventions.

On the other hand, regulations may encourage herd behaviors, especially when their implementations work as additional uncertainty. This is closely related to the debate over the effectiveness of the MITI's industrial policies: it remains to be seen whether government interventions in business investment plans encouraged herd behaviors. In

[3] According to Uemura (2005, p.2), "what the Ministry called pay and used in the calculation is actually salary, an incredible misuse of the definitions, thereby misleading general public and hiding the actual situations." He concluded "there was little chance local government employees' salary was lower than national counterpart, if comparison is based on pay, i.e. remuneration including various allowances" (Uemura 2005, p.5).

the 1960s, the MITI coordinated business investment plans in some heavy sectors such as the steel, petrochemical, and paper-pulp industries. Tsuruta (1984) argued that the government coordination encouraged each firm to implement the same amount of investment at the same time, destabilizing the investment fluctuations. However, Asaba (2002) argued that weakened interventions since the middle of the 1970s strengthened the tendency of small firms to follow major firms' investments, thereby reinforcing overall herd behaviors.

With regard to pay system, as explained above, the weighting allowances are not included in standard fiscal demand and, therefore, are not financed by the local allocation tax. That is, they are clearly outside the intergovernmental financial support system. Remaining uncertainty for local governments may concern generally accepted ideas about pay levels of local government officials. Because a convenient yardstick is other local governments, it may be natural for each local government to monitor others.

3.2 An Information- or Rivalry-based Theory

According to Lieberman and Asaba (2006), theories of herd behaviors are classified into two categories, namely information-based and rivalry-based theories. Because local governments do not compete with each other in markets, their herding behavior should belong to the former, as a first approximation.

However, if we think the latter holds in our case, there may remain a difficulty: the uncertainty surrounding the municipalities is unlikely to be so severe, compared to that envisaged in the information-based theory (Hirshleifer and Teoh, 2003, 2009). For example, the uncertainty over Japanese FDI in North America, which Lieberman and Asaba (2006) ranked as intermediate in the degree of uncertainty, seems much greater than that faced by municipalities, say, in terms of budgetary costs.

Given low uncertainty, it may be better to resort to the rivalry-based theory. If competition takes place on many local fronts, rivalry-based imitation may occur. For example, rivalry-based imitation induced each company to introduce similar products in the Japanese soft drink industry (Asaba, 2002). It may be easy to think of local governments as competing with each other to attract resources, such as subsidies from the central government[4] and new graduates in local labor markets.

4 Empirical Methodologies

4.1 A Simple Model

First of all, let's consider how to model herding behaviors among municipal governments. Intuitively, "herding" means y_i, the weighting allowance rate of city i, is affected by city j's counterpart, y_j ($j \neq i$). Thus, the vector, $\boldsymbol{y} = [y_1\ y_2 \ldots y_N]'$ can be expressed as follows:

$$\boldsymbol{y} = \boldsymbol{\Lambda} \boldsymbol{y} + \boldsymbol{X}\boldsymbol{\beta} + \varepsilon\,, \qquad (3.4)$$

where $\boldsymbol{X} = [x_1\ x_2\ \ldots\ x_k]$ is fundamental to determining $\boldsymbol{y}$. For example, x_i is a column vector of a variable showing fiscal conditions, and $\boldsymbol{\Lambda}$ is an $N \times N$ matrix with diagonal elements of zeros. A non-zero off-diagonal element, Λ_{ij}, captures the effects of city j's behaviors on city i's. Modifying the matrix, $\boldsymbol{\Lambda}$, leads us to a model of spatial econometrics, as explained in the next section.

4.2 Spatial Econometrics Models

In spatial econometrics, the SAR (Spatial Autoregression) model is expressed as below,[5]

$$\boldsymbol{y} = \rho \mathbf{W} \boldsymbol{y} + \mathbf{X}\beta + \varepsilon\,, \qquad (3.5)$$

which looks similar to Eq.(3.4), and where ρ is a parameter measuring the extent to which the data are spatially autocorrelated. Then, $\boldsymbol{W}$ is a weight matrix constructed

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4 Tanaka (2013) emphasizes the competitive aspects among local governments.

5 The exposition here is based on Anselin (2001) and LeSage (2005b).

from a matrix, $\boldsymbol{W}^*$. Each element of $\boldsymbol{W}^*$, w^*_{ij}, indicates geographical relationship between city i and j. The diagonal elements are set equal to zero ($w^*_{ij} = 0$), and the rest are set equal to one if cities i and j are "close" to each other, and zero otherwise. We can define "closeness" in various ways[6]. Suppose one defines it as "neighboring" (i.e., two cities share a border). Then, Chart 1 is translated in the following $\boldsymbol{W}^*$:

$$W^* = \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix}. \tag{3.6}$$

Finally, the weight matrix, $\boldsymbol{W}$, is obtained by standardizing the elements of $\boldsymbol{W}^*$, that is, adjusting them so that the sums of the elements in each row equal one ($w_{ij} \equiv w^*_{ij} / \sum_i w^*_{ij}$). Thus, the weight matrix, $\boldsymbol{W}$, is a row-standardized or row-stochastic matrix.

$$W^* = \begin{bmatrix} 0 & 1 & 0 \\ 0.5 & 0 & 0.5 \\ 0 & 1 & 0 \end{bmatrix}. \tag{3.7}$$

As this example shows, adding a spatially lagged variable, $\boldsymbol{W}y$, to the right-hand side is equivalent to using a weighted average of the y's of cities close to each other as an explanatory variable.

(Figure 3.1)

Spatial autocorrelation shown by the parameter ρ means, in general, (1) the spillover effects of neighboring cities on the city, which might imply a problem due to the inappropriate units of observations; (2) herding (or imitation) behavior or competition among local governments, which might imply interdependence among decision-makers; (3) other unobservable interactions, such as factors not captured by variables at hand, **X**. Introducing spatial autocorrelation is a useful way to overcome

[6] The values of w^*_{ij} are not always limited to zero and one. As is the case in Aten (1996), it is possible to use the inverse of distance or trade values as weights.

these difficulties.

Ignoring spatial autocorrelation is surely costly in estimation. The following transformation of Eq.(3.5) shows the point. Note $\boldsymbol{I}_N$ is an $N \times N$ identity matrix and N is the sample size.

$$(\boldsymbol{I}_N - \rho\, \boldsymbol{W})\, \boldsymbol{y} = \mathbf{X}\beta + \varepsilon \tag{3.8}$$

$$\boldsymbol{y} = (\boldsymbol{I}_N - \rho\, \boldsymbol{W})^{-1}\mathbf{X}\beta + (\boldsymbol{I}_N - \rho\, \boldsymbol{W})^{-1}\varepsilon\,. \tag{3.9}$$

The above shows that if we use **X**, instead of $(\boldsymbol{I}_N - \rho\, \boldsymbol{W})^{-1}\mathbf{X}$, as an explanatory variable, the OLS estimator, $\hat{\beta}$, is biased and inconsistent. As shown in Eq.(3.10), being multiplied by $(\boldsymbol{I}_N - \rho\, \boldsymbol{W})^{-1}$ is equivalent to taking account of indirect effects through neighboring municipals' behaviors, in other words, a kind of multiplier effect.

$$(\boldsymbol{I}_N - \rho \boldsymbol{W})^{-1} = \boldsymbol{I}_N + \rho \boldsymbol{W}^1 + (\rho \boldsymbol{W})^2 + (\rho \boldsymbol{W})^3 + \dots \tag{3.10}$$

The following example assumes that the weight matrix $\boldsymbol{W}$ is given by Eq.(3.7):

$$(I_N - \rho W)^{-1} = \begin{bmatrix} 1.021 & 0.208 & 0.021 \\ 0.104 & 1.042 & 0.104 \\ 0.021 & 0.208 & 1.021 \end{bmatrix} \quad \text{if } \rho = 0.2$$

$$= \begin{bmatrix} 1.889 & 2.222 & 0.889 \\ 1.111 & 2.778 & 1.111 \\ 0.889 & 2.222 & 1.889 \end{bmatrix} \quad \text{if } \rho = 0.8.$$

As ρ is larger, each element is larger, and the diagonal elements are much larger than unity. Hence, ignoring strong spatial autocorrelation is likely to overestimate the effects of explanatory variables.

Note that when spatial autocorrelation is taken into account, adding another regressor, ***Wy***, when estimating Eq.(3.5) by OLS may cause another bias because the regressor ***Wy*** may be correlated with ε. Thus, ML or Bayesian estimation is necessary.

A more general approach than the above-mentioned SAR is the SD (Spatial Durbin) model, which includes the spatial lag of independent variables (***WX***) and the dependent variable (***W****y*) on the right-hand side.

$$\boldsymbol{y} = \rho\,\boldsymbol{Wy} + \boldsymbol{X}\beta + \boldsymbol{WX}\gamma + \varepsilon \tag{3.11}$$

$$\boldsymbol{y} = (\boldsymbol{I}_N - \rho\,\boldsymbol{W})^{-1}\boldsymbol{X}\beta + (\boldsymbol{I}_N - \rho\,\boldsymbol{W})^{-1}\boldsymbol{WX}\gamma + (\boldsymbol{I}_N - \rho\,\boldsymbol{W})^{-1}\varepsilon\,. \tag{3.12}$$

As inferred from the explanation of ***Wy*** in the SAR model, adding a regressor of ***WX*** is equivalent to using a weighted average of ***X*** of “close” municipalities as an independent variable. The SD model in spatial econometrics may correspond to ARDL (Autoregressive Distributed Lags) in time series econometrics.

The general-to-specific methodology *à la* David Hendry, advises us to begin with an estimation of a general model, such as the SD model, and then simplify it into a specific model, such as the SAR or SE (explained later) model, if the restrictions imposed are not rejected.[7]

Imposing a so-called common factor restriction, $\rho\beta = \gamma$, on an SD model leads to the following SE (Spatial Error) model, where spatial autocorrelation appears only in the error terms.

$$\boldsymbol{y} = \boldsymbol{X}\beta + \mathrm{u} \tag{3.13}$$

$$\mathrm{u} = \rho\boldsymbol{W}\mathrm{u} + \varepsilon \tag{3.14}$$

$$\boldsymbol{y} = \boldsymbol{X}\beta + (\boldsymbol{I}_N - \rho\,\boldsymbol{W})^{-1}\varepsilon. \tag{3.15}$$

If one applies OLS to Eq.(3.13), the estimator is not biased, but it is inefficient.

4.3 Comparison with OLS using Dummy Variables

An alternative method to using spatial models may be to use dummy variables to control regional variations: here, we have various dummies for different intercepts and

[7] Note, Florax, Folmer, and Rey (2003) argued that traditional forward stepwise procedures perform better in data with spatial autocorrelation than do backward stepwise procedures, including the general-to-specific methodology, thereby inviting discussion. For this point, see also Florax, Folmer, and Rey (2006) and Hendry (2006).

their cross products with regressors for different slopes. Suppose we have *N* regions in our sample and use *M* (< *N*) regional dummies to eliminate the regional effects. Here is a simple example where the regression with an intercept and an independent variable is augmented with dummies:

$$y_i = \alpha_1 + \sum_{j=2}^{M} \alpha_j d_j + \beta_1 X_i + \sum_{j=2}^{M} \beta_j (d_j X_i) + \varepsilon_i . \tag{3.16}$$

An interesting question is which of the spatial models or traditional regression models, such as Eq.(3.16), are better. This chapter will examine this point later.

4.4 Comparison with the LSV Indicator

Empirical studies of herd behaviors often use the LSV indicator, defined as follows:

$$LSV_i = |p_{it} - p_t| - E[|p_{it} - p_t|],$$

where p_{it} is the share of companies who increase investment, for example, in industry *i* at *t*. Lakonishok, Shleifer, and Vishny (1992) created the indicator to measure the degree of one-sidedness of transactions, that is, buying or selling, in the stock market. Uchida and Nakagawa (2007) applied the indicator to the Japanese bank loan market, and Hisa (2007) applied it to business investment in tangible assets by Japanese listed companies.

Obviously, the simplicity of the LSV indicator is very attractive, but it is also a weakness: it fails to capture the structure of the herding, namely who imitates whom. The weight matrices in the spatial models are more informative because they partially capture the structure: they can identify interactions, although they are unable to distinguish leaders from followers.

5 Empirical Results

5.1 Data

5.1.1 Dependent Variable

This chapter tries to explain the variations of weighting allowance rates across municipalities in FY 2003. The data are calculated from *the Survey of Local Governments' Settlement Situations*, following Eq.(3.3). Because the data for 23 special wards in the Tokyo metropolitan area are available, they are included in our sample. Therefore, "city" includes these special wards.

The ordinance issued by the National Personnel Authority stipulates the details of the weighting allowances of central government employees.[8] Those who work in urban areas and suffer from high living expenses are eligible to receive extra portion of their salaries.[9] Therefore, one could regard the allowances as a measure to reconcile nationwide uniform pay tables and variations in living costs at work places.[10] Table 3.2 provides examples of the allowances given in FY 2003. Seventy three cities are ranked A, which entitles public employees working there to allowances worth 6, 10, or 12 percent of their salaries. Similarly, 67 are ranked as B, entitling employees to 3 percent of their salaries.[11]

(Table 3.2)

According to the aforementioned Survey, about 60 percent of our sample, 428 out of 712 cities, disbursed the weighting allowances in FY 2003. It turns out that only four cities set lower rates than that of the central government, with almost all setting higher

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[8] See the National Personnel Authority (2003) for details of systems of salaries of national government employees.

[9] In the case of local government employees, because working places are rather limited, it may not be necessary to set up a system of weighting allowances: salaries themselves could be adjusted. Ministry of General Affairs (2006) says, "it is necessary to make a proper judgement so as to make contents and necessity of the system understood by citizens" (p.17).

[10] Note that reviews of the system have been under way since FY 2006. For example, while overall pay levels were lowered, higher allowance rates were permitted.

[11] We use the latitude and longitude of each municipality main municipal building, which are based on ITRF94. They are contained in *the Latitude and Longitude Database of Prefectures, Municipalities, Towns and Villages in Japan for GPS* (Ver.2.20), constructed by Naoshi Takeda and available at http://www.asahinet.or.jp/ xj6t-tkd/index.html.

rates (Figure 3.2). The data seem to suggest that setting the rate is largely up to each local government's discretion, and the central government's practice is just one aspect of the information used to make this decision.

(Figure 3.2)

We limit the sample to cities where the data are available in both FY 2002 and 2003 because we will use FY 2002 data as independent variables, which reduces the number of our sample to 693.

5.1.2 Independent Variables

We choose the following four kinds of variables as regressors. First, we pick up fiscal indicators to show fiscal situations of each municipality from the Survey. Assuming a lag in decision making, we use their FY 2002 data. More specifically, the following nine variables are used:

(1) actual fiscal balance ratio (Jisshitu Shushi Hiritu);

(2) debt service burden ratio (Kosaihi Futan Hiritsu);

(3) debt service ratio (Kosaihi Hiritsu);

(4) reference ratio to limit new bond issues (Kisai Seigen Hiritsu);

(5) fiscal capability index (Zaiseiryoku Shisuu);

(6) current expenditures share in general revenues (Keijo Shushi Hiritsu);

(7) personnel expenses (Jinkenhi) as a part of (6);

(8) debt service (Kosaihi) as a part of (6);

(9) current expenditures ratio, adjusted for bond issues to compensate for tax reductions and to fund temporary revenue shortages.

We use these variables, ignoring the fact that they are sometimes highly correlated, which may cause multicollinearity between them. This is because we focus on estimating a parameter, ρ, that is, the extent to which the weighting allowance rates are spatially autocorrelated, and want to avoid possible biases due to omitted variables.

Second, the central government weighting allowance rate is added to the right-hand side because each municipality seem to consider it one of the determinants. Third, we pick up land prices for residential areas, which are available from *the Survey of Land Prices by Prefecture* (Todofuken Chika Chosa, Ministry of Land, Infrastructure, Transport, and Tourism), which are supposed to reflect the living costs in each city. While the prices of the mobile, with low transportation costs, should be equalized among municipalities, those of the immobile, with high transportation costs, are likely to remain different, reflecting the living costs in each area. Note that the central government weighting allowance rate is set to adjust for the living costs differentials. Therefore, this variable is expected to explain the effects that the central government weighting allowance rate cannot catch fully.

Finally, per capita taxable incomes are added, calculated as the taxable incomes taken from the *Survey of Local Government Taxation Situations* (Shichoson-zei Kazei Jokyo no Shirabe, Ministry of General Affairs), divided by the municipality population registered in the *Residential Basic Book* (Jumin Kihon Daicho). This shows the general income situations and could be a proxy for wages in the private sector. Insufficient market forces may leave higher local price levels in cities with many high income earners. Thus, the variable could also show the living costs levels, to some extent.

5.1.3 Weight Matrices

Specifying the weight matrices needs to determine the “location” of each municipality and define the “closeness” between them. For the former, we select the latitude and longitude of a main municipal building of each municipality, rather than its population or area centroid, as its location.

This chapter defines “closeness” in two ways. First, it is defined as “neighboring” (i.e., sharing a border). Here, there is a subtlety if there is a lake or sea between two cities. Our definition excludes such cases. Second, we determine that city A is “close” to city B if the distance between A and B ranks within the shortest five of all the distances from city B to the other cities.

Then, $\boldsymbol{W}_n$ and $\boldsymbol{W}_5$ are weight matrices, based on the above definitions. Figures 3.3 and 3.4 visualize these 693 × 693 matrices, with the (1,1) element on the upper left corner and dots representing non-zero elements. As observed, $\boldsymbol{W}_5$ has more non-zero elements than does $\boldsymbol{W}_n$. The number of cities close to a city is 2.68 on average, with a standard deviation of 1.98 for $\boldsymbol{W}_n$, about half that of $\boldsymbol{W}_5$. In particular, about 100 cities (15 percent) have no "neighbor" and, therefore, are not affected by other cities: they are isolated.

(Figure 3.3)
(Figure 3.4)

Various models with the above two kinds of weight matrices[12] and independent variables are estimated using the maximum likelihood method.[13]

5.1.4 Dummy Variables

As a traditional approach, such as that shown in Eq.(3.16), in comparison with the above spatial econometrics approach, we use dummy variables that take a value of unity if a city is located within 30 km of ordinance-designated cities.

There are 14 ordinance-designated cities: Sapporo, Sendai, Saitama, Chiba, Tokyo (Chuo-ward), Yokohama, Kawasaki, Nagoya, Kyoto, Osaka, Kobe, Hiroshima, Kita-kyushu, and Fukuoka. Some cities are located within 30 km of more than one ordinance-designated city. To cope with these cities, we define greater city areas: the Greater Tokyo Area is composed of cities within 30 km of any of Saitama, Chiba, Chuo-ward of Tokyo, Yokohama, and Kawasaki; the Greater Kansai Area for Kyoto, Osaka, and Kobe; and the Greater Fukuoka Area for Kita-kyushu and Fukuoka. As a result, we have seven dummy variables: three for the greater city areas, and four for the remaining ordinance-designated cities.[14]

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12 We examined another weight matrix, constructed based on Delaunay triangulation, a popular methodology in geography, especially in recent years when GIS data are more widely utilized (Okunuki, 2005). This definition reveals the number of neighboring cities to be 5.96 on average with a standard deviation of 1.54, which might enable us to capture interactions among cities more comprehensively. However, this rather mechanical nature of "closeness" is fatal: it regards a city in Hokkaido as next to one in Okinawa, which is hardly justifiable in terms of realistic economic activities. That is why we do not report the results of this case.

13 See Appendix 3.B.1 for the details.

14 We also try an alternative to using a dummy variables for each of the 14

However, it difficult to estimate Eq.(3.16) because of the multicollinearity due to strong correlations between dummy variables (the second term on the right-hand side) and the products of dummies and independent variables (the fourth on the right-hand side). In addition to the seven dummies, we keep only cross products between these dummies and two independent variables, the actual fiscal balance ratio (jisshitu shushi hiritu) and the weighting allowance rates for central government officials, omitting the other cross products.

5.2 Estimation Results

5.2.1 Weight Matrix based on Neighborhood

Various estimation results are summarized in Table 3.3. The table shows the OLS results in the first row. It also provides results of the SAR, SD and SE models in the third to fifth rows, respectively, all of which are based on the weight matrix, $\boldsymbol{W}_n$. Because LR tests applied to the three models reject SAR and SE, the SD model, the most general one, is adopted.

(Table 3.3)

We estimate the auto-correlation parameter ρ to be slightly less than 0.7 and to be statistically significant in the SAR and SD models. The strong spatial autocorrelation would greatly affect other estimates, unless it is explicitly considered, as shown by the numerical examples in Section 2.2. In fact, the OLS estimates in column < 1 > in Table 3.4 tend to be larger than their SAR counterparts (not reported in the table) in terms of absolute values.

(Table 3.4)

Now, we turn to the independent variables. Residential land prices (in log form) and central government employees weighting allowance rates are estimated to be significantly positive, which may represent the effects of living costs and the

ordinance-designated cities and obtain results little different from those in the main text.

consideration of central government behaviors (Kokako Junkyo). Per capita taxable incomes (in log form) are estimated to be positive significantly in the OLS and SE models, but not in the more general SD model (see column＜3＞ of Table 3.4).

For the fiscal indicators of local governments, the debt service ratio is found to be significantly negative in all models. This robust result is likely to imply that fiscal discipline affects local governments' behaviors, to some extent. However, robust results are not obtained for the other indicators. The actual fiscal balance ratio turns out to be significant in the SE model, as is the financial capability index in the OLS and SAR models. However, neither is significant in the more general SD model. This may be because their spatially lagged variables, $\boldsymbol{WX}$, seem to deprive them of their explanatory powers in the SD model. Overall, the significant coefficients on the three spatially lagged independent variables, $\boldsymbol{WX}$, in the estimation result of the SD model may detect complex interactions among municipal governments.

5.2.2 Weight Matrix based on Distance and Heteroscedasticity

Next, Table 3.4 provides estimation results of the SAR and SD models using $\boldsymbol{W}_5$ as a weight matrix, in the two lines at the bottom. The column of residual variance ($\hat{\sigma}^2$) tells us that using $\boldsymbol{W}_5$ slightly improves the explanatory power in both models. The spatial autocorrelation parameter is estimated to be 0.76, slightly higher than that with the matrix of $\boldsymbol{W}_n$. This may imply the narrowly defined weight matrix does a good job, but still fails to detect some parts of complex spatial interdependence in the data.

Now, we consider heteroscedasticity in the estimation, which is motivated by the heterogeneous nature of the data. The data include various cities whose populations range from some ten thousand to more than million. Taking account of heteroscedasticity requires a Bayesian estimation.[15] The results with $\boldsymbol{W}_5$ are reported in the last line of Table 3.3 and in column <5> of Table 3.4. The residual variance $\hat{\sigma}^2$ turns out to be a quarter of that without heteroscedasticity, a great improvement. The spatial autocorrelation parameter, ρ, is estimated to be slightly below 0.9 and higher

[15] See Appendix 3.B.2 for details.

than that without heteroscedasticity, thereby suggesting strong bias resulting from the OLS estimation.

5.2.3 Comparing the OLS Estimation with Dummy Variables

Next, we compare the above results obtained from spatial econometric models with those from the OLS model with dummy variables, as discussed in Section 3.1.4. The latter results are reported in the second line of Table 3.3 and column <7> of Table 3.4. LeSage (2004) argued that the OLS is very unlikely to outperform spatial econometric models. A look at the values of $\hat{\sigma}^2$ verifies his argument. Remembering OLS of Eq.(3.16) uses 50 parameters, the parsimonious nature of the spatial models is quite appealing.

In addition, note that adding dummy variables produces smaller estimates in absolute value terms for the coefficients on regressors, such as weighting allowance rates for the central government, land prices for residential areas, and taxable incomes per capita, while they are still larger than those of the spatial models. This may suggest biases resulting from the OLS estimation are not completely eliminated, even if various dummies are added, the detailed study of which is beyond the scope of this chapter.

5.2.4 Re-examination

Herding behavior does not always mean closeness or a short distance between two cities. For example, as Uemura (2005) showed, in Chiba prefecture, Ichikawa raised its weighting allowance rate to 8 percent in 1973. This was followed by Funabashi in 1975, Matsudo in 1976, and Chiba in 1977. The approaches based on distance may be unable to explain the series of increases in Chiba prefecture because Chiba city is not that close to the preceding three cities.

Coming back to Figure 3.1, suppose cities 1 and 3 are big, while city 2 is small. Furthermore, suppose there is interdependence between the big two cities, 1 and 3, while no interdependence between the small city and the other two. The resulting weight matrix is as follows:

$$W = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}. \tag{3.17}$$

In other words, here is the assumption is that herding behaviors may take place among cities with a similar size population in the same prefecture. We try three kinds of weight matrices, $\boldsymbol{W}_{pi}$, (i=1,2,3). Herding behaviors are assumed to take place among: (1) cities with populations of more than 200 000, (2) those more than 100 000, and (3) each of five groups of cities classified according to population size (below 50, 100, 200, 300 thousand, and the rest). The first two matrices are based on the fact that weighting allowance rates are set mainly in major cities, resulting in a small level of interdependence, as observed in Table 3.5. The last is constructed to complement the difficulty.

(Table 3.5)

The bottom part of Table 3.5 shows that $\hat{\rho}$ turns out be very close to zero. That is, there is no spatial autocorrelation in the data. This result, together with those in Sections 3.2.1 to 3.2.3, suggests physical distance does matter in estimating spatial autocorrelation.

This finding is consistent with the hypothesis that neighboring cities are herding each other, but may not be conclusive because of a potential problem of omitted variables. There is no denying this chapter fails to detect something affecting neighboring cities, even though it includes four explanatory variables.

A word is in order in selecting the best weight matrix. More generally, the topic of model comparison is currently under intensive study. LeSage and Parent (2006) developed the MC^3 (Markov Chain Monte Calro Model Comparison) using Bayesian methods to deal with SAR and SE models. However, unfortunately, there is no general approach to dealing with SD models. Hence, selecting the best weight matrix based on the results obtained from various models is a future task to be tackled.

6 Conclusion

This chapter examines whether herding behaviors are observed in weighting allowance rates set by 693 municipalities in FY 2003, employing spatial econometric methods. In particular, the spatial autocorrelation parameter is closely studied in the SAR, SD, and SR models with various weight matrices. In estimating the model, we try to control factors other than herding by adding four explanatory variables of various indicators that reflect local governments' fiscal situations, weighting allowance rates for the central government, land prices for residential areas, and taxable incomes per capita.

The spatial autocorrelation parameter is significant, and estimated to lie in the range of 0.7 to 0.9, using weight matrices based on "closeness." Weight matrices based on broadly defined closeness, which regards cities in the five shortest distances as "close" to the city, account for the variations in the rate across municipalities better than those based on narrowly defined "closeness." Once physical distance is ignored, spatial autocorrelation can no longer be detected.

The above results suggest herding behavior among cities located close to each other. This is robust to changes in the specifications of the models. However, this finding may suffer from an omitted variable problem because, potentially, there may be independent variables other than the four studied here.

In addition, our spatial econometric models outperform OLS estimations in terms of residual variance and simplicity. The latter point may be worth emphasizing: introducing a weight matrix could purge a number of parameters and enable a parsimonious model that outperforms complex OLS models.

Table 3.1 Developments of Weighting Allowance Rates in Cities in Chiba Prefecture

unit: %

	1990s	1970s										1980s									1990s			2000s						reference
	67	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	91	94	96	'00	'01	'02	'03	'04	'05	central gov. (05)
Chiba	3					6			8					9			10												10	6
Ichikawa	3			6	8									9			10												10	3
Funabashi	3					6	8							9			10												10	3
Kisarazu	3										5		6		7	8			9		10						9		8	0
Matsudo	3					6	8							9			10												10	3
Noda	3							4				6		8	9		10										9		9	0
Narita	3											6	8		9				10										10	0 (partially 10)
Sakura	3											6		8			9		10										10	0
Narashino	3								6		7	8		9				10											10	3
Kashiwa	3							6		8				9			10												10	3
Ichihara	fixed amount	6	3	0	3			6			8			9				10											10	0
Nagareyama	3								6				7	8			10												10	0
Yachiyo	3								6			8		9				10											10	3
Abiko	3								4		6		7	8	9		10											9	9	0
Kamagaya	3									5					7	9		10											10	0
Kimitsu	3											4	5	6	7	8				9	10								10	0
Futtsu	3													5	7						9	8	7	2					2	0
Urayasu	0				1.5	3			5			6–8		9			10												10	3
Yotsukaido	3										4	5			8					9				10					10	3
Sodegaura	3											5	6		7	8				9						10			10	0

source: Uemura (2005)

Table 3.2 Examples of Central Government Employees' Weighting Allowance Rates

rank with rate	city examples
A with 12%	special wards of Tokyo
A with 10%	Yokohama, Mitaka, Nagoya, Osaka, Kyoto, etc.
A with 6%	Saitama, Chiba, Fukuoka, etc.
B with 3%	Sendai, Tsukuba, Matsudo, Fujisawa, Hiroshima, etc.

Source: National Personnel Authority (2003)

Table 3.3 Estimation Results

	$\hat{\rho}$ or $\hat{\lambda}$	# of para.	$\hat{\sigma}^2$	ML
OLS		14	6.944	-1648.22
OLS with dummies		55	5.567	-1549.56
SE/W_n	0.764	15	2.692	-1193.49
SAR/W_n	0.675	15	2.416	-1125.28
SD/W_n	0.672	27	2.292	-1106.74
SAR/W_d	0.774	15	2.555	-1118.89
SD/W_d	0.823	27	2.352	-1099.64
SAR/W_5	0.763	15	2.249	-1083.05
SD/W_5	0.757	27	2.195	-1073.03
SD/W_5,H	0.881	28	0.611	

Table 3.4 Details of Selected Estimation Results

column number		<1>			<2>			<3>			<4>			<5>		
estimation method		OLS			OLS/dummies			SD/ML			SD/ML			SD/Bayesian, hetero		
weight matrix		-			-			Wn			W_5			W_5		
	expected	coeff.	t-value		coeff.	t-value		coeff.	t-value		coeff.	t-value		coeff.	t-value	
constant		-29.493	-9.309	**	-20.109	-6.640	**	-12.206	-6.095	**	-4.243	-1.580		-1.397	-0.786	
X_1: actual fiscal balance ratio（%）	+	0.033	0.732		0.029	0.643		0.035	1.283		0.015	0.541		-0.017	-1.039	
X_2: debt service burden ratio（%）	-	-0.090	-0.934		-0.046	-0.520		-0.006	-0.107		0.010	0.188		-0.001	-0.026	
X_3: debt service ratio （%）	-	-0.208	-2.612	**	-0.296	-4.040	**	-0.139	-2.777	**	-0.120	-2.327	**	-0.056	-1.971	**
X_4: reference ratio to limit new bond issues （%）	-	-0.108	-1.603		-0.032	-0.508		0.003	0.069		0.008	0.193		0.023	0.894	
X_5: fiscal capability index	+	3.130	5.307	**	3.167	5.760	**	0.449	1.001		0.229	0.477		-0.375	-1.269	
X_6: current expenditures ratio （%）	-	-0.054	-0.403		-0.002	-0.016		-0.098	-1.250		-0.017	-0.214		0.026	0.524	
X_7: of which, personnel expenses （%）	-	0.081	3.230	**	0.056	2.420	**	0.020	1.287		0.022	1.398		0.003	0.339	
X_8: debt service （%）	-	0.128	1.264		0.062	0.663		0.065	1.066		0.052	0.871		0.020	0.589	
X_9: current expenditures ratio adjusted for special bond issues （%）	-	0.124	1.023		0.053	0.463		0.098	1.365		0.013	0.175		-0.023	-0.506	
X_{10}: central government employees' WARs （%）	+	0.220	4.224	**	0.311	5.360	**	0.077	2.255	**	0.105	2.914	**	0.056	2.502	**
X_{11}: land prices for residential areas （対数）	+	2.160	8.596	**	1.652	7.040	**	1.186	7.254	**	0.803	3.848	**	0.314	2.569	**
X_{12}: per capita taxable incomes （in log）	+	3.528	4.140	**	1.390	1.740	*	0.643	1.018		0.353	0.451		0.610	1.321	*
Wy								0.672	19.004	**	0.757	25.822	**	0.881	58.301	**
WX_1								-0.070	-1.629		-0.140	-2.739	**	-0.021	-0.636	
WX_2								-0.092	-1.129		-0.057	-0.468		0.020	0.274	
WX_3								0.034	0.461		-0.045	-0.511		-0.029	-0.572	
WX_4								-0.197	-3.279	**	-0.074	-0.981		-0.079	-1.820	**
WX_5								1.353	2.122	**	1.275	1.870	*	1.222	2.961	**
WX_6								0.144	3.492	**	-0.265	-1.927	*	-0.188	-2.047	**
WX_7								0.001	0.023		-0.030	-1.184		0.001	0.038	
WX_8								0.089	0.993		0.056	0.485		0.014	0.197	
WX_9								-0.099	-1.970	**	0.246	1.873	*	0.168	2.023	**
WX_{10}								-0.013	-0.265		-0.033	-0.588		0.022	0.593	
WX_{11}								-0.289	-2.469	**	-0.136	-0.502		-0.054	-0.330	
WX_{12}								-0.070	-0.081		-0.557	-0.583		-0.860	-1.559	*
r (degree of freedom of Chi-squared distribution)															4	
sigma^2			6.944			5.705			2.292			2.195			0.611	

Note 1： expected sign is shown for eaxh of fiscal variables when fiscal discipline functions.

2： ** for 5%，* for 10% significance level.

Table 3.5 Weight Matrix based on Population Size

weight matrix	W_{p1}	W_{p2}	W_{p3}
population size	more than 200,000	more than 100,000	five categories
# of cities			
cities with interactions	382	1140	4178
# of interactions per city	0.55	1.65	6.03
estimation results of Rho			
SAR	0.016	-0.005	-0.005
SD	0.000	0.067	0.067

Figure 3.1 Conceptual Illustration of “Closeness”

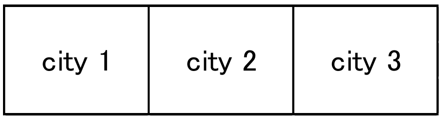
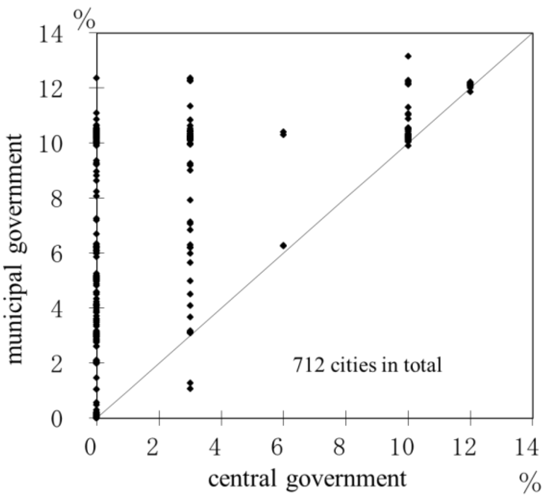


Figure 3.2 Comparison with Central Government Employees’ Weighting Allowance Rates

(FY 2003)



Source: Ministry of General Affairs,
Survey of Local Governments’ Settlement Situations

Figure 3.3 Visualization of $\boldsymbol{W}_n$

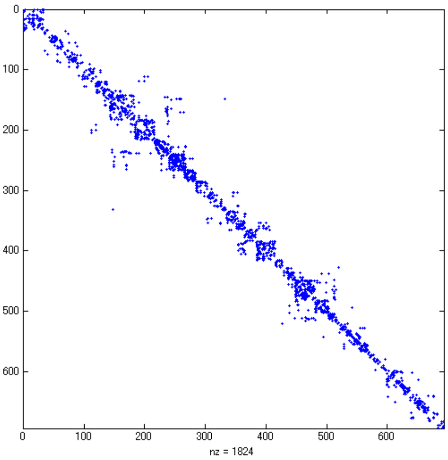
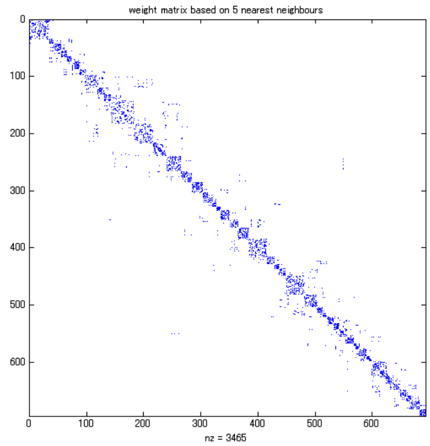


Figure 3.4 Visualization of $\boldsymbol{W}_5$



Appendix 3.A

This appendix examines the extent to which changes in the fiscal situations of municipal governments explain rises or falls of weighting allowance rates. Figure A.1 shows the changes in the weighting allowance rates for the period FY 1996 to FY 2003. The number of sample municipalities is 681: 221 raised the rate, 214 lowered, and 246 kept the same rate. The figure also shows that municipalities with a rate lower than 10 percent in FY 1996 tend to be located below the 45 degree line, while those with a rate higher than 10 percent are above the line. This may suggest divergent behavior of the rate among municipalities.

（Figure 3.A.1 Comparison of FY1996 and FY2003）

Ordered probit models will be estimated. The dependent variable is an index, which is zero if the weighting allowance rate decreases during the sample period, one if the rate remains the same, and two if the rate increases. We use two kinds of independent variables: (1) those showing changes in the fiscal situations of municipal governments, and (2) those showing changes in the rate for national government employees.

The former are changes during the sample period of nine fiscal indicators available in the Survey of Local Governments' Settlement Situations, which are used in the empirical analyses in Section 5. Multicollinearity among these variables is a concern because some of them are strongly correlated, by definition. Therefore, we should pay attention to not only the explanatory power of individual variables, but also their combined power.

The latter are dummy variables that represent changes in weighting allowance rates applied to national government employees working in each city. These dummies are produced from Appendix Three of Uemura (2005), which summarizes such changes.

We conduct estimations in two sample periods, FY 1996 to 2000 (Case A) and FY 2001 to 2003 (Case B). We also use different sample periods for dependent and independent variables: FY 2001 to 2003 for the former, and FY 1996 to 2000 for the latter (Case C). This additional case was set up to deal with two concerns. First, there might be a bias due to possible correlation between independent variables and a disturbance term if both are taken in the same period. Second, it may take some time to take necessary policy measures to deal with deteriorations of fiscal situations.

Table 3.A.1 provides a summary of the estimation results. Overall, fiscal variables do not have much explanatory power. In Case A, only the debt service ratio has an expected effect at the 5% significance level. Furthermore, the hypothesis that all the coefficients on the fiscal variables are equal to zero cannot be rejected, which indicates a loss of fiscal discipline.

（Table 3.A.1 Estimation Results of the Ordered Probit Models）

In Cases B and C, individual fiscal variables do not have much explanatory power. As expected, only two are effective in Case B, namely the fiscal capacity index and current expenditure share in general revenues, and only one in Case C, namely the reference ratio to limit new bond issuance. Some have opposite and statistically significant signs, for example, the actual fiscal balance ratio in Case B and the debt service burden ration in Case C.

However, we can find evidence of fiscal discipline in Cases B and C. The hypothesis that the coefficients of the fiscal variables (except for those with opposite and statistically significant signs) are equal to zero is rejected in both cases. This might suggest fiscal discipline was lost in the 1990s, but recovered in the 2000s, although the overall fit of the models is very low.

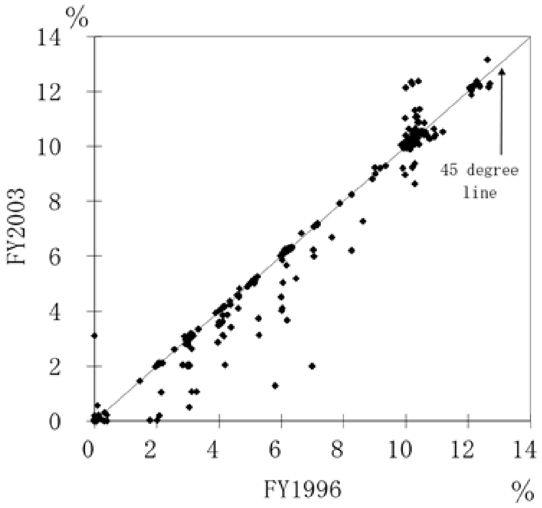
Note that changes in the rate for national government employees are not estimated to affect the dependent variable. The dummy for an increase has the opposite sign in Case A, and both dummies have expected, but statistically insignificant estimates in Case C. No dummies are available in Case B, because there were no changes in FY 2001 to 2003.

In summary, there seem to be divergent behaviors of the weighting allowance rates among municipalities from FY 1996 to 2003. Overall, fiscal situations of municipal governments cannot account for the changes, but may be of some help in the 2000s. The changes in the national counterpart explain little of the municipality changes.

Table 3.A.1 Estimation Results of the Ordered Probit Models

	A		B		C	
dependent variables in:	FY 1996 to 2000		FY 2001 to 2003		FY 2001to 2003	
independent variables in:					FY 1996 to 2000	
sample size	689		690		681	
dependent variable ＜expected sign＞	estimate	p value	estimate	p value	estimate	p value
X1: actual fiscal balance ratio <+>	0.0150	0.4816	-0.0466	0.0442	0.0317	0.1422
X2: debt service burden ratio <->	-0.0059	0.8149	-0.0348	0.3691	0.0655	0.0100
X3: debt service ratio <->	-0.1225	0.0273	-0.0916	0.2671	-0.0333	0.5501
X4: reference ratio to limit new bond issues <->	0.0357	0.3616	0.0191	0.7526	-0.0844	0.0335
X5: fiscal capability index <+>	1.2508	0.2144	5.1916	0.0003	-1.9250	0.0588
X6: current expenditures ratio <->	-0.0509	0.2066	-0.0729	0.0320	-0.0018	0.9643
X7: of which, personnel expenses <->	0.0119	0.6479	-0.0163	0.6294	0.0128	0.6246
X8: debt service <->	0.0881	0.1430	0.1060	0.2211	-0.0102	0.8672
X9: current expenditures ratio adjusted for special bond issues <->	0.0636	0.1266	0.0452	0.0499	0.0309	0.4642
dummy for a fall in central governemnt weighting allowance rate <->	-0.3578	0.2845	-	-	-0.1183	0.7200
dummy for a rise in central governemnt weighting allowance rate <+>	-0.0905	0.9137	-	-	0.3292	0.4448
Log likelihood		-747.6983		-742.6362		-733.3596
LR index (Pseudo-R2)		0.0080		0.0175		0.0166
F test of H0 of coefficients of fiscal variables being equal to zero		0.3216		0.0028		0.0170

Figure 3.A.1 Weighting Allowance Rates in FY 1996 and 2003



Source: Ministry of General Affairs,
Survey of Local Governments' Settlement Situations

Appendix 3.B

3.B.1 Maximum Likelihood

Here, we provide the details of the ML estimation used in Section 5. Resorting to LeSage (2004, 2005a,b) enables us to get the value of ρ ($-1 < \rho < 1$) that maximizes Eq. (3.18) shown below. Once the value of ρ is obtained, it is possible to compute other parameters, β and $\hat{\sigma}^2$. In estimating Eq. (3.18), we utilize the MATLAB Toolbox which LeSage put on his homepage.

$$ln\ L = C + ln\ |\mathbf{I}_N - \rho\mathbf{W}| - (n/2)\ ln\ (e'e) \tag{3.18}$$

$$e = e_0 - \rho\ e_d$$

$$e_0 = \boldsymbol{y} - \mathbf{X}\beta_0$$

$$e_d = \mathbf{W}\boldsymbol{y} - \mathbf{X}\beta_d$$

$$\beta_0 = (X'X)^{-1} X'y$$

$$\beta_d = (X'X)^{-1} X'Wy$$

3.B.2 Estimation taking into account Heteroscedasticity

The Bayesian MCMC (Markov Chain Monte Carlo) method is used to estimate the model with heteroscedasticity. See LeSage (2005a) for more details. A key is to introduce $\boldsymbol{V}$ = diag(v_1, ..., v_n), instead of an identity matrix $\boldsymbol{I}_N$, into Eq. (3.5), and to assume in prior information (expressed as π) that v_i/r follows a Chi-squared distribution with degree of freedom r.

$$e \sim N(0,\sigma^2\boldsymbol{V}),\ \boldsymbol{V} = \mathrm{diag}(v_1, ..., v_n) \tag{3.19}$$

$$\pi(v_i/r) \sim \mathrm{IID}\ \chi^2(r). \tag{3.20}$$

If r is small, v_i could be larger. As r becomes larger, the distribution could become closer to a normal distribution.

Chapter 4

What Is the Economic Value of Japanese Longevity?

Estimating the Outcome of Economic Growth

1. Introduction

The life span of Japanese people has increased dramatically, and is an outcome often attributed to economic growth (e.g., Yoshikawa 2003). Such biological or physiological aspects of economic growth were emphasized by Fogel (1994) and Steckel (2008). This chapter will try to quantify the advantages of greater longevity. To be specific, we will measure people's willingness-to-pay (WTP) with respect to an increase in the survival rate, $dS = S^2 - S^1$, between S^1 and S^2. We can think of the value of WTP as the economic advantage of longevity.

Wage disparity is often used to study the relationship between prices and risks. In labor markets, jobs with high risk tend to offer higher wages than those with low risk, and such research attempts to determine how wages vary according to jobs' risk characteristics. This price-risk trade-off is often summarized in the value of statistical life (VSL), the premium divided by the additional level of danger, that is, the WTP per unit of additional risk (WTP/dS). This normalized indicator is calculated in many policy evaluation studies. Cropper, Hammitt, and Robinson (2011) provided an overview of recent literature on the VSL. This chapter instead highlights the WTP, putting it in terms of size and scope, before adjusting for dS, because estimating the size itself is a primary purpose here.

However, because of regulations, it is generally difficult to obtain good data on health care from the market, making the method cited above difficult to employ. For instance, rarely do we hear hospitals say that they will provide an obsolete health care service, but at a discount. Under these circumstances, Murphy and Topel (2003, 2006) put forth a method to estimate the WTP. Here, this method is applied to data for Japan to determine the value of the decrease in the mortality rate that occurred in the 35 years from 1970 to 2005. The WTP is estimated based on the population in 2005, and it is also possible to project the effects of future changes in the population on the WTP, as an extension. Furthermore, if we can identify the factors contributing to the greater longevity, it would be possible to calculate their costs. This chapter implements a cost-benefit analysis on trial, following Murphy and Topel (2003).

This chapter is structured as follows. Section 2 reviews literature related to the VSL, WTP, and health capital. Section 3 shows our theoretical framework, in which our model to estimate the WTP and its extension are examined. Section 4 estimates the WTP due to the declines in mortality rates from 1970 to 2005. Section 5 undertakes two additional analyses: the effects of changes in population size and its compositions; and a trial calculation of the cost-benefit. Finally, Section 6 concludes the chapter.

2 Literature Review

The WTP is illustrated in Figure 4.1, where a decline in wealth by the WTP together with an increase in the survival probability keep the utility level unchanged. The VSL is calculated as WTP/dp and, therefore, can be interpreted as the slope of the indifference curve between risk and wealth.

(Figure 4.1)

Two approaches are taken to estimate the VSL, namely revealed- and stated-preference approaches (Cropper *et al*., 2011). The former often depends on an estimation of hedonic wage equations from data on jobs' wages and risk characteristics. Please note that, because the market transaction data reflect only the views of the employed, the result may be different from what we want, that is, those obtained from the total population, and is likely to be downwardly biased. The latter asks respondents about hypothetical situations, which can be tailored to a specific need. Obviously, it might be difficult to obtain serious answers.

These methods are widely used as tools of a regulatory impact analysis (RIA). The

RIA was institutionalized in the United States in the 1980s, the UK in the 1990s, and in EU countries in the 2000s. Therefore, there have been many examples and several studies that have surveyed these experiences[1]. Cropper *et al*. (2011) summarizes various meta-analysis results of both approaches, and report estimation results for developed countries, mainly, but not limited to the United States, ranging from 2.0 to 11.1 million dollars in 2009 prices for the former, and those from 2.7 to 8.5 for the latter.

A related idea is that of health capital. Grossman (1972) introduced the idea of health capital, which yields an output of healthy time. From a physiological perspective, it would be interesting to measure changes in health capital over time. This line of research was conducted by Culter and Richardson (1998, 1999), and by Arrow, Dasgupta, Goulder, Mumford, and Oleson (2012, 2013) and Arrow, Dasgupta, and Mumford (2014). Their calculation is rather straightforward: they add up the expected number of quality-adjusted life years (QALY) over people in the economy, and multiply it by the value of statistical life years (VSLY), that is, the VSL divided by the expected discounted life remaining.

Note that the WTP and changes in health capital are comparable. Suppose a simple case where one can ignore quality of life. That is, “to be healthy” means “to survive.” In this situation, the product of VSL and dS represents the WTP, as well as a change in health capital.

For Japan, Miyazato (2010) is a recent example in the line of VSL research. He used microdata and estimated the VSL to be 217 to 264 million yen from the risk premium related to occupational hazards and accidents. This is close to the 280 million yen that Oka (1999) predicted from industry-specific data in the labor market, but is much lower than the 0.8 to 1 billion yen that Furukawa and Isozaki (2004) obtain from vehicle purchasing behaviors. Fukui and Iwamoto (2004) perform a cost-benefit analysis using data from 1990 to 1999, based on the idea of health capital.

[1] Informative surveys are provided by Ashenfelter (2006) and Viscusi (2014), among others.

3. Theoretical Framework

3.1 The Model

I explain the theoretical basis for my estimates based on Becker (2007). While Murphy and Topel (2003, 2006), among others, are cited for the general model used in this case, the simple two-period model as indicated in Becker (2007) is sufficient to explain the essence of their analysis.

Each person's life is divided into early life (*t*=0) and late life (*t*=1), and his/her utility is modeled as follows:

$$U = u_0(x_0, l_0) + BS(h)u_1(x_1, l_1). \tag{4.1}$$

Here, the utility for each period depends on goods and services, x_i and leisure l_i, while B is the discount rate (B =1/(1 + β)); S is the rate of those surviving from early life to later life, and is a function of h, health conditions.

However, in order to get health condition h, expenditures for health in early life g(h) are required. The result is the following budget constraint:

$$x_0 + \frac{Sx_1}{1+r} + g(h) = w_0(1 - l_0) + \frac{Sw_1(1 - l_1)}{1+r} = W. \tag{4.2}$$

The first-order condition (hereinafter FOC) in the utility maximization problem, which maximizes Eq.(4.1) under Eq.(4.2), is the following:

$$\frac{dS}{dh}Bu_1 = u_{0x}\left(\frac{x_1 - w_1(1 - l_1)}{1+r}\frac{dS}{dh} + g'(h)\right). \tag{4.3}$$

The left side is the marginal benefit when costs related to health care are increased, and the right side of the equation is marginal cost. The former depends on the future utility level, u_1. In other words, as the income level increases so does u_1, thereby increasing the marginal benefit.

If we substitute another FOC, $u_{0x} = B(1 + r)u_{1x}$ into Eq.(4.3), we get the following equation:

$$\frac{1}{1+r}\frac{dS}{dh}\frac{u_1}{u_{1x}} = \frac{1}{1+r}\frac{dS}{dh}[x_1 - w_1(1-l_1)] + g'(h) = \text{WTP}. \tag{4.4}$$

The left side of the equation measures the size of the marginal benefit relative to the marginal utility of goods in later life. In other words, this suggests how many units of consumption of goods and services in later life can be given up for marginal improvements in health care, which can be interpreted as the WTP.

Next, assuming homogeneity γ, in the utility function[2], we get the following:

$$\frac{u_1}{u_{1x}} = \frac{1}{\gamma}(x_1 + w_1 l_1). \tag{4.5}$$

When substituted into Eq.(4.4), we get the following:

$$\frac{1}{1+r}\frac{dS}{dh}\left(\frac{1}{\gamma} - 1\right)(x_1 + w_1 l_1) = g'(h) - \frac{1}{1+r}\frac{dS}{dh}w_1. \tag{4.6}$$

Here, if $\gamma = 1$, the left side will be zero[3]. However, because with a normal concave utility function $\gamma < 1$, it will not be zero.

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[2] Because the utility function $u_i(x_i, l_i)$ is homogenous of degree γ, we get the following ($i = 0, 1$):

$$\begin{aligned} \gamma u_i &= u_{ix}x_i + u_{il}l_i \\ &= u_{ix}x_i + (w_i u_{ix})l_i = u_{ix}(x_i + w_i l_i). \end{aligned}$$

[3] In this case, Eq.(4.6) is equal to the FOC derived from maximizing the following net income with respect to h:

$$ny_i \equiv w_0 + \frac{Sw_1}{1+r} - g(h).$$

In Eq.(4.2), moving $g(h)$ to the right side, we get the following:

$$x_0 + \frac{Sx_1}{1+r} = w_0(1-l_0) + \frac{Sw_1(1-l_1)}{1+r} - g(h).$$

Setting $(l_0, l_1) = (0, 0)$ results in the newly defined variable, *ny*. Thus, Eq.(4.6) shows the condition to attain the maximum amount of resources devoted to consumption of goods and services with optimal choice of h.

In Eq.(4.4), if we consider the WTP when dh = 1, we get the following:

$$\mathrm{WTP} = \frac{1}{1+\mathrm{r}} \mathrm{dS} \frac{\mathrm{u}_1}{\mathrm{u}_{1\mathrm{x}}} = \frac{1}{1+\mathrm{r}} \mathrm{dS} \frac{1}{\gamma} (\mathrm{x}_1 + \mathrm{w}_1 \mathrm{l}_1)$$
$$= \frac{1}{1+\mathrm{r}} (\mathrm{S}^2 - \mathrm{S}^1) \frac{\mathrm{C}_1}{\gamma} \ . \qquad (4.7)$$

Here, C_1 is essentially full consumption, which includes not just goods, but leisure in terms of wages as an opportunity cost. When health conditions improve by a unit of 1, the survival rate goes from S^1 to S^2 and, since leisure is enjoyed in addition to goods by those in later life, it is valid to add both together in order to evaluate the merit in terms of full consumption.

This simple two-period model can be easily transformed into a multi-period one. In fact, Murphy and Topel (2003) showed a continuous-time model in this scenario. In order to prepare for estimations in the next section, we first derive the following multi-period equation at discrete times:

$$\mathrm{WTP}_{s,a} = \sum_{t=1}^{\infty} \frac{1}{(1+r)^t} \left(\frac{S^2_{s,a+t}}{S^2_{s,a}} - \frac{S^1_{s,a+t}}{S^1_{s,a}} \right) \frac{C_{s,a+t}}{\gamma} \quad \mathrm{s} = \mathrm{m,f};\ \mathrm{a} = 0,1,2 \ldots\ , \qquad (4.8)$$

where $\mathrm{WTP}_{s,a}$ is the willingness of people, males ($s = m$), and females ($s = f$) of age a to pay when the future survival probability curve shifts from S^2 to S^1, on an individual basis. The overall society WTP is:

$$WTP^* = \sum_{s=m,f} \sum_{a=0}^{\infty} WTP_{s,a} \cdot N_{s,a}\ , \qquad (4.9)$$

where $N_{s,a}$ is the population per sex and per age.

2.2 An Extension

Health expenditures are regarded as “investment” in the basic model because they do not directly affect utility, but instead indirectly through changes in the survival rate, S. However, there are many medical treatments that increase patients’ current utility, but do not raise their survival rate, such as palliative care. Such care should be treated as "consumption." Both investment and consumption natures are captured in an extended model shown by Arrow, Dasgupta, and Mumford (2014), which is a simplified version of the used in Arrow *et al*. (2012, 2013).

In their model shown below, utility depends on health capital, H, ignoring leisure and time preference for simplicity.

$$\mathrm{U} = \mathrm{u}(H, x_0) + S(H)u(H, x_1) \tag{4.10}$$

$$x_0 + S(H)x_1 + h = W(H). \tag{4.11}$$

Note that an increase in health expenditure, h, increases H, thereby raising utility in the current and next periods, a reflection of its mixed nature. Lifetime wealth, W, is also a function of H: although abstracting leisure makes the amount of labor supply fixed as long as he survives, increased health capital raises the survival rate, thereby increasing wealth.

Using a FOC of $\mathrm{u_{x0}} = \mathrm{u_{x1}}$, another FOC is derived as follows:

$$(1 + S(H))u_H \frac{\partial \mathrm{H}}{\partial h} + \frac{\partial \mathrm{S}}{\partial H}\frac{\partial \mathrm{H}}{\partial h}\mathrm{u}(H, x) + u_x \frac{\partial \mathrm{W}}{\partial H}\frac{\partial \mathrm{H}}{\partial h} = u_x. \tag{4.12}$$

The LHS of Eq.(4.12) has three terms: the first is a direct effect of health on wellbeing; the second is the longevity effect; the third is a productivity effect. Therefore, the WTP in the simple model is based on the second term only and leaves out the first and the third terms. This implies that the results shown below are likely to be underestimated, although they will turn out to be quite large.

4. Empirical Methodologies

4.1 Data

I compare survival rates for 1970 and 2005, determining the value of improvements in health care conditions during this period with WTP*. I use a cross section of data (age profile) for 2005 in this forward-looking decision-making estimate of the model. In other words, people of age a in 2005 are assumed to use information available in cross section data such as a survival probability of $a + t$ (t = 1,2, ...). This assumption is required to make up for data that do not span enough time to allow tracking of a full life span.

As explained in detail in Appendix 4.A, I calculate the variables used in Eq.(4.8). The results are summarized in Table 4.1.

(Table 4.1)

Consumption in both males and females increases up to age 40 but begins to decrease after age 50. However, the consumption of males in the 70-year-old age bracket increases compared to those at age 60. It seems only natural that consumption would decrease, as it does with females. The reason for the aberration may be a sample bias in the National Survey on Family Income and Expenditures; therefore, before performing the analysis, I adjusted consumption for 70-year-old males to that of the 60-year-old group. The results show that consumption is greater for males up to age 40, but for females beginning at age 50.

In the following, I report regular wages by themselves, and regular wages plus overtime and bonus payments (labeled “including bonus”). For males, a large peak occurs after their mid-40s whereas females peak in their 30s while the height of the peak for females is roughly half that of males. The differences in the profiles are most likely a reflection of the higher percentage of part-time jobs held by females in their mid- and late careers.

Leisure time takes a U-shaped curve across age groups, as we would expect: long hours in young and old ages, but short hours in the 30s and 40s. Moreover, in every age group across the board, males have 5 to 10 percent more leisure time than do females.

The stationary population is the number of people in each age bracket surviving at any point in time when a population of 100,000 people is born. Clearly, this figure is greater for females than it is for males. Compared to 1970, there are 20,000 more males who are 70, 75, and 85 years old, while the number for females increases by 30,000 at ages 80, 85, 90. If we calculate a change in the survival probability rate in Eq.(4.8), for example, for a period of five years, $S_{s,a+5}^{2005}/S_{s,a}^{2005} - S_{s,a+5}^{1970}/S_{s,a+5}^{1970}$, males increases by over 20 percentage points in the categories of 75 to 80, 80 to 85, and 85 to 90 years old, and females by over 25 percentage points in the categories of 80 to 85, 85 to 90, and 90 to 95 years old. The change in the survival probability rate is delayed in the life stages for females compared to males, and also occurs to a larger extent.

Finally, the last column shows the population multiplied by per capita WTP. We must take note of the baby-boomer generation (born in 1947 to 49) in 2005 when they reach the latter half of their 50s.

4.2 Results of Estimation

4.2.1 Case 1

Using the variables explained above, I perform the estimation. However, at this point, I must set values of two parameters: the discount rate, roughly the same as the average real, long-term interest rate after the 1990s, r = 0.03; and the utility function parameter at $\gamma = 1/3$.

Since not all of the above-mentioned data can be used across all ages from 0 to 114 of the life table, we must decide how to handle the age groups for which data are lacking. As Table 4.1 shows, data for consumption spending, wages, and leisure time are missing in the early and late life age brackets.

Therefore, for Case 1, I insert figures into these age brackets, assuming them to be equal to those available in the closest age brackets. As a result, consumption spending and wages are set constant during age 0 to 15 and age 75 to 114, a rather drastic assumption. This, however, reduces the arbitrariness and makes it easier to understand. We try these assumptions in Case 1.

Figure 4.2 (1) shows the results of calculating full consumption $C(= x+wl)$ for each sex and age bracket. The peak for males using regular wages was just short of 8 million yen around the late 40s, but when wages with bonus were used, the figure was about 9 million yen. Females reach a peak in their late 40s with another increase of around 6 million yen in later years.

(Figure 4.2)

For this *C*, using the survival probability rate determined from the stationary population in the life table, we get the WTP per capita from Eq.(4.8) (Figure 4.2 (2))[4]. For both males and females at regular wages, the peak was around 75 million yen, with males reaching a peak in their early 60s compared to females at around 70. When bonuses are included, both males and female tend to reach a peak around the same time at a level of 80 million yen, males being slightly higher. As can be seen in Figure 4.2 (1) and (2), at full consumption, males consume at a greater level than females, yet when WTP per capita is considered, females are at a higher level than males after age 70, suggesting that improvements in the survival probability rate for females have been more significant, as mentioned earlier.

Figure 4.2 (3) shows the WTP of each age bracket ($WTP_{s,a}$) multiplied by the population. However, since the National Census gives only the total population over 100 years of age, the figures for 100 years and older is the total WTP for the age group of 100 years or older. We can see a WTP peak because of the baby-boomer generation aged 56 to 58 about 80 trillion yen for regular wages for both males and females. If bonuses are included, the figure is 87 trillion yen for males, and 82 trillion yen for females.

Totaling the WTP for each age group, we get 3,240 trillion yen for males at regular wages and 3,228 trillion yen for females, and a total for both sexes of 6,468 trillion yen. The difference between regular wages and wages including bonuses is only 6 percent. While these figures are the cumulative benefit over 35 years between 1970 and 2005, on an annualized basis, we get 93 trillion yen for males and 92 trillion yen for females, if regular wages are used. When bonuses are included, the figures are 100 trillion yen

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4 For people over 100 years old, I took the average value. Therefore, the graph shows the average value for all age groups over 100. This is because the *National Census* provides only a total value for ages over 100, as explained later in the article.

for males and 97 trillion yen for females. Thus, the total for both sexes amounts to around 200 trillion yen, representing a significant benefit of 40 percent of GDP.

4.2.2 Case 2

In Case 2, I adjust several points to correct the possible overestimation in Case 1. For instance, estimates may be overstated in Case 1 in the following ways: full consumption *C*, (1) is assumed to be the same during young childhood as in their later teens, and (2) does not decrease in the older years and, in fact, increases. These are the consequences of assuming data for periods where personal consumption spending and wages are missing to be the same as those in the closest age brackets. In Case 2, it is assumed that the younger or older the age is, the less consumption and wages become.

First, pursuant to the terms of the Labor Standards Act, labor is not recognized for people between zero and 15 years old, and their wages are set at zero. The result is that full consumption *C* of those age 15 and younger will depend on expenditures on goods and services only and, thus, will not be affected by increases or decreases in leisure time. For people older than 70, wages for the 90 and older age group are set the same as for those 17 and younger. To find a new wage profile decreasing from the level of the late 60s to that newly set for those 90 and older, I had to interpolate wages of the four age groups, that is, early and late 70s and early and late 80s. As a result, wages from the late 60s and for the next 20 years were decreased to roughly half for males and 70 percent for females.

Next, consumption expenditures *x* for up to 30 years old were applied only to people in their early 20s, while I applied 80 percent of the figure for those in their 20s to those in their teens, and again, 80 percent of the figure derived for teens was applied to those from age zero to nine. Similarly, the value for those 70 years old and older was applied only to those in their 70s, and the value for those older than 90 was set the same as for those in their 20s. Finally, to determine the fixed rate of decrease from those in their 70s to 90s and older, I interpolated consumption for those in their 80s who fall between. Therefore, consumption spending was decreased by about 10 percent for males aged 70 to 90 years old, and by about 15 percent for females.

Now, the age profiles for full consumption *C*, after correcting for the two points above, are redrawn in Figure 4.3 (1). For people 15 years old and younger, *C* is 1.3 million yen, or about 30 percent of the value in Case 1. In addition, in Case 1, where the early half of the 60s hit a low and then increased, consumption was corrected so that the decrease continues from the 70s onwards. The level for those 90 years old and over is about 4.8 million yen for males and 4.5 million yen for female, roughly 50 to 60 percent and 80 percent lower than their respective peaks achieved in their late 40s.

(Figure 4.3)

Using per capita WTP and the corrected full consumption, we see in Figure 4.3 (2) that wages for males peak at around 60 years old at 61 million yen for regular wages and 64 million yen when a bonus is included. The peak for females occurs in their late 60s with both wages ranging from about 64 to 65 million yen. Compared to Figure 4.2 (2), the downward shift is smaller for females. The reversal of per capita WTP for males and females goes from the mid-60s in Case 1 to the late 50s in this instance.

Figure 4.3 (3) shows that when the WTP is multiplied by the number of people, the peak is again located with the baby-boomers in their late 50s. However, the height of the peak for regular wages shows a decrease of about 12 trillion yen compared to Case 1, to 68 trillion yen for each of males and females. For wages including bonuses, the figure decreases 16 trillion yen to 71 trillion yen for males, and 12 trillion yen to 70 trillion yen for females.

For the entire economy, using regular wages for males, we get 2,742 trillion yen, and 2,817 trillion yen for females for a total of 5,559 trillion yen. Wages including bonuses yields 2,889 trillion yen for males and 2,877 trillion yen for females, amounting to 5,766 trillion yen in total. As in Case 1, I convert this to an annual basis, arriving at 159 trillion yen for regular wages (78 trillion yen for males and 80 trillion yen for females) and 165 trillion yen for wages including bonuses (83 trillion yen for males and 82 trillion yen for females). The results of Case 1 and Case 2 are summarized in Table 4.2. The results of the estimates performed in Case 2 are approximately 85 percent of their Case 1 counterparts. Further, we see that regular wages yield a greater

WTP for females, while wages including bonuses do so males.

(Table 4.2)

4.3 Re-examining Parameters

We now re-examine how robust the results obtained in the preceding section are. In the estimate, two parameters remained fixed. One is the interest rate r equal to the real, long-term rate of 3 percent. A higher interest rate would discount more heavily the outcome of future improvements in the survival probability rate, thereby reducing the WTP for the overall economy, WTP^*. The other parameter is γ in the utility function, which is set at 1/3. In Eq.(4.8), it is clear that γ acts as a scale parameter, and, if it doubles, WTP^* will be halved.

Now, let us see how WTP^* changes in response to changes in the values for these parameters (r, γ). Figure 4.4 shows WTP^* as contour lines on the plane $r-\gamma$. Moving close to the origin on the plane will obtain a higher WTP^* value. Note the WTP^* values are calculated from the wages including bonuses and are converted to an annual basis. From this figure we can see what combinations of parameters would produce results similar to what we obtained in the preceding section (shown as ◊ in Figure 4.4).

To see in more detail how WTP^* changes, the line in Figure 4.5 is a cross section of Figure 4.4 cut by the straight line $\gamma = 1/3$. Further, the dotted line in Figure 4.5 is the upper limit of Figure 4.4, that is, cut by $\gamma = 1$. The dotted line is equivalent to the lower limit when γ becomes larger causing the solid line to shift downward. On the other hand, when γ becomes smaller, the solid line will shift upward.

(Figure 4.4)

(Figure 4.5)

4.4 Changes by Period

Up to this point, I have discussed and estimated the change in the survival rate from 1970 to 2005 ($S^{2005} - S^{1970}$). Now, I divide this time frame into two separate periods, 1970 to 1990 and 1990 to 2005, in order to determine the WTP for each one separately. However, because I use the full consumption and population for 2005, there will be differences in survival rate changes, causing differences in the size of WTP from $S^{1990} - S^{1970}$ and $S^{2005} - S^{1990}$ only.

The results of these calculations are shown in Table 4.3, lines (3) − (6) [see Ref. column of the table]. On an annual basis, the change occurring in the first 20-year period is greater: about 70 percent of all the WTP occurred in the period spanning just short of 60 percent (= 20/35) of the entire period. Furthermore, it is interesting to observe that in the first 20-year period, the change in survival rate makes the value for males greater, while for the next 15 years, it is higher for females. This is because females have a larger population in their elderly years, with a significant rise in survival rate.

(Table 4.3)

5. Further Analysis

5.1 Aspects of Changes in Population

5.1.1 Decomposing WTP

Note that the WTP for the entire economy is obtained as the sum of per capita WTP ($WTP_{s,a}$) multiplied by population per sex and age group in Eq.(4.9). In the actual calculations above, we used the population as of 2005, that is, $N_{s,a} = N_{s,a}^{2005}$. Therefore, if we were to use the population in 1970, $N_{s,a} = N_{s,a}^{1970}$, the results for WTP^* will naturally be different.

In fact, the size of the population and the age structure vary significantly between the two periods. First, the population of 104 million in 1970 increased to 127 million in 2005, for a 22.7 percent increase. When viewed by sex, the population of males increased 21.9 percent, while that of females grew at a greater rate of 23.5 percent.

Next, the birthrate continues to fall and the aging population gets underway significantly between these two periods. If we consider the population pyramid[5] for Figure 4.6(1) for both periods, we see that the population up to age 29 for both males and females is lower in 2005, and greater for ages 30 and older. The difference accounts for more than 30,000 people per age group from 50 to 70 years old for males and 50 to 80 years old for females. What is even more indicative of aging is the increases in the population older than 85. On the graph line showing 1970, there is a curious increase at age 85 because the population is not divided into age groups after 85, instead giving the total of people older than that age. However, Figure 4.6(2), which shows the population of males and females older than 85, reveals that males have increased from 89,000 to 811,000, while females have increased from 207,000 to 2,116,000, a nine- and tenfold increase, respectively.

(Figure 4.6)

An increase in population in conjunction with the changes in age structure from 1970 to 2005 will boost WTP^*. Eq.(4.9) clearly demonstrates that as the population increases, WTP^* increases proportionally. Furthermore, the younger population with a smaller per capita WTP decreases, as shown in Figure 4.3(2), while the older population with a greater WTP increases, causing the balance to shift to a greater WTP^*.

Now, turn to a quantitative analysis of demographic impacts on WTP^*. Specifically, how will WTP^* change if we use 1970, $N_{s,a}^{2005}$, instead of $N_{s,a}^{1970}$, and how do the increase in population and the changes in the age structure between those years contribute to its changes? First, the following must be defined:

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5 Looking at Figure 4.6(1), below the left axis, a bar graph for 2005, and a line graph for 1970, respectively, shows the population pyramid.

$$WTP^* = \sum_s \sum_a WTP_{s,a} \cdot N_{s,a}^{2005} = \sum_s \sum_a WTP_{s,a}\left(\alpha_{s,a}^{2005} \cdot N_{s,\cdot}^{2005}\right) \tag{4.13}$$

$$WTP' \equiv \sum_s \sum_a WTP_{s,a}\left(\alpha_{s,a}^{1970} \cdot N_{s,\cdot}^{2005}\right) \tag{4.14}$$

$$WTP'' \equiv \sum_s \sum_a WTP_{s,a}\left(\alpha_{s,a}^{2005} \cdot N_{s,\cdot}^{1970}\right) \tag{4.15}$$

$$WTP^{1970} \equiv \sum_s \sum_a WTP_{s,a}\left(\alpha_{s,a}^{1970} \cdot N_{s,\cdot}^{1970}\right) \tag{4.16}$$

where $N_{s,\cdot}^{y}$ is the population in year *y* for sex *s* across all age groups. Then, we get the outcome of the population increase (PC) and the change in age structure (AC) from the following, respectively:

$$\Delta \mathrm{WTP} = WTP^* - WTP^{1970} \tag{4.17}$$
$$= (WTP^* - WTP') + WTP' - WTP^{1970} = \mathrm{AC} + WTP' - WTP^{1970} \tag{4.18}$$
$$= (WTP^* - WTP'') + WTP'' - WTP^{1970} = \mathrm{PC} + WTP' - WTP^{1970}. \tag{4.19}$$

The results of the above calculations are shown in Table 4.3, lines (21)-(26) [see Ref. column of the table]. Replacing $N_{s,a}^{1970}$ by $N_{s,a}^{2005}$ decreases the WTP by 1,666 trillion yen or roughly 30 percent. The decrease for females is approximately 20 percent more than that of males: AC has a greater impact on females, whereas there is little difference in PC between males and females. However, note that PC does have a greater overall effect than AC, accounting for two-thirds of ΔWTP for males and 60 percent for females. The total of males and females yields 737 trillion yen for AC and 1,067 trillion yen for PC.

5.1.2 Estimating Future WTP based on a Demographic Projection

Based on the foregoing analysis, we can consider the future trends in WTP^*. It is not an easy task to predict a future path of per capita WTP ($WTP_{s,a}$). However, if we hold it constant and use future demographics, we can get an idea of the general trend.

Because the period in my analysis included the 35 years up to 2005, I now estimate the same analysis for another 35 years, from 2005 to 2040. The following insights are gained from a brief look at the medium case of the demographic projections provided by the National Institute of Population and Social Security Research.

First, the trend toward fewer children and greater aging is likely to increase AC, thereby pushing the entire economy WTP in a positive direction. Second, we can expect the pace of improvements in survival rates to slow down if we look at trends in average life expectancy.[6] Finally, in 2040, the population will decrease to 106 million, on a par with 1970 levels at 104 million people.[7] Therefore, PC will cause the WTP of the entire economy to shrink. Taking into account these conflicting forces, we can expect the WTP in the next 35 years to be less than it was in the past 35 years.

Actually, we estimate the WTP to be 2,048 trillion yen in 2040 (Table 4.3, line 13), which is just over a third of the WTP for the past 35 years. If, instead, we calculate using the 2005 population and age structure, which may be justified if this is regarded as decision as of 2005, the WTP turns out to be 2,300 trillion yen (Table 4.3, line 19), or about 10 percent greater, and still near 40 percent of the 35-year preceding level. The 60 percent decrease reflects a decrease in improvements to survival rates. AC may increase WTP by 7 percent to 2,472 trillion yen, while PC may decrease it by 17 percent to 1,904 trillion yen. The decrease for males will be approximately 2.5 times that for females because, not only is the decrease due to male PC greater than that for females, the increase from AC is less significant than it is for females.

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[6] At age 0, the average life expectancy increases between 1970 and 2005 by 9.25 years for males (=78.56−69.31) and 10.86 years for females (=85.52−74.66), but the corresponding figures from 2005 to 2040 will be 4.15 years (= 82.71−78.56) and 3.91 years (=89.43−85.52), respectively. The same picture is drawn for life expectancy at age 65. From 1970 to 2005, the margin was 5.63 years (= 18.13−12.50) and 7.85 years (=23.19−15.34) for males and females, respectively, which translates in the next 35 years to 3.19 years (=21.32−18.13) and 3.32 years (=26.51−23.19), respectively.

[7] Comparing population estimates as of as of October 1 in various years, as published by Statistics Bureau, Ministry of Internal Affairs and Communications, the population of Japan peaked in 2004. Therefore, in terms of the size of the population, WTP would be greatest in 2005, the year used in this estimate.

5.2 Aspects of Cost-Benefit

5.2.1 Determining Net WTP

Performing a cost-benefit analysis needs to determine cost[8]. Cost refers to the necessary expenditures to improve health conditions *h* by one unit of measure, $dg = g'(h)$. This study has not considered the cost, and therefore, the WTP obtained is in gross terms. However, to think of WTP in net terms, we subtract costs and express it using the two-period model used above:

$$WTP^{*N} = WTP^{*} - dg. \tag{4.17}$$

Cost in the multi-period model is:

$$dg = \sum_{a=0}^{\infty} dg_a \cdot N_a \tag{4.18}$$

$$dg_a \equiv \sum_{t=0}^{\infty} \frac{1}{(1+r)^t} S_{a+t}^2 \cdot d\tilde{g}_{a+t} \ . \tag{4.19}$$

This is the discounted present value of change $d\tilde{g}_a (= \tilde{g}_a^2 - \tilde{g}_a^1)$ in health-related expenditures per age group $\tilde{g}_a$, to get the value with survival rate S^2 after the change.[9]

5.2.2 Estimate

I use the WTP (Case 2, wages including bonuses) in Section 3.2.2 as the benefit to perform a cost-benefit analysis. I use the *National Medical Care Expenditures* published annually by the Ministry of Health, Labor, and Welfare as a major source of information on costs. These expenditures are defined as “all expenditures for treatment

[8] Appendix 4.B explains recent recommendations to improve the SNA. They should make it much easier to implement a cost-benefit analysis at aggregate or semi-aggregate levels, if they are implemented and are combined with appropriate benefit estimates.

[9] Note there is no subscript *s* in the equation, unlike in Section 2. Per capita national medical care expenditures are published for each age group, but not by sex, which disallows the calculation employed for benefit by sex and age group to get a total.

necessary for accident or illness," which leaves out some of the cost for health-care conditions, such as pregnancy or immunizations, thus resulting in a narrower target.[10] In this model, however, with respect to measuring the benefit of increased survival rates, it is possible that our target is too wide if we consider only the costs that directly contribute to the increase in survival rates. We must also be cognizant that introducing a system of long-term care insurance caused a shift in expenditure level in FY 2000.

The National Medical Care Expenditures were 2 trillion yen in 1970 and increased to 33 trillion yen in 2005. To calculate the costs using Eq.(4.21) and (4.22), we need per capita expenditure by age, which the Ministry of Health, Labor, and Welfare has tracked only since 1997. The general medical care expenditures, its largest component, has information on a per capita per age group basis, but unfortunately only after 1977.[11] Table 4.4 summarizes the available data, and I fill in blanks with estimates (shown in *italic*).[12] These estimates in 1970 are used for the cost calculation after being converted to 2005 figures using the consumer price index (total).

(Table 4.4)

Now, let us calculate the costs. The cumulative total for 1970 to 2005 is 548 trillion

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10 National medical care costs include expenditures for medical and dental treatments, pharmacy dispensing expenditures, food and living care expenditures during hospitalization, and home-visit nursing care expenditures, as well as other costs such as transportation for medical purposes covered by health insurance. On the other hand, as they are limited to treatments for diseases and injuries, they exclude the following: (1) costs for normal pregnancies and deliveries; (2) costs for medical check-ups and immunizations to maintain and enhance health; and (3) costs for prosthetic devices for eyes and limbs, etc. required for established physical disabilities. Furthermore, they also exclude extra charges for hospitalization and dentistry, which are not covered by health insurance. The explanation stated above is provided on the website of the Ministry of Health, Labor, and Welfare.

11 The national expenditure for health care in 2005 (¥33.1 trillion) is the total of general medical exam and treatment costs (¥24.9 trillion), dental treatment (¥2.6 trillion), pharmacy dispensing costs (¥4.6 trillion), food and living care expenditures during hospitalization (¥1.0 trillion), and home-visit nursing care (¥0.04 trillion). General medical exam and treatment costs include hospitalizations (¥12.1 trillion) and outpatient care (¥12.8 trillion).

12 Specifically, based on the published 1997 data of national medical care expenditures and general medical care expenditures, both of which are on per capita and age group, I estimated 1990 figures of the former, using the latter's counterparts and other available information in 1990. Once done with the estimates for 1990, based on this result, I applied the same method to obtain the 1977 estimates. For 1970, I estimated expenditures by age group, using the 1977 estimates and less, but still available information in 1970, such as the total amount of national medical expenditures, and total population and its age components.

yen, and 16 trillion yen on an annual basis, as shown in the left columns in Table 4.5. Of the 35 years, the first 20 years annualized are 22 trillion yen, and the next 15 years annualized are 7 trillion yen. Thus, the first period saw costs increase at a rate of almost three times that of the second period. Next, I turn to the benefit. Using the benefit as determined from wages including bonuses, the net benefit, on a cumulative basis from 1970 to 2005, is 5,218 trillion yen, or approximately 90 percent of gross benefit. In other words, the cost-benefit ratio (B/C) is 10.5. The ratio for the 20 years up to 1990 is 8.8, and increases in the following 15 years after 1990 to 17.5.

(Table 4.5)

Murphy and Topel (2003) treat net benefit, WTP^N, as a Solow residual and think it depends on an increase in knowledge regarding health care. They go on to compare it with investments in health-care research and development. In Japan, annual data on investment in research and development are available from the *Survey of Research and Development* by the Ministry of Internal Affairs and Communications, although they are classified into only broadly defined sectors. Just for reference, let us use the total expenditures for research and development. The cumulative sum from 1970 to 2005 (adjusted for inflation and real 3 percent interest rate) was 565 trillion yen, which corresponds to 16 trillion yen per year, or less than 10 percent of WTP^N.

6. Conclusion

In this chapter, I attempted to quantify the value of the decrease in the mortality rate of Japanese citizens from 1970 to 2005 using the WTP in accordance with Murphy and Topel (2003, 2006). The results of these estimates were about 5,800 trillion yen on a cumulative basis for the 35-year period, and 165 trillion yen when annualized as of 2005. Unfortunately, because all the data for sex and age group necessary to perform this estimate were not available in official statistics, I was compelled to make arbitrary assumptions with regard to consumption at young and very old ages. Depending on those assumptions, I indicated that the estimates could be overstated by

20 percent.

The assumptions for the discount rate and utility function parameters (γ homogeneity assumptions) are major factors influencing the results of the estimate. The interest rate is the average real, long-term interest rate of 3 percent, while γ is set at 1/3. However, I observed in Figures 4.3 and 4.4 how WTP changes when $0.01 \le r \le 0.25$, and $0.1 \le \gamma \le 1$. For these reasons, the above results should be interpreted with considerable latitude. I also analyzed the effect of two demographic changes from 1970, the increase in population and its compositional changes, on the results of my estimate. These two factors contributed to an increase in WTP of 30 trillion yen and 20 trillion yen, respectively. Furthermore, based on changes in survival rates projected from 2005 to 2040, given 2005 population figures, WTP is expected to be about 2,300 trillion yen or about 40 percent of WTP for 1970-2005. If we determine WTP based on the population as of 2040, we get 2,048 trillion yen because of the decrease in the population. Although the pace of the decrease in population has somewhat leveled off, baby boomers are now reaching the older age at which per capita WTP becomes higher, so the WTP should continue to rise. One of the current difficulties in containing health-care costs growth is that this drive to actually expand health-care expenditures is becoming more apparent.

In a cost-benefit analysis, with cost as the discounted present value of the increases in health-care expenditures, the cost from 1970 to 2005 is 538 trillion yen, or about one-tenth of the WTP. Although this cost-benefit analysis is very rough, the increase in health-care costs up to now may be reasonable and understandable.

Our estimate of the WTP seems consistent with newly available estimates by UNU-IHDP and UNEP (2012). Their *Inclusive Wealth Report* provided estimates of health capital of Japan for the period 1990 to 2008, based on Arrow *et al*. (2012). Their estimate of change in health capital from 1990 to 2005 is 23 trillion dollars, which is a quarter larger than our estimate, 1,829 trillion yen, assuming 1 dollar is equal to 100 yen. The difference could reflect the fact that the report is based on the concept of health, not just longevity.

Table 4.1 Selected Variables for Each Age Group

	Consumption Expenditure		Hourly Wages				Leisure Time		Stationary Population				Population	
	National Survey on Family Income and Expecditures		Survey of Wage Structure				Survey on Time Use and Leisure Activities		Life Table				Population Census	
	single/all household, 2004 excluding healthcare 2005 prices, monthly, yen		2004 weighted average of general and pert-time workers 2005 prices, yen				2006 Tertiary Activities hour		for minimum age in each age group				2005 for minimum age in each age group (total for age 100 and over)	
	Male	Female	Males		Females		Male	Female	Males		Females		Male	Female
Age Group			regular	incl. overtime and bonus	regular	incl. overtime and bonus			2005	difference from 1970	2005	difference from 1970		
0-4									99,764	1,025	99,800	761	539,668	517,132
5-9									99,581	1,564	99,653	1,179	607,278	575,699
10-14							7.18	6.67	99,517	1,760	99,611	1,300	616,199	588,325
15-19			839	862	799	811	7.15	6.58	99,451	1,912	99,571	1,387	632,362	601,812
20-24			1,116	1,258	1,046	1,188	6.72	5.83	99,258	2,271	99,476	1,519	741,422	701,168
25-29	176,399	169,210	1,405	1,694	1,214	1,461	5.97	5.47	98,943	2,593	99,322	1,709	786,273	760,627
30-34	235,728	229,629	1,687	2,075	1,278	1,534	5.55	5.13	98,599	2,948	99,160	1,960	949,205	924,371
35-39			2,022	2,515	1,280	1,526	5.40	5.15	98,187	3,380	98,940	2,257	945,606	926,907
40-44	252,707	246,593	2,253	2,821	1,230	1,447	5.37	5.25	97,607	4,034	98,628	2,659	882,923	870,861
45-49			2,389	2,985	1,202	1,408	5.55	5.55	96,735	4,877	98,177	3,250	774,589	769,944
50-54	203,622	226,292	2,379	2,959	1,179	1,371	5.80	5.67	95,352	5,933	97,481	4,110	816,353	815,028
55-59			2,297	2,808	1,173	1,356	6.08	6.00	93,183	7,469	96,423	5,406	1,043,747	1,060,582
60-64	193,404	216,658	1,633	1,872	1,047	1,155	7.55	6.73	89,839	9,915	94,914	7,424	718,324	752,586
65-69			1,424	1,579	1,036	1,123	8.73	7.02	85,123	14,119	92,831	10,937	763,350	820,761
70-74	219,215	197,961					9.27	7.47	78,367	20,194	89,664	16,447	667,385	762,627
75-79							9.45	7.83	68,058	26,284	84,396	24,848	511,696	645,035
80-84							9.45	8.43	53,598	29,113	75,746	34,692	339,083	519,961
85-89							9.53	9.22	35,609	24,988	61,193	39,645	160,746	354,088
90-94									17,679	14,687	40,453	32,881	64,379	174,451
95-99									5,628	5,178	18,938	17,324	15,942	59,638
100-									969	941	5,202	5,020	3,760	21,593

Table 4.2 Comparison between Case 1 and Case 2

Trillion yen

			Male	Female	Total
Case 1					
	Regular Wages	total for 1970-2005	3,240	3,228	6,468
		annualized as to 2005	93	92	185
	Incl. overtime and bonus	total for 1970-2005	3,507	3,387	6,894
		annualized as to 2005	100	97	197
Case 2					
	Regular Wages	total for 1970-2005	2,742	2,817	5,559
		annualized as to 2005	78	80	159
	Incl. overtime and bonus	total for 1970-2005	2,889	2,877	5,766
		annualized as to 2005	83	82	165

Table 4.3 Summary and Comparison of Results

trillion yen

Change in survival rate		Population			Male	Female	Total	Reference
First year	Final year	Age structure	Count					
1970	2005	2005	2005	Cumulative	2,889	2,877	5,766	(1)
				Annualized	83	82	165	(2)
1970	1990	2005	2005	Cumulative	2,056	1,881	3,937	(3)
				Annualized	103	94	197	(4)
1990	2005	2005	2005	Cumulative	833	996	1,829	(5)
				Annualized	56	66	122	(6)
1970	2005	1970	2005	Cumulative	2,591	2,438	5,029	(7)
				Annualized	74	70	144	(8)
1970	2005	2005	1970	Cumulative	2,371	2,328	4,699	(9)
				Annualized	68	67	134	(10)
1970	2005	1970	1970	Cumulative	2,126	1,974	4,100	(11)
				Annualized	61	56	117	(12)
2005	2040	2040	2040	Cumulative	1,112	936	2,048	(13)
				Annualized	32	27	59	(14)
2005	2040	2005	2040	Cumulative	1,051	853	1,904	(15)
				Annualized	30	24	54	(16)
2005	2040	2040	2005	Cumulative	1,367	1,105	2,472	(17)
				Annualized	39	32	71	(18)
2005	2040	2005	2005	Cumulative	1,293	1,007	2,300	(19)
				Annualized	37	29	66	(20)

Demographic breakdown

Target period		Effect		Male	Female	Total	Reference
First year	Final year						
1970	2005	Change	Cumulative	763	903	1,666	(21) =(1)-(11)
			Annualized	22	26	48	(22) =(2)-(12)
		Age Comp. (AC)	Cumulative	298	439	737	(23) =(1)-(7)
			Annualized	9	13	21	(24) =(2)-(8)
		Pop. Comp. (PC)	Cumulative	518	549	1,067	(25) =(1)-(9)
			Annualized	15	16	30	(26) =(2)-(10)
2005	2040	Change	Cumulative	-181	-71	-252	(27) =(13)-(19)
			Annualized	-5	-2	-7	(28) =(14)-(20)
		Age Comp. (AC)	Cumulative	74	98	172	(29) =(17)-(19)
			Annualized	2	3	5	(30) =(18)-(20)
		Pop. Comp. (PC)	Cumulative	-242	-154	-396	(31) =(15)-(19)
			Annualized	-7	-4	-11	(32) =(16)-(20)

Note: This table is for Table 2 Case 2 （incl. bonus).

Table 4.4 Trends in per Capita National Medical Care Expenditures by Age

Age group	2005	1997	1990	1977	1970
	Fiscal year				
	National medical care expenditures (A), ¥1,000				
0 － 14	129.5	93.3	*58.6*	*30.2*	*10.2*
15 － 44	103.5	94.5	*82.1*	*55.2*	*18.6*
45 － 64	250.9	245.2	*205.4*	*108.7*	*36.6*
65 － 69	444.8	453.9	*368.3*	*172.3*	*58.1*
70 and over	742.3	802.0	*655.0*	*272.3*	*91.8*
average	259.3	229.2	*166.7*	*75.1*	*24.1*
（ref） total （trillion yen）	33.1	28.9	20.6	8.6	2.5
	General medical care expenditures (B), ¥1,000				
0 － 14	94.2	74.4	51.4	27.7	
15 － 44	71.6	70.2	67.1	47.1	
45 － 64	183.7	195.4	180.2	99.5	
65 － 69	332.6	377.3	336.9	164.5	
70 and over	595.6	650.4	584.4	253.6	
average	196.2	182.6	145.4	67.6	
（ref） total （trillion yen）	25.0	23.0	18.0	7.7	
	ratio (=B/A), per cent				
0 － 14	72.7	79.7	87.7	91.6	
15 － 44	69.2	74.3	81.7	85.3	
45 － 64	73.2	79.7	87.7	91.6	
65 － 69	74.8	83.1	91.5	95.5	
70 and over	80.2	81.1	89.2	93.2	
average	75.6	79.7	87.2	90.0	

Note: Figures in *italics* are author's estiates.

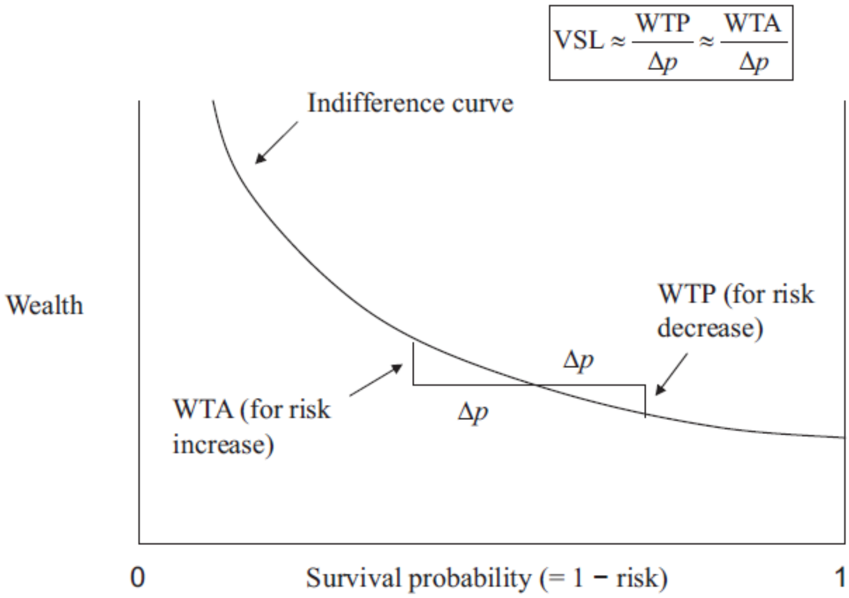
Table 4.5 Results from Estimating Cost and Benefit

trillion yen

Period		Cost (C)	Benefit (B)	Net Benefit (=C-B)
1970-2005	Cumulative	548	5,766	5,218
	Annualized	16	165	149
1970-1990	Cumulative	449	3,937	3,488
	Annualized	22	197	174
1990-2005	Cumulative	99	1,829	1,730
	Annualized	7	122	115

Note: Costs are the same for Table III, Line 1-6.

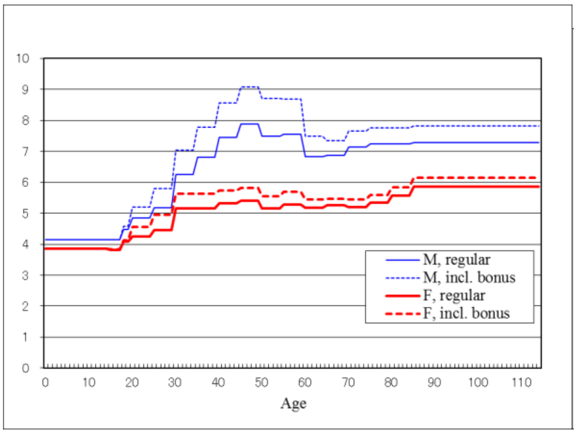
Figure 4.1 WTP and SVL



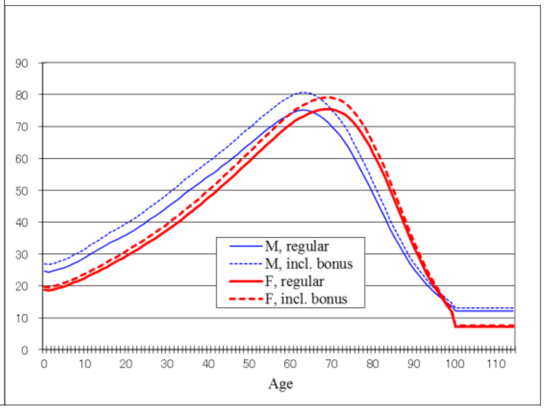
(source) Cropper *et al*. (2011) Figure 1.

Figure 4.2 Results of Case 1

(1) Full Consumption (million yen)



(2) Per Capita WTP (million yen)



(3) WTP for the Entire Economy (million yen)

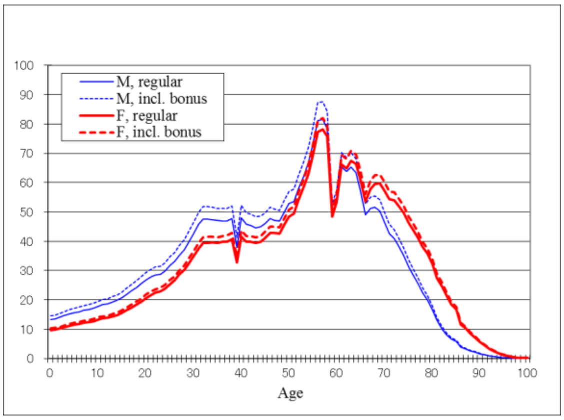
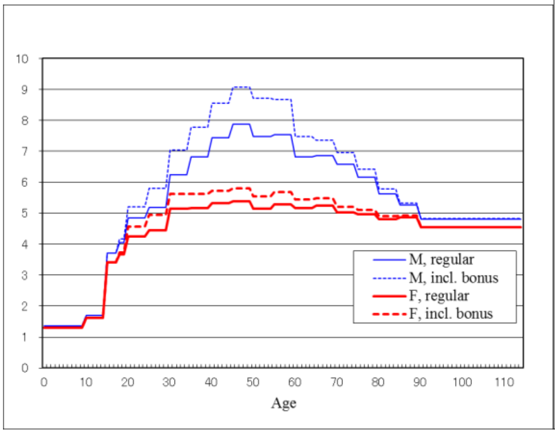
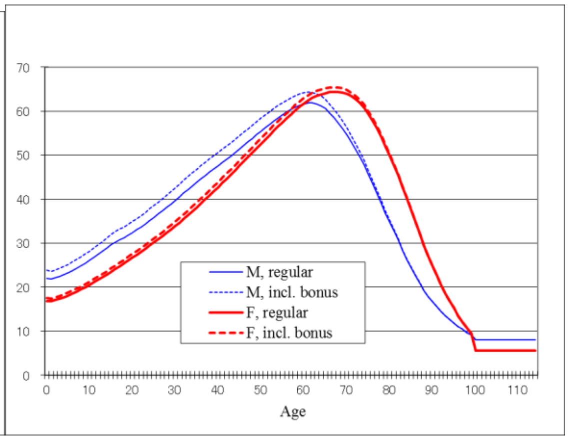


Figure 4.3 Results of Case 2

(1) Full Consumption (million yen)



(2) Per Capita WTP (million yen)



(3) WTP for the Entire Economy (million yen)

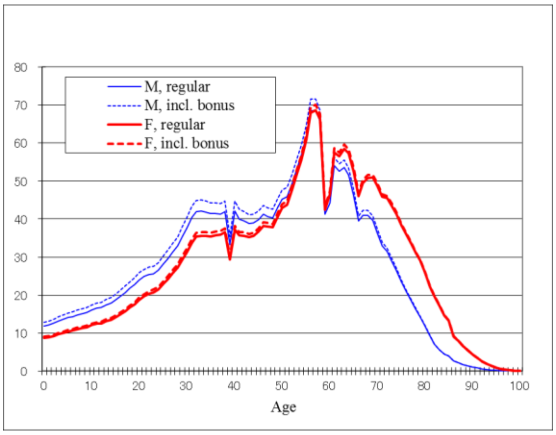


Figure 4.4 Combination of (r, γ) and WTP*

(annualized, trillion yen)

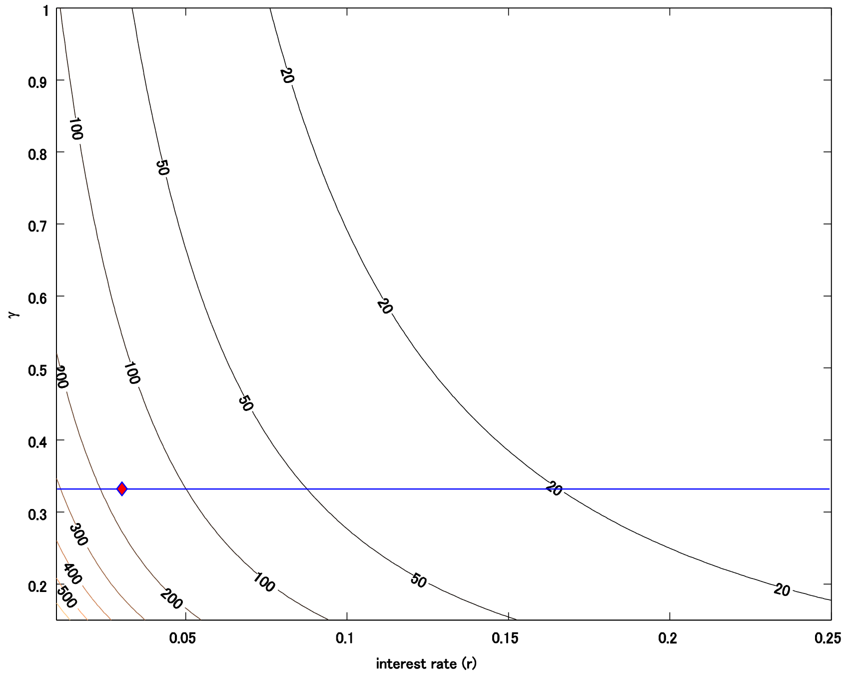


Figure 4.5 WTP* as a Function of r (given γ = 1/3 and 1)

(annualized, trillion yen)

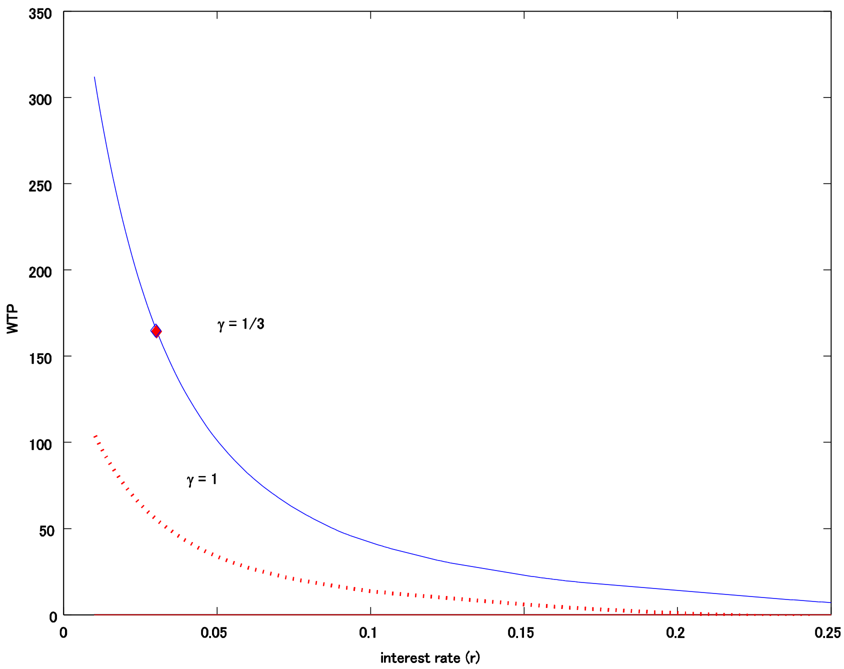
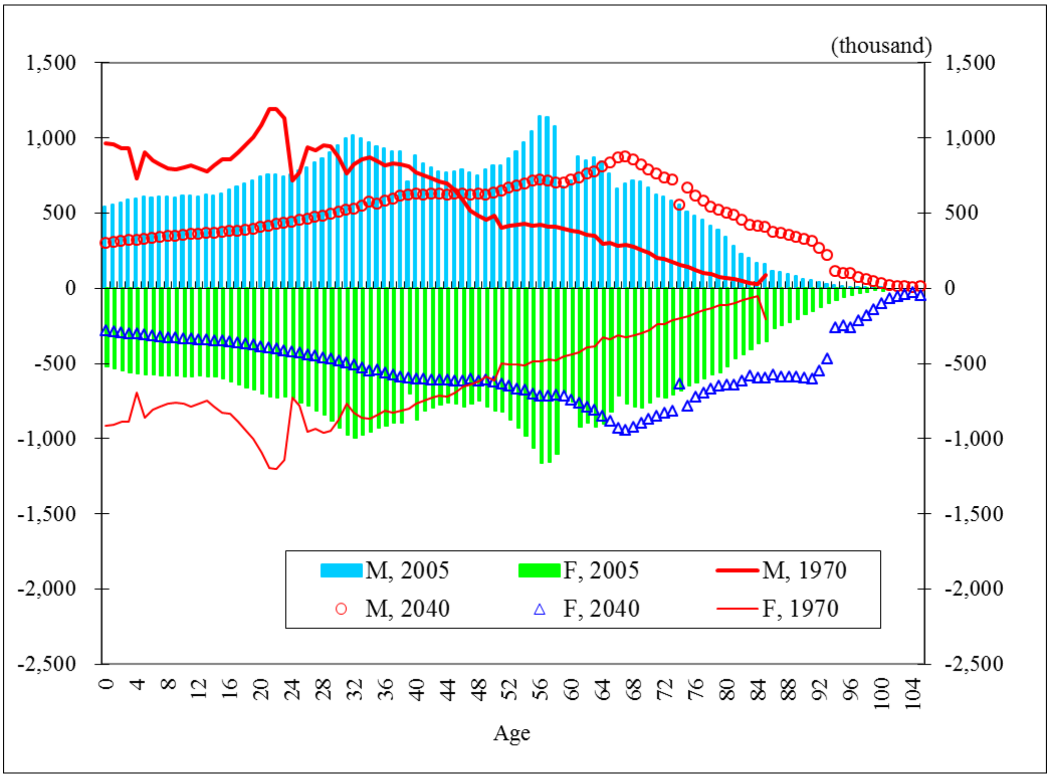
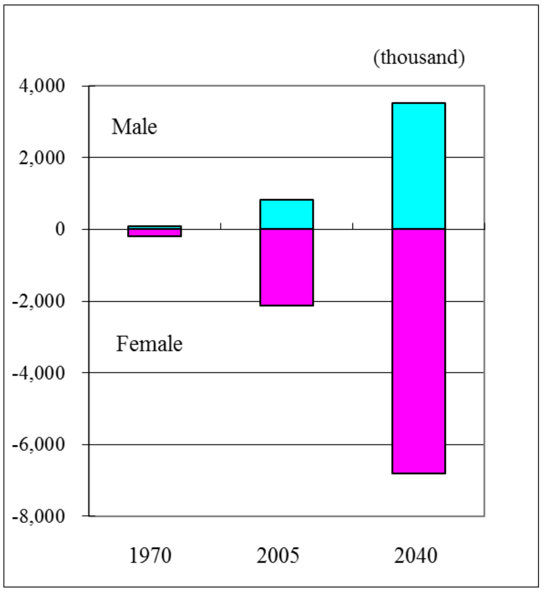


Figure 4.6 Population in 1970, 2005, and 2040.

(1) Male and Female Population by Age



(2) Population aged 85 and over by sex



Appendix 4.A Details of Data Used

This appendix will explain how to calculate the variables in Section 3.1.

I selected 3 percent for the discount interest rate used in the data, considering the average real, long-term interest rate after the 1990s. However, to obtain the expected rate of inflation in order to calculate the real interest rate, I used the actual consumer price index (excluding perishable food) from the previous year.

The survival rate is determined from stationary population S according to the sex and age bracket from the life table published by the Ministry of Health, Labor, and Welfare. S^1 comes from the Twentieth Life Table (2005), while S^2 comes from the Thirteenth Life Table (1970).

Goods and services x_t is the sum of expenditures (excluding health care costs) by sex, broken down in 10-year age brackets, and imputed rent, both of which are taken from the *National Survey of Family Income and Expenditure* (2004) published by the Ministry of Internal Affairs and Communications. I expressed these expenditures in the 2005 prices, using the consumer price index. Since it is difficult to determine the expenditure pattern over the life cycle in households with multiple members, I used data for single-person households. Furthermore, I add imputed rent to eliminate the differences that arise from living circumstances where homes are either owned or rented.

Data for wages w_t come from hourly wages divided according to company size (more than 10 people and five to nine people) for general and part-time workers in each age bracket, by sex, compiled by the Ministry of Health, Labor, and Welfare's *Survey of Wage Structure* (2004). I then calculated their weighted average for the number of workers. The data for wages was divided into two groups: (1) regular wages and (2) nonregular wages, that is, wages including overtime payments and bonuses. I then converted these numbers in terms of 2005 price levels using the consumer price index.

Leisure time l_t was derived from total average time for tertiary activities, by age bracket and by sex, compiled by the Ministry of Internal Affairs and Communications, *Survey on Time Use and Leisure Activities* (2006). Tertiary activities include time devoted to transportation other than to work or school; watching television, listening to the radio, reading the newspaper, and other such relaxation; study time other than at school; and time devoted to hobbies or entertainment and sports; and volunteer activities and other social activities, meetings, health care, and so on.

Population N_t, is the population according to one-year age brackets for each sex compiled by the Ministry of Internal Affairs and Communications in the *National Census* (2005). However, the only statistic available for persons older than 100 is the total population older than 100, by sex.

Appendix 4.B Output, Outcome, and Cost-Benefit Analysis in SNA[13]

This appendix surveys measurement issues of the non-market sector in SNA and shows how useful a recommendation in the 2008 revision of the SNA is in implementing a cost-benefit analysis at aggregate or semi-aggregate levels, showing a US trial as an example of an advanced approach.

B.1 Overview

In market sectors, prices reflect social evaluations. Their unavailability makes it difficult for us to evaluate performance of non-market sectors. Output and outcome can be different in non-market sectors, but the same in the market sectors. Concepts and measurements of these two, as well as inputs, can be organized as shown in Figure 4.B.1.

(Figure 4.B.1)

One can measure inputs in a usual manner, but may have to measure outputs by counting the number of operations, outpatients, and so on. If one wants to take into account quality changes, counting may have to be conducted on a category basis, say, operation by disease. Furthermore, an outcome could be measured by improvements in health conditions, such as the number of permanent cures. An outcome is likely to be affected by many socio-economic factors, such as age, sex, education, and so on. Note that the SNA measures output, or quality adjusted output, if possible, but not an outcome, even in the latest version called 2008SNA.

However, measuring an outcome is sometimes essential, for example, in judging the effectiveness of policy interventions, however difficult it is. In the context of this Chapter, even if one can measure the benefit of decline in mortality rate, it is very difficult to define what the corresponding costs are because, as stated above, the outcome is likely to be subject to many factors: advances in medical science, prevailing existing knowledge of medicine, improvements in dietary and/or sanitary

[13] This appendix is based on Kawagoe and Suzuki (2016).

conditions, and so on.

A breakdown of medical expenditures by disease could be of great help to cost-benefit analyses on a semi-macro basis, and is proposed in recommendations to upgrade the SNA to the 2008 version. To be specific, the 2008 SNA manual recommended compiling several satellites, one of which was the Health Satellite Account (HSA). The OECD encourages its member countries to improve their accounting by compiling a handbook of education and health care (Schreyer, 2010).

An innovation is to measure medical expenditure on a disease basis. The OECD handbook defines the health care as "treatment of a disease or medical services to prevent a disease", and its measurement unit as a completion of the treatment (para. 4.9.). Consequently, the "price" should be the unit price of the treatment. Furthermore, the unit price has been easily observed by statisticians as more countries introduce the DRG (Diagnosis Related Groups) into their health-care systems.

Diewert (2011) argued there are three ways to aggregate various prices of goods and services into a single price. The first best is, obviously, to utilize market prices. When this option is unavailable, for example, in non-market sectors, one has to rely on the second best option to use unit production costs of output producers. Unfortunately, when the second option is not still available, one should depend on input price information as the third best option. Remember a certain level productivity is implicitly assumed here because the same price is utilized in calculating input and output quantities. Thus, the innovation brought about by the introduction of the DRG enables one to use the second best options rather than the third.

However, it is noteworthy that there is a certain limit to this approach. Although the measurement unit is completion of the treatment, there may be many cases where it is difficult to judge whether the treatments have been completed or not. As some advocate a shift from "cure" to "care," such cases are likely to increase. Hence, it may be increasingly difficult to define the measurement unit, thereby undermining the validity of this approach.

B.2 BEA's Trial Calculation

The United States has begun to compile the HSA. In January, 2015, the Bureau of Economic Analysis published a trial calculation of the HSA (Table 4.B.1), which provides a macro picture of disease-based expenditures, following the ICD (International Classification of Diseases) of the WHO (Dunn, Rittmueller, and Whitmire, 2015).

(Table 4.B.1)

The merits of the HSA are more visible if it is combined with information from the Global Burden of Disease project by WHO. Because the project showed benefits of medical interventions as results of calculating DALY (disability-adjusted life year), the combination of the two allows one to implement a new cost-benefit analysis, as in Highfill and Bernstein (2014). They set costs equal to changes in medical expenditures from 1987 to 2010, and regarded benefits as reductions of DALY during the period[14], both on a disease basis, thereby calculating the difference between the two as net benefits (Table A.2). Given that there have been many cost-benefit analyses of individual diseases, and that the project of the WHO has been conducted since 1990, the innovation this time is to make it possible to conduct a broad range of cost-benefit analyses covering all medical expenditure in a way that makes it easy to draw implications for resource allocations on a disease basis. Reservations are required in interpreting the results of Table 4.B.2. For example, a large positive value of net benefits in the first row is likely to reflect permeating smoking abstinence as well as advance in lung cancer treatments.

(Table 4.B.2)

[14] Strictly speaking, the value in 1990 rather than that in 1987 was used in the calculation because the latter was not available.

Table 4.B.1 BEA's Trial Calculation of HSA

(1)NIPA and HAS (2010, billion dollars)

	NIPA	HAS
Health, Total	2080.4	2080.4
Serivice		
medical services by disease		1722.4
phisician services	*402.8*	
paramedical services	*260.6*	
hospitals	*770.5*	
nursing homes	152.3	152.3
dental services	104.5	104.5
Goods		
pharmaceutical products	330.1	
prescription drugs	*288.5*	
Nonprescription drugs	41.7	41.7
other medical products	4.0	4.0
therapeutic appliances and equipment	55.6	55.6

(Note) "medical services by disease" is equal to the sum of underlined items.

(2) Desease-based Details

Infectious and parasitic diseases	58.2
Neoplasms	116.1
Endocrine; nutritional; and metabolic diseases and immunity disorders	125.6
Mental illness	79.1
Diseases of the nervous system and sense organs	119.6
Diseases of the circulatory system	234.5
Diseases of the respiratory system	143.9
Diseases of the digestive system	101.6
Diseases of the genitourinary system	111.0
Complications of pregnancy; childbirth; and the puerperium	38.2
Diseases of the skin and subcutaneous organs	38.3
Diseases of the musculoskeletal system and connective tissue	169.9
Injury and poisoning	109.8
Symptoms; signs; and ill-defined conditions	206.9
Other	69.9
Diseases of the blood and blood-forming organs	20.9
Congenital anomalies	7.6
Certain conditions originating in the perinatal period	6.7
Residual codes; unclassified; all E codes	34.6
Total	1722.4

(source) Author's calculation based on Dunn, Rittmueller, and Whitmire (2015) Table 2 and 3.

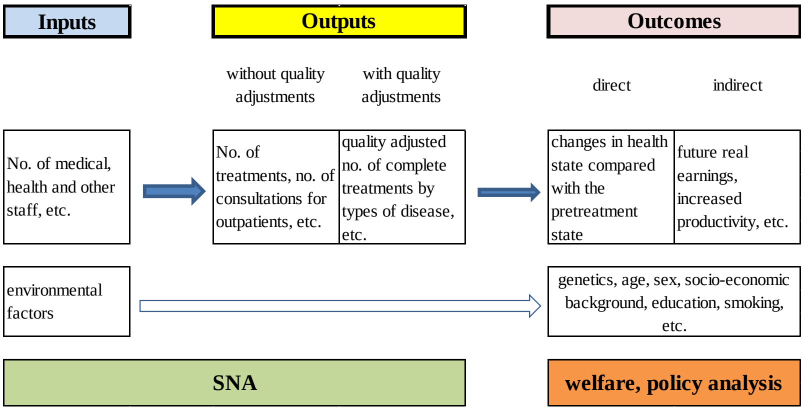
Table 4.B.2 Disease-based Cost-benefit Analysis (1987 to 2010)

	Condition	change in per-patient spending (a)	change in health outcome (b)	net value (=b-a)
1	Trachea, bronchus, and lung cancers	2,423	153,137	150,714
2	Ischemic heart disease	-1,018	36,622	37,640
3	Colon and rectum cancers	-884	32,064	32,948
4	Prostate cancer	-2,962	16,860	19,822
5	Breast cancer	-926	11,104	12,030
6	Non-melanoma skin cancer	189	3,885	3,696
7	Benign prostatic hyperplasia	-1,438	-10	1,428
8	Rheumatoid arthritis	-796	244	1,040
9	Glaucoma	472	1,461	989
10	Peptic ulcer disease	-23	652	675
11	Cataracts	-415	7	422
12	Osteoarthritis	-410	-3	407
13	Asthma	104	311	207
14	Refraction and accommodation disorders	149	324	175
15	Epilepsy	710	826	116
16	Gout	-1	3	4
17	Eczema	92	6	-86
18	Dental caries	98	-1	-99
19	Fungal skin diseases	135	1	-134
20	Pruritus	268	2	-266
21	Diabetes mellitus	-98	-400	-302
22	Urticaria	494	7	-487
23	Endometriosis	524	-12	-536
24	Chronic obstructive pulmonary disease	533	-71	-604
25	Psoriasis	967	3	-964
26	Periodontal disease	1,382	2	-1,380
27	Gastritis and duodenitis	24	-1,788	-1,812
28	Non-infective inflammatory bowel disease	3,255	-1,651	-4,906
29	Parkinson's disease	2,059	-12,694	-14,753
30	Alzheimer's disease and other dementias	598	-14,525	-15,123
	All Causes (Average Per-Patient Spending)	554	2,406	1,852

Notes: In 2009 US dollar prices (PCE deflator). Monetized value of healthy life year set equal to 100,000 dollars.

(source) Author’s calculation based on Highfill and Bernstein (2014) Table 1and 2.

Figure 4.B.1 Inputs, Outputs, and Outcome of Health Care Sector



(source) a simplified version of Schreyer (2010) Figure 4.1.

Reference

Chapter 1

Barro, Robert J. and Xavier Sala-i-Martin (1992) "Regional Growth and Migration: A Japan-United States Comparison," *Journal of Japanese and International Economies*, 6:312-346.

Coyle, Diane (2014) *GDP: A Breif but Affectionate History*. Princeton University Press.

Decressin, Jörg and Antonio Fátas (1995) "Regional Labor Market Dynamics in Europe," *European Economic Review*, 39: 1627-1655.

Fogel, Robert W. (1994) "Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy," *American Economic Review*, 84:369-395.

Friedman, Milton and Anna Jacobson Schwartz (1963) *A Monetary History of the United States, 1967-1960*. Princeton University Press.

Gilbert, Christopher (1986) "Professor Hendry's Econometric Methodology," *Oxford Bulletin of Economics and Statistics*, 48: 283-307.

Hendry, David (1993) *Econometrics: Alchemy or Science*. Blackwell.

Murphy, K. M., and R. H. Topel. (2003) "The Economic Value of Medical Research," in K. M. Murphy and R. H. Topel ed. *Measuring the Gains from Medical Research: An Economic Approach*, 41-73. Chicago: University of Chicago Press.

Murphy, K. M., and R. H. Topel. (2006) "The Value of Health and Longevity," *Journal of Political Economy*, 114: 871-904.

Stuckler, David and Sanjay Basu (2014) *The Body Economic: Why Austerity Kills*, HarperCollins Publishers.

UNU-IHDP and UNEP (2012) *Inclusive Wealth Report 201: Measuring Progress toward Sustainability*. Cambridge: Cambridge University Press.

Chapter 2

Azariadis, Costas, and Allan Drazen (1990) “Threshold Externalities in Economic Development,” *Quarterly Journal of Economics*, 105: 501-526.

Barro, Robert J. and Xavier Sala-i-Martin (1992a) "Convergence," *Journal of Political Economy*, 100:223-251.

Barro, Robert J. and Xavier Sala-i-Martin (1992b) "Regional Growth and Migration: A Japan-United States Comparison,” *Journal of Japanese and International Economies*, 6:312-346.

Barro, Robert, Gregory Mankiw, and Xavier Sala-i-Martin (1995) “Capital Mobility in Neoclassical Models of Growth,” *American Economic Review*, 85: 103-115.

Bernard, Andrew B. and Durlauf, Steven N. (1995) “Convergence in International Output,” *Journal of Applied Econometrics*, 10:97-108.

Bernard, Andrew B. and Durlauf, Steven N. (1996) “Interpreting Tests of the Convergence Hypothesis,” *Journal of Econometrics*, 71:161-173.

Blanchard, Olivier Jean and Lawrence Katz (1992) “Regional Evolutions,” *Brooking Papers on Economic Activities*, 1: 1-75.

Breinlich, Holger, Gianmarco Ottaviano, and Jonathan R.W. Temple (2014) “Regional Growth and Regional Decline” in Philippe Aghion and Steven Durlauf ed. *Handbook of Economic Growth*, vol.2. pp. 683-779 Elsevier.

Dao, Mai and Furceri, Davide and Loungani, Prakash, (2014) “Regional Labor Market Adjustments in the United States and Europe,” *IMF Working Paper* No. 14/26.

Decressin, Jörg and Antonio Fátas (1995) “Regional Labor Market Dynamics in Europe,” *European Economic Review*, 39: 1627-1655.

Durlauf, Steven, Andros Kourtellos, and Artur Minkin (2001) “The Local Solow Growth Model,” *European Economic Review*, 45: 928-940.

Durlauf, Steven, Paul Johnson, and Jonathan Temple (2005) “Growth Econometrics,” in Philippe Aghion and Steven Durlauf ed., *Handbook of Economic Growth*, Vol.1 Elsevier. pp. 555-677.

Durlauf, Steven, Paul Johnson, and Jonathan Temple (2009) “The Econometrics of

Convergence” in Terence C. Mills and Kerry Patterson ed. *Palgrave Handbook of Econometrics*, Palgrave Macmillan, pp 1087-1118.

Durlauf, S.and Danny Quah (1999) “The New Empirics of Economic Growth,” in J. Taylor and M. Woodford ed., *Handbook of Macroeconomics*. North-Holland. pp. 235-308.

Fátas, Antonio (2000) “Intranational Labor Migration, Business Cycles, and Growth,” in Gregory D. Hess and Eric van Wincoop. ed. *Intranational Macroeconomics*, University of Chicago Press. pp. 156-186.

Friedman, Milton (1992) “Do Old Fallacies Ever Die?” *Journal of Economic Literature*, 30: 2129-2132.

Galor, Oded (1996) “Convergence? Inferences from Theoretical Models,” *Economic Journal*, 106: 1056-1069.

Geweke, John, Robert C. Marshall and Gary A. Zarkin (1986) “Mobility Indices in Continuous time Markov Chains,” *Econometrica*, 54:1407-1423.

Hayashi, Fumio (1982) “Tobin’s Marginal Q and Average Q: A Neoclassical Interpretation,” *Econometrica*, 50: 213-24.

Jimeno, Juan F. and Bentolila, Samuel (1995) “Regional Unemployment Persistence (Spain, 1976-94),” *Labor Economics*, 5:25-51.

Johnson, Paul A. (2000) “A Nonparametric Analysis of Income Convergence across the US States,” *Economics Letters*, 69: 219-223.

Johnson, Paul A. (2005) “A Continuous State Space Approach to “Convergence by Parts”,” *Economics Letters*, 86: 317-321.

Kakamu, Wago, and Otsuka (2011) “Regional Income Distribution and Convergence Hypothesis,” *Japan Statistics Society Journal*, 41: 181-200 (in Japanese).

Kwiatkowski D., P. C. Phillips, P. Schmidt, and Y. Shin (1992) “Testing the Null Hypothesis of Stationarity against the Alternative of a Unit Root,” *Journal of Econometrics*, 54:159-178.

Lee, Kevin, M. Hashem Pesaran, and Ron Smith (1997) “Growth and Convergence in a Multi-country Empirical Stochastic Solow Model,” *Journal of Applied Econometrics*, 12: 357–392.

Lucas, Robert E. Jr. (1990) “Why Doesn't Capital Flow from Rich to Poor Countries?” *American Economic Review*, 80: 92-96.

Magrini, Stefano (2004) “Regional (Di)convergence,” in J. V. Henderson and J. F. Thisse ed., *Handbook of Regional and Urban Economics*, vol.4, Elsevier. pp. 2741-2796.

McCallum, J. C. P. (1995) “National Borders Matter: Canada-U.S. Regional Trade Patterns,” *American Economic Review*, 85: 615-623.

Quah, Danny (1992) “International Patterns of Growth:II. Persistence, Path Dependence, and Sustained Take-Off in Growth Transition,” Working Paper LSE.

Quah, Danny (1993a) “Empirical Cross-Section Dynamics in Economic Growth,” *European Economic Review*, 37:426-434.

Quah, Danny (1993b) “Galton's Fallacy and Tests of Convergence Hypothesis,” *Scandinavian Journal of Economics*, 95:427-443.

Quah, Danny (1994) “One Business Cycle and One Trend from (Many,) Many Disaggregates,” *European Economic Review*, 38:605-613.

Quah, Danny (1996) “Empirics for Economic Growth and Convergence,” *European Economic Review*, 40:1353-1375.

Quah, Danny (1997) “Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs,” *Journal of Economic Growth*, 2:27-59.

Rappaport, Jordan, (2005) “How Does Labor Mobility Affect Income Convergence?” *Journal of Economic Dynamics and Control*, 29: 567-581.

Rey, Sergio J. and Brett D. Montouri (1999) “US Regional Income Convergence: A Spatial Econometric Perspective,” *Regional Studies*, 33: 143-156.

Sala-i-Martin X. (1996) “Regional Cohesion: Evidence and Theories of Regional Growth and Convergence,” *European Economic Review*, 40:1325-1352.

Sala-i-Martin, Xavier (1997) “I Just Ran Two Million Regressions,” *American Economic Review*, 87(2): 178-183.

Schluter, Christian (1998) “Statistical Inference with mobility Indices,” *Economics Letters*, 59:157-162.

Shorrocks, A.F. (1978) “The Measurement of Mobility,” *Econometrica*, 46:1013-1024.

Smith, Ron P. and Ana-Maria Fuertes (2004) *Panel Time-Series*. mimeo.

Seya, Hajime, Morito Tsutsumi, and Yoshiki Yamagata (2012) "Income convergence in Japan: A Bayesian Spatial Durbin Model Approach," *Economic Modelling*, 29:60-71.

Shibamoto, Masahiko, Yoshiro Tsutsui, and Chisako Yamane (2011) "Understanding Regional Growth Dynamics in Japan: Panel Cointegration Approach utilizing the PANIC Method," DP-243 RIEB Kobe University.

Togo, Ken (2002) "Productivity Convergence in Japan's Manufacturing Industries," *Economics Letters*, 75: 61-67.

Tokui, Makino, Fukao, Miyagawa, Arai, Inui, Kawasaki, Kodama, Noguchi (2013) "Creating Industrial Productivity Database and Analyzing Regional Productivity Disparity," RIETI 13-J-037.

Chapter 3

Anselin, Luc (2001) "Spatial Econometrics," in Badi H. Baltagi. ed. *A Companion to Theoretical Econometrics*. Oxford, UK: Blackwell Publishers. pp. 310-330.

Asaba, Shigeru (2002) *Competition Principles of Japanese Firms: Empirical Studies of Behavioral Similarity*, Toyo Keizai Shinpo-sha (in Japanese).

Aten, Bettina (1996) "Evidence of Spatial Autocorrelation in International Prices," *Review of Income and Wealth*, 42:149-163.

Bikhchandani, Sushil, David Hirshleifer and Ivo Welch (1998) "Learning from the Behavior of Others: Conformity, Fads, and Informational Cascades," *Journal of Economic Perspectives*, 12:151-170.

Çelen, Boğaçhan, and Shachar Kariv (2004) "Distinguishing Informational Cascades from Herd Behavior in the Laboratory," *American Economic Review*, 94: 484-498.

Chamley, Christophe P. (2004) *Rational Herds: Economic Models of Social Learning*, Cambridge University Press.

Florax, Raymond J.G.M., Hendrik Folmer, and Sergio J. Rey (2003) "Specification Searches in Spatial Econometrics: the Relevance of Hendry's Methodology," *Regional Science and Urban Economics*, 33:149-163.

Florax, Raymond J.G.M., Hendrik Folmer, and Sergio J. Rey (2006) "A Comment on Specification Searches in Spatial Econometrics: the Relevance of Hendry's Methodology: a Reply," *Regional Science and Urban Economics*, 36:300-308.

Hendry, David F. (2006) "A Comment on "Specification Searches in Spatial Econometrics: the Relevance of Hendry's Methodology," *Regional Science and Urban Economics*. 36:309-312.

Hirshleifer, David and Siew Hong Teoh (2008) "Thought and Behavior Contagion in Capital Markets," Thorsten Hens and Klaus Reiner Schenk-Hoppé ed. *Handbook of Financial Markets: Dynamics and Evolution*, North-Holland/Elsevier.

Hirshleifer, David and Siew Hong Teoh (2003) "Herd Behaviour and Cascading in Capital Markets: A Review and Synthesis," *European Financial Management*, 9: 25-66.

Hisa, Shoichi (2007) "Instability of Japanese Firms' Investment Behaviors and Its Determinants" Nihon Keizai Kenkyu, 57:1-22 (in Japanese).

JCER (2005) *The 32nd Medium-term Forecast of the Japanese Economy FY2005 - 2015 Longer Work, Global Division Of Labor: A Key To Growth*. (research director: Masaaki Kawagoe) (in Japanese).

Kawagoe, Masaaki and Katsuyoshi Honjo (2008) "Does Herding Mentality Affect Weighting Allowance Rates Set by Municipal Governments? A Special Econometric Approach," *Policy Analysis Quarterly*, 3:3-14. Network for Policy Analysis (in Japanese).

Kawagoe, Masaaki and Katsuyoshi Honjo (2006) "How Does Fiscal Discipline Work in Local Governments? An Empirical Study of Weighting Allowance Rates," *ESP*, No.412 pp.332-336 (in Japanese).

Lakonishok, Josef, Andrei Shleifer, and Robert W Vishny (1992) "The Impact of Institutional Trading on Stock Prices," *Journal of Financial Economics*, 32:23-43.

LeSage, James P. and R. Kelly Pace (2009) *Introduction to Spatial Econometrics*, CRC Press.

LeSage, James P. and Olivier Parent (2006) "Bayesian Model Comparison and Model Averaging," mimeo. University of Toledo.

LeSage, James P. (2004) “Maximum Likelihood Estimation of Spatial Regression Models,” mimeo. University of Toledo.

LeSage, James P. (2005a) “Bayesian Estimation of Spatial Regression Models,” mimeo. University of Toledo.

LeSage, James P. (2005b) “Spatial Econometrics,” in Kimberly Kempf-Leonard. ed. *Encyclopedia of Social Measurement*, vol.3. Amsterdam, Netherlands: Elsevier Inc. pp. 613-619.

Lieberman, M. B., and Shigeru Asaba (2006) “Why do firms imitate each other?” *Academy of Management Review*, 31: 366-385.

Ministry of General Affairs (2006) *Report of the Study Group on Local Government Officials' Pay*, March (in Japanese).

National Personnel Authority (2003) *Basic Report of the Study Group on Pays of Central Government Officials Working in Various Regions*, July (in Japanese)

Ohta, Soichi (2013) “Determinants of Local Government Officials' Pay,” *Japanese Journal of Labor Studies*, 637: 20-32. (in Japanese)

Okunuki, Keiichi (2005) “Obtaining GIS and Database” Murayama Yuji ed. *Geographic Information System*, pp.55-84. Asakura Shoten (in Japanese)

Tanaka, Hiroki (2013) *Economic Analysis of Policy Competition among Local Governments in Japan*, Keiso Shobo (in Japanese).

Uemura, Junzo (2005) “Hidden Unjustifiable Salary: A Study of Local Government Employees' Salary,” *JCER PAPER*. No. 76. (in Japanese)

Uchida, Hirofumi and Ryuichi Nakagawa (2007) "Herd Behavior in the Japanese Loan Market: Evidence from Bank Panel Data,” *Journal of Financial Intermediation*, 16:555-583.

Chapter 4

Arrow, K.J., Dasgupta, P., Goulder, L.H., Mumford, K.J. and Oleson, K. (2012). “Sustainability and the Measurement of Wealth,” *Environment and Development Economics*, 17: 317-353.

Arrow, K.J., Dasgupta, P., Goulder, L.H., Mumford, K.J. and Oleson, K. (2013). “Sustainability and the Measurement of Wealth: Further Reflections,” *Environment and Development Economics*, 18: 504-516.

Arrow, Kenneth, Partha Dasgupta and Kevin Mumford (2014) “Health Capital,” in UNU-IHDP and UNEP. *Inclusive Wealth Report 2014: Measuring Progress toward Sustainability*. Cambridge: Cambridge University Press.

Ashenfelter, Orley (2006) “Measuring the Value of a Statistical Life: Problems and Prospects,” *Economic Journal*, 116: C10-C23.

Becker, G. (2007) “Health as Human Capital: Synthesis and Extensions,” *Oxford Economic Papers*, 59: 379-410.

Cropper, Maureen, James K. Hammitt, and Lisa A. Robinson (2011) “Valuing Mortality Risk Reductions: Progress and Challenges,” *Annual Review of Resource Economics*, 3:313-36.

Cutler, D., and E. Richardson. (1998) “The Value of Health: 1970-1990,” *American Economic Review*, 88: 97-100.

Cutler, D., and E. Richardson. (1999) “Your Money and Your Life: The Value of Health and What Affects It,” in Alan Garber, ed. *Frontiers in Health Research*, 41-73. Cambridge, MA: MIT Press.

Diewert, W. Erwin (2011) “Measuring productivity in the public sector: some conceptual problems,” *Journal of Productivity Analysis*, Springer, 36: 177-191, October.

Dunn, Abe, Lindsey Rittmueller, and Bryn Whitmire (2015) “Introducing the New BEA Health Care Satellite Account,” *Survey of Current Business*, January.

Fogel, Robert W. (1994) “Economic Growth, Population Theory, and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy,” *American Economic Review*, 84:369-395.

Fukui, T., and Y. Iwamoto. (2004) “Medical Spending and the Health Outcome of the Japanese Population, 2002-03,” Collaboration projects organized by the Economic and Social Research Institute, Cabinet Office, Japanese Government.

Furukawa, J., and H. Isozaki. (2004) “The Value of Statistical Life and Evaluating

Regulation and Policy," *Nihon Hyouka Kenkyu* 4: 53-65. (in Japanese).

Grossman, M. (1972) *The Demand for Health: A Theoretical and Empirical Investigation*. New York: National Bureau of Economic Research.

Highfill, Tina and Elizabeth Bernstein (2014) "Using Disability Adjusted Life Years to Value the Treatment of Thirty Chronic Conditions in the U.S. from 1987-2010," *BEA Working Paper*, WP2014-9.

Kawagoe, Masaaki and Yoshimitsu Suzuki (2016) "Healthcare Performance" in Masaaki Honmma, Nariaki Matsuura, Masaaki Kawagoe, and Masahiro Hidaka ed. *Healthcare and Economics*, Osaka University Press (in Japanese).

Kishimoto, Mitsuo (2005) "Public Use of VSL: UK and US Cases," *Kaikei Kensa Kenkyu* 31: 221-234. (in Japanese).

Miyazato, N. (2008) "Estimation of the Value of Statistical Life Using Labor Market Data," Nihon Keizai Kenkyu, 63: 1-28. (in Japanese).

Murphy, K. M., and R. H. Topel. (2003) "The Economic Value of Medical Research," in K. M. Murphy and R. H. Topel ed. *Measuring the Gains from Medical Research: An Economic Approach*, 41-73. Chicago: University of Chicago Press.

Murphy, K. M., and R. H. Topel. (2006) "The Value of Health and Longevity," *Journal of Political Economy* 114: 871-904.

Nakajima, T. (2008) "How to Evaluate Service Output," *ESRI Discussion Paper*, no. 195. Cabinet Office, Economic and Social Research Institute. (in Japanese).

Oka, T. 1999. *Environmental Policy Theory*, Tokyo: Iwanami shoten. (in Japanese).

Schreyer, Paul (2010) "Towards Measuring the Volume Output of Education and Health Services: A Handbook," OECD Statistics Working Papers 2010/02.

Steckel, R. (2008) "Biological Measures of the Standard of Living," *Journal of Economic Perspectives*, 22: 129-52.

UNU-IHDP and UNEP (2012) *Inclusive Wealth Report 2012: Measuring Progress toward Sustainability*, Cambridge University Press.

UNU-IHDP and UNEP (2014) *Inclusive Wealth Report 2014: Measuring Progress toward Sustainability*, Cambridge University Press.

Viscusi, W. Kip (2014) "The Value of Individual and Societal Risks to Life and Health," in Mark J. Machina and W. Kip Viscusi ed. *Handbook of the Economics of Risk and Uncertainty*. Elsevier.

Yoshikawa, H. (2003) *Structural Reform and the Japanese Economy*, Tokyo: Iwanami shoten. (in Japanese).