Domestic Capital Mobility: A Panel Data Approach

Nagayasu, Jun

University of Tsukuba

1 November 2010

Domestic Capital Mobility: A Panel Data Approach

Jun Nagayasu[*]

Nov 2010

Abstract

This paper analyzes capital mobility within Japan based on the consumption-based correlation method developed by Obstfeld (1994). This thoery suggests that consumption in one region is closely related to that in other regions if the capital market is open. We test this theoretical implication in the panel data context using the dynamic factor model which enables us to estimate unobservable common factors. Then we provide evidence of perfect capital mobility and capital integration having advanced rapidly between 1965 and 1975. Furthermore, the common factor is found to affect regional consumption heterogeneously and to be closely associated with stock returns.

JEL classification: C33, E21, F36

Keywords: Capital mobility, Dynamic factor model

---

[*]Associate Professor. Mail address: University of Tsukuba, Graduate School of Systems and Information Engineering, 1-1-1 Tennodai, Tsukuba, Ibaraki 305-8573 JAPAN; Tel/Fax: +81 29 853 5067; Email: nagayasu@sk.tsukuba.ac.jp.

1 Introduction

We shall look at the practice of risk-sharing by analyzing domestic capital mobility in Japan. Capital market integration has been studied intensively at the international and intra-country levels, and the literature can be broadly classified into two types: one, utilizing interest rate parity conditions and the other, macroeconomic variables. In the latter group, a seminal paper is Feldstein and Horioka (FH hereafter) (1980) which suggests that domestic investment and savings should have a one-to-one relationship in a closed capital market. In contrast, an insignificant savings-investment relationship is expected in an open capital market since investors can borrow from abroad and do not need to rely on domestic resources. Their theoretical prediction was supported by their empirical study. Evidence of high correlation (i.e., 0.89) suggesting imperfect capital mobility is obtained in data from industrial countries through 1974, a period when international capital markets were believed to be highly regulated.

Since then, many studies have applied FH theory to different countries or time periods, but empirical results often failed to meet the researchers' expectations.[1] For example, the correlation level between savings and investment is still high even during the recent period of capital market deregulation (Obstfeld and Rogoff 2000). From data of OECD countries in the 1990s, they report a coefficient equal to 0.6 which differs significantly from zero. Furthermore, this correlation is found to be higher in developed countries than developing ones which should have less access to international capital markets (Sinha and Sinha 2004). Not only the data brought into question the validity of the FH hypothesis, but Frankel (1982) cast doubt on the theoretical capability of the FH to measure capital mobility.[2] Thus this has remained as one of the myths in international finance.

Against this background, we study domestic capital mobility using the consumption-based economic model originally developed to measure international capital mobility (Obstfeld 1994). This approach has several attractive features. First, while it is related to the FH theorem (see Obstfeld and Rogoff 2000), there is a more solid theoretical foundation which leads to less contentiousness about the interpretation of results. Furthermore, this model suffers less from measurement errors since it is relatively easier to obtain high-quality data on consumption compared with savings. In short, it is one of the second best options for studying capital mobility in the absence of regional interest rate data in Japan.

There are several studies which have examined domestic capital mobility using Japanese saving/investment data (e.g., Yamori 1995, Dekle 1996, Iwatomoto and van Wincoop, 2000), but the consumption-based approach has been much less utilized before. To our knowledge, Taki (2008) is the only study using the consumption-

---

[1] See Apergis and Tsoumas (2009) for the recent developments in FH related studies. In addition, Yu, Fung and Tam (2010) review statistical methodologies and empirical results on the financial market integration in Asia.

[2] For example, Frankel (1992) viewed that the FH hythesis is not appropriate for measuring capital mobility since it relies on several economic assumptions. He then argued that the convered interest rate parity condition is the most suitable methodology for such a study.

based approach to examine Japanese domestic capital mobility. We will explain in more details later, but unlike Taki who conducted a time-series analysis for each prefecture, we employ a panel data (dynamic factor) approach to regional data and estimate an unobservable common factor, and further analyze its behavior using economic variables. The importance of considering common factors has been underscored in the analysis of investment-savings relationship (e.g., Corbin 2001).

Finally, this paper contributes to the important discussion on regional (prefectural) heterogeneity and inequality. For example, Tachibanaki (2005) highlighted a growing inequality in Japan, and Nagayasu (2010) showed heterogeneous effects of monetary policy on regional inflation. This paper looks at regional heterogeneity from the perspective of capital markets.

2 A Theoretical Model of the Consumption-Based Approach

We follow a theoretical model developed by Obstfeld (1994) in order to examine domestic capital mobility. Intuitively, this model predicts perfect capital mobility when consumption in one region is perfectly correlated with others because this becomes evidence of consumers being able to borrow/lend money from other regions if necessary. Thus access to capital outside the home region works as a buffer to smooth consumption (i.e., risk-sharing) when there are shocks in the home region. On the other hand, consumption in less integrated regions should be independent of other regions. Below we shall summarize his model.

First, consider the case of a constant relative risk aversion (CRRA) utility function for consumers in region i in world of frictionless and perfectly competitive economies:

$$u(C_{it}) = \frac{C_{it}^{1-\theta}}{1-\theta} \tag{1}$$

where t represent time ($t = 0, ..., T$) and this equation suggests $u'(C_{it}) = C_{it}^{-\theta}$. We assume a positive constant risk aversion coefficient ($\theta > 0$). If there is another region j and her utility can be written like (1), the Euler equations should be equalized in two regions if capital markets are perfectly open.

$$\frac{\beta_i^t C_{it}^{-\theta}}{C_{i0}^{-\theta}} = \frac{\beta_j^t C_{jt}^{-\theta}}{C_{j0}^{-\theta}} \tag{2}$$

The parameter β is a discount factor and measures the degree of patience of consumers (i.e., $\beta = 1/(1+\rho)$ where ρ is a discount rate), and for simplicity expectations errors are ignored in this derivation.[3] The θ is assumed to be homogenous across regions. This assumption is also used in international capital mobility analysis and

---

[3]With the rational expectations assumption that the expected value of errors is zero, the final message from the model remains unchanged even if an error term is introduced in the model.

is more reasonable in our context as residents in the same country can be expected to posses similar tastes than ones in different countries. The log form of equation (2) is

$$\log C_{it} = \log C_{jt} + \log(C_{i0}/C_{j0}) + \log(\beta_i/\beta_j)(t/\rho) \tag{3}$$

According to this equation, there is an equi-proportional relationship between consumption among regions under the assumption of perfect capital mobility, and this becomes a basis for our statistical test. Furthermore, equation (3) suggests that consumption contains a time trend unless $\beta_i = \beta_j$ and a difference in the initial level of consumption can be represented as the constant.

3 Empirical Model

The two-region setting which we discussed is of limited use when analyzing actual data since Japan comprises 7 regions. In the multi-regional framework, the definition of C_{jt} used in the previous sub-section has to be modified, and one which includes multi-regional consumption but excludes that in region i can be written as:

$$C_{w_i t} = \sum_{j=1}^{N} n_{jt} C_{jt}$$

where n is a weight and $\sum_{j=1}^{N} n_{jt} = 1$ and will be determined by the size of the population. Using this notation, equation (3) can be re-expressed as:

$$\log C_{it} = \log C_{w_i t} + \log(C_{i0}) + \log(\beta_i)(t/\rho) - \log\left(\sum_{j=1}^{N} \beta_j^{t/\rho} n_{jt} C_{j0}\right) \tag{4}$$

Like (3), this equation suggests the presence of a trend in the consumption function. With smaller letters denoting as log values (i.e., $\log(C) = c$), this equation in a testable form becomes:

$$c_{it} = \alpha_i + \phi_i c_{w_i t} + e_{it} \tag{5}$$

where $\alpha_i = \log(C_{i0})$, and for simplicity, the last item in equation (4) is dropped since this term decreases as t increases. We maintain the same definition of c_{it} and $c_{w_i t}$, but they are expressed in terms of per capita. Under the null hypothesis of perfect capital mobility, a parameter restriction ($\phi = 1$) must hold. Taki (2008) estimated this parameter for the period of 1975-2004 using the OLS along with another explanatory variable which represents regional domestic resources. Then he indicated perfect capital mobility, and furthermore showed that domestic capital mobility is higher than the international capital mobility.[4] However, a time-series analysis does not take account of any cross-sectional information which may become important in our study. Let us explain this next.

---

[4]Taki did not conduct any statistical tests to check if $\phi = 1$.

Now, in order to highlight the role of cross-sectional correlation (or common factors), we assume that regional consumption can be expressed as follows:

$$c_{it} = \alpha_i + \lambda_i F_t^{c_i} + u_{it}$$

$$c_{w_i t} = \alpha_{w_i} + \lambda_{w_i} F_t^{c_{w_i}} + u_{w_i t}$$

where common factors for c_{it} and $c_{w_i t}$ are denoted as $F_t^{c_i}$ and $F_t^{c_{w_i}}$ respectively, and their time dependent region-specific components are shown as u_{it} and $u_{w_i t}$. A combination of these two equations will bring about:

$$c_{it} = (\alpha_i - \alpha_{w_i}) + c_{w_i t} + \lambda_i \left(F_t^{c_i} - \frac{\lambda_{w_i}}{\lambda_i} F_t^{c_{wi}} \right) + (u_{it} - u_{w_i t}) \tag{6}$$

This equation shows the potential importance of common factors in the analysis, and in the absence of these terms the consumption-based study will suffer from a misspecification bias. This still predicts an equi-proportional increase of consumption but importantly suggests that common factor terms (i.e., $F_t^{c_i} - \frac{\lambda_{w_i}}{\lambda_i} F_t^{c_{wi}}$) may be negatively associated with c_{it} given that $F_t^{c_{wi}} > F_t^{c_i}$ and coefficients $(\lambda_i, \lambda_{w_i})$ are positive and are of the same magnitude (i.e., $\lambda_i = \lambda_{w_i} > 0$). Furthermore, this equation suggests that common factors may affect regional consumption heterogeneously, which is reflected in parameters λ_i and λ_{w_i}. Thus, the standard panel data estimation approach with the cross-section average as a proxy for common factors and the assumption of homogeneous effects suffers from this bias.

When estimating this equation, whether data should be differenced or not is one issue for consideration. Obstfeld used the differenced data because an analysis of nonstationary data will be based on a spurious regression to which the conventional statistical distribution cannot be applied. Furthermore, fixed effects can be removed by using a differenced mode. In order to maintain consistency with previous studies, his approach is also implemented in this study. The differenced version of equation (6) can be expressed as:

$$\Delta c_{it} = \Delta c_{w_i t} + \lambda_i \left(\Delta F_t^{c_i} - \frac{\lambda_{w_i}}{\lambda_i} \Delta F_t^{c_{wi}} \right) + e_{it} \tag{7}$$

In this study, we do not differentiate between common factors originated from home or other regions (i.e., $F_t^{c_i}$ and $F_t^{c_{wi}}$), but rather consider them (in the parenthesis) as a common factor for computational ease.

Previous studies often employed time-series and/or cross-sectional estimation approaches. The former is believed to estimate the short-term relationship, while the latter the long-run relationship (Obstfeld 1995) since a cross-sectional method is used to analyze time average data which are assumed not to contain cyclical movements of the data. However, several researchers (Sinn 1992, Krol 1996, Obstfeld 1995) argued that use of time-average data will bias the outcome.[5] Given the limited sample periods in our analysis (see next section), a panel data approach seems to be

---

[5] The direction of this bias can be positive or negative.

most appropriate in our context, and consideration of the common factor estimated by the dynamic factor model becomes one contribution of this paper.

4 Data Description and Preliminary Analysis

Our data are annual and cover the time period from 1955 to 2007 for 7 regions (namely, Hokkaido-Hokuriku (HH), Kanto, Chubu, Kinki, Chugoku, Shikoku and Kyushu). The composition of these regions is explained in Table 1 and follows the classification method of the Cabinet Office which is responsible for the compilation of national accounts statistics. Given this data frequency and the limited number of time-series, we choose to analyze regions (rather than prefectures (smaller units)) in order to estimate the dynamic factor model which allows for calculation of unobservable common factors and for their heterogeneous impacts on consumption across regions. Since consistent historical data on consumption are not readily available during this period, we have made adjustments to the original data.[6] The country-level consumption is shown in Figure 1.

Throughout the analysis, consumption is expressed as per capita. Consumption data are obtained from the Cabinet Office, and regional population data from the Ministry of Internal Affairs and Communications. For convenience, the following expressions will be used for two types of consumption.

c_i Log regional consumption per capita for region i
c_{w_i} Log consumption per capita excluding region i

Tables 2 and 3 show that consumption in one region is highly correlated with other regions. For example, Table 2 shows that correlation coefficients of regional consumption, c_i, are more than 0.9 in all cases, which is consistent with Backus, Kehoe and Kydland (1992) who predict this value from the frictionless economy model constructed to analyze world business cycles. Furthermore cross-sectional correlation tests (Friedman 1973, Frees 1995, Pesaran 2004) provide strong evidence of correlation in c_i and c_{w_i}. Thus these results imply a high level of domestic capital mobility in Japan (Table 3).

The stationarity of consumption is also analyzed in the panel data context. Table 4 summarizes the results from the Fisher-type panel unit root test based on the Augmented Dickey Fuller (ADF) applied to individual series. We have conducted this test for both original and demeaned data, and obtained strong evidence of the stationarity of consumption growth (i.e., Δc_i and Δc_{w_i}). Thus the standard statistical approach can be implemented.

Finally, causality among the data is examined. Equation (7) suggests that c_{w_i} causes c_i, and Obstfeld (1994) argued that it is an appropriate specification since

---

[6]The data from 1975 to 2007 are based on official stastistics constructed from 3 data sets, and data through 1974 is merged to this new data set. Since there is no regional information for year 1975 in these data sets, we utilized the growth rate of national-level consumption between 1974 and 1975 and made adjustments to data prior to 1974. The data will be available from the author's homepage.

consumption in one region may be very small in size compared with c_{w_i}. In this regard, we examine causality using the Granger non-causality test based on the second order vector autoregression (VAR(2)). The result is, as expected, that there is no evidence of causality running from c_i to c_{w_i} on the basis of the conventional significance level (Table 5). Instead, there are 3 cases where there is strong evidence of unidirectional causality from c_{w_i} to c_i, and therefore, it seems appropriate to assume the causal relationship as in equation (7).[7]

In addition to consumption data, we gather the following data which will be used in the analysis of common factor dynamics. Our choice of data is largely determined by their availability. Nikkei Average data are obtained from the Nikkei Needs Database and others from the IMF's International Financial Statistics. In the analysis, they are transferred to annual changes using log. These data are expected to capture general economic trends common to all regions.

food	Log food prices
beverage	Log beverage prices
agri	Log prices of agriculture and raw materials
metal	Log metal prices
gold	Log gold prices
oil	Log oil prices (London)
nikkei	Log Nikkei average (stock prices)

5   Empirical Results

We use the dynamic factor model which allows us to model unobservable common factors and persistence in consumption, and estimate heterogeneous impacts of common factors on regional consumption growth. As discussed in Section 3 and also suggested by our preliminary study, our data contain significant cross-sectional correlation and thus show a common factor. Furthermore, persistence appears to exist in consumption from our preliminary exercises since the unit root and non-causality tests required lagged consumption growth.[8] Here we introduce lagged common factor variables to capture the persistent effect in order to avoid increasing substantially the size of parameters to be estimated.[9]

The dynamic factor model with the factor being AR(2) can be expressed as follows:

---

[7]This assumption is also technically convenient since a dynamic factor model with instrumental variables to deal with endogeneity has not yet been developed.

[8]One could consider including lagged regional consumption variables in order to capture persistence, but this will significantly increase the size of parameters and result in the problem of non-convergence in the model estimation.

[9]One could consider including lagged regional consumption in order to capture persistence. But this approach will increase the number of parameters by seven which would lead to a non-convergence problem.

7

$$
\begin{pmatrix} \Delta c_{HH,t} \\ \Delta c_{Kanto,t} \\ \vdots \\ \Delta c_{Shikoku,t} \\ \Delta c_{Kyushu,t} \end{pmatrix} = \begin{pmatrix} \phi_{HH} \\ \phi_{Kanot} \\ \vdots \\ \phi_{Shikoku} \\ \phi_{Kyushu} \end{pmatrix} f_t + \begin{pmatrix} e_{HH,t} \\ e_{Kanto,t} \\ \vdots \\ e_{Shikoku,t} \\ e_{Kyushu,t} \end{pmatrix} \tag{8}
$$

where

$$
\begin{pmatrix} f_t \\ f_{t-1} \end{pmatrix} = \begin{pmatrix} \lambda_1 & \lambda_2 \\ 1 & 0 \end{pmatrix} \begin{pmatrix} f_{t-1} \\ f_{t-2} \end{pmatrix} + \begin{pmatrix} v_t \\ 0 \end{pmatrix} \tag{9}
$$

and

$$
Var \begin{pmatrix} e_{Hokhok,t} \\ e_{kanto,t} \\ \vdots \\ e_{Shikoku,t} \\ e_{Kyushu,t} \end{pmatrix} = \begin{pmatrix} \sigma^2_{Hokkaido} & 0 & \cdots & 0 & 0 \\ 0 & \sigma^2_{Kanto} & & 0 & 0 \\ \vdots & \vdots & \ddots & & \vdots \\ 0 & 0 & & \sigma^2_{Shikoku} & 0 \\ 0 & 0 & \cdots & 0 & \sigma^2_{Kyushu} \end{pmatrix} \tag{10}
$$

where e and v are residual, and Greek letters are parameters to be estimated. This model is estimated by the maximum likelihood method, and the estimator is consistent and asymptotically normal given the stationarity of our data. The Kalman filter is used to form a likelihood function and estimate unobservable common factors for each t by the recursive method (See Appendix).[10]

Table 6 shows several interesting results. First, the common factor is found to be statistically significant in most regions, but its impact differs between them. Generally, there is often a negative relationship between consumption growth and the common factor in industrial areas (i.e., Kanto and Kinki). Since the common factor is a data-driven variable, it is difficult to interpret the sign. Thus, a further interpretation of the common factor will be given later when the factor has been meaningfully specified economically. Second, using the conventional statistical criterion, we find evidence of perfect domestic capital mobility in all regions except Hokkaido-Hokuriku region. The fact that Hokkaido is a relatively large economy and in a remote location may contribute to this outcome. However, the joint null hypothesis of capital mobility in all regions is accepted by our data (Table 7). Thus, we can conclude that, generally speaking, Japan's domestic market is perfectly open during our sample period.

---

[10] Thus, our model differs from the factor VAR model (also often called the dynamic factor model) which is often used in empirical studies.

This result is a unique feature of this country and is consistent with previous studies on the Japanese economy. For example, Taki (2008) drew a similar conclusion from the analysis of prefecture's data from 1975, and Yamori (1995) reported evidence of insignificant correlation between savings and investment. Furthermore, such a high degree of capital mobility domestically has not been obtained from other intra-country analyses on e.g., China, Europe and the US (e.g., Atkeson and Bayoumi 1993, Boyreau-Debray and Wei 2004). Certainly, our evidence in favor of perfect capital mobility is in sharp contrast to multi-country studies (e.g., Kim, Kim and Wang 2006) which show that consumption risk sharing is very low in East Asia.

Furthermore, in order to check the robustness of our findings, we conducted the same analysis using sub-sample periods (1965-2007 and 1975-2007).[11] The results are also reported in Table 7 where we obtained evidence of perfect capital mobility from all different sample periods. While the significance rate (p-value) is just over 5 percent in the full (1955-2007) and sub- (1965-2007) sample periods, it increases substantially from 1975 and becomes beyond 45 percent. Therefore, it seems that much progress was made in capital markets between 1965 and 1975.

Actually, this timing is consistent with the development in the consumer loan market. The history of this market may go back to 1929 when the Nihon Chuya Ginko (Bank) initiated consumer loans to the private individuals. But the consumer loan market ceased during the aftermath of the World War II, and the major development took place from the 1960s onwards. Both commercial banks and non-bank financial institutions have flourished since then in response to strong demand from a growing number of individual consumers.[12] Furthermore, in 1967 the Nippon Diners Club began cash advance services to private consumers through its credit cards, and the Japan Consumer Finance Association was established in 1969 in order to develop and monitor this market. In addition, in 1972 commercial banks began lending operations (known as 'cash loans') to private consumers using their cash cards. Now, it is said that one in ten people (about 13 million people) are using the consumer loan market.

Then what explains the common trend in regional consumption? We use the common factor estimated by the dynamic factor model to respond to this question. Table 8 summarizes the results using the explanatory variables discussed earlier. Again a lagged common factor is introduced in order to capture persistence.[13] Using the conventional statistical significance level, it is only stock returns (i.e., Nikkei) which are found to be statistically significant and they are negatively associated with the common factor. Together with the evidence in Table 6 of a negative correlation between common factors and regional consumption in industrial areas, our results in Table 8 suggest that an increase in stock returns affects consumption positively in industrial regions but negatively in others. This asymmetric outcome may result

---

[11]In order to meet a convergence criterion, the second order (without the first lag) and static dyamic models are estimated for the sample periods (1965-2007 and 1975-2007) respectively.

[12]In constrast to a growing consumer loan market, the traditional market through Shichiya (non-bank financial institutions) which requested collateral goods when making a loan has diminished.

[13]A lag order of two is chosen since the first order model fails to converge.

from the close association with the location of the large firms listed on the stock exchange and with the location of shareholders. Large firms (and their headquarters) are often located in Tokyo and Osaka (Kanto and Kinki regions respectively),[14] and similarly shareholders are also concentrated in such areas.[15] Therefore, this result is consistent with the positive relationship between consumption and financial wealth observed in the literature on consumer savings/spending decisions (Nagayasu 2009). This also seems to reflect the rising inequality across Japan which has been increasing since around 1980 (Tachibanaki 2005) whereby economic returns are concentrated in industrial areas and rural regions are becoming relatively worse-off. Finally, prices of raw materials such as oil and metals are found to be statistically insignificant, partly reflecting efforts of manufacturers to discover energy alternatives particularly after the 1973 oil crisis.

Furthermore, Figures 2 and 3 show the recursive estimates of parameters and t-values associated with the explanatory variables. Figure 2 suggests that parameters are stable in our sample period since they stay within the confidence interval. However, Figure 3 shows that they may change in the future. A notable example is the price of metals whose t-values has been falling and approaching zero. In contrast, a change in importance (significance) cannot be observed in lagged common factors (particularly the second lagged factor). Thus, these figures predict that persistence in the common element of consumption will not disappear but other determinants may do so later.

6   Conclusion and Discussion

This paper analyzed capital mobility within Japan which is often considered as a homogeneous country in many respects. Given the importance of cross-sectional correlation recently pointed out by researchers, we estimated an unobservable common factor using the dynamic factor model. Taking account of this common factor and heterogeneities in our data, we drew the following conclusions.

First, consistent with previous studies, we obtained evidence of perfect capital mobility. The parameter restriction is accepted individually in most regions, and the joint test to examine capital mobility in all regions is supported by our data. Furthermore, while the significance rate (p-value) was low in the full sample, this rate increases once old observations are removed from the analysis. In particular, our results suggest that rapid developments in the capital market took place between 1965 and 1975.

Secondly, the common factor is found to be statistically significant in most regions, confirming its importance in the statistical model. Interestingly, the impact

---

[14] Tokyo is the center of commercial and political activities, and Osaka was the commercial center of Japan before Tokyo took over.

[15] According to the Development Bank of Japan, 84 percent of firms listed on the first and second sections on the Tokyo Stock Exchange (TSE) were located in Tokyo, Osaka and Nagoya areas in 2000. Furthermore, according to the TSE, 64 percent of stocks are held in Kanto and 20 percent in Kinki in 2000.

of the common factor is strongly heterogeneous across regions, which suggests that the conventional panel data approach which imposes homogeneous parameter restrictions is inappropriate. We also find that this factor is closely related to stock prices and less to prices of raw materials. Stock returns are found to be positively related to regional consumption in industrial regions.

The finding of perfect capital mobility within Japan may not be very surprising given her relatively small geographical area and the historical timing of movements toward a market economy. However, to some researchers, our results may be counter-intuitive given her premature consumer loan market. In Japan, the banking sector has a long history but did not target private consumers as main customers for lending. In such circumstances, one might think that Japanese private consumers would face the borrowing constraints. But our results suggest that such constraints were not statistically significant, and may also reflect in part less reliance on consumer loans but more on personal savings. Japanese consumers tend to hold liquid assets, and the savings ratio had been high traditionally although it now has declined to less than 5 percent of GDP. Furthermore, the traditional non-banking financial institutions (Shichi-ya) may have played a significant role in lending to private customers. But the increased level of capital mobility since the 1960s suggests that the modern consumer loan system has more than replaced the traditional one (Shichi-ya).

Appendix

Here we shall briefly explain the Kalman filter used to estimate the dynamic factor model. For simplicity, equations (8) and (9) will be expressed respectively as:

$$x_t = A_t'\beta + u_t \tag{A1}$$

$$\zeta_{t+1} = B\beta_t + e_{t+1} \tag{A2}$$

where $E(e_t, e_z') = Q$ for $t = z$, and $E(e_t, e_z') = 0$ otherwise, and similarly $E(u_t, u_z') = R$ for $t = z$, and $E(u_t, u_z') = 0$ otherwise. In addition, $E(e_t, w_z') = 0$. Equation A2 is a one-step ahead version of equation (9). The Kalman filter method essentially calculates recursively the unobservable value using linear least square forecasts based on information available through time t, and can be summarized as:

$$\widehat{\beta}_{t+1} = E(\beta_{t+1}|X_t)$$

where X_t contains all information in x through time t and the constant term. Furthermore, their mean squared errors can be written as:

$$K_{t+1|t} = E[(\beta_{t+1} - \widehat{\beta}_{t+1})(\beta_{t+1} - \widehat{\beta}_{t+1})']$$

Following Hamilton (1994) and given the stationarity of our data, the initial values for these terms are $\widehat{\beta}_{1|0} = 0$ and $vec(K_{1|0}) = E[(\beta_1 - E(\beta_1)][(\beta_1 - E(\beta_1)'] = [I - B \otimes B)]^{-1}vec(Q)$.

References

[1] Apergis, N and C Tsoumas. 2009, A Survey of the Feldstein-Horioka Puzzle: What Has Been Done and Where We Stand. Research in Economics 63, 64-76.

[2] Atkeson, A and T Bayoumi. 1993. Do Private Capital Markets Insure Regional Risk? Evidence from the United States and Europe. Open Economies Review 4, 303-324.

[3] Backus, D., P. Kehoe, and F. Kydland. 1992. International Real Business Cycles. Journal of Political Economy 100, 745-775.

[4] Boyreau-Debray, G and S-J Wei. 2004. Can China Grow Faster? A Diagnosis of the Fragmentation of Its Domestic Capital Market. IMF Working Paper WP/04/76.

[5] Corbin, A. 2001. Country Specific Effect in the Feldstein-Horioka Paradox: A Panel Data Analysis. Economics Letters 72, 297-302.

[6] Dekle, R. 1996. Saving-Investment Associations and Capital Mobility: on the Evidence from Japanese Regional Data. Journal of International Economics 41, 53-72.

[7] Feldstein, M. and Horioka, C. 1980. Domestic Saving and International Capital Flows. Economic Journal 90(358), 314–329,

[8] Frankel, JA. 1992. Measuring International Capital Mobility: a Review. American Economic Review 82(2), 197-202.

[9] Frees, EW. 1995. Assessing Cross-sectional Correlations in Panel Data. Journal of Econometrics 69: 393-414.

[10] Friedman, M. 1937. The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. Journal of the American Statistical Association 32: 675-701.

[11] Hamilton, JD. 1994. Time Series Analysis, Princeton: Princeton University Press.

[12] Iwatomoto, Y and E van Wincoop. 2000. Do Borders Matter? Evidence from Japanese Regional Net Capital Flows. International Economic Review 41(1), 241-269.

[13] Kim, S, SH. Kim and Y Wang. 2006. Financial Integration and Consumption Risk Sharing in East Asia. Japan and the World Economy 18, 143-157.

[14] Krol, R. 1996. International Capital Mobility: Evidence from Panel Data. Journal of International Money and Finance 15(3), 467-474.

[15] Nagayasu, J. 2009. Stocks, Consumption, and Wealth: Evidence from the Tokyo Stock Exchange, George I. Ellison (ed.) in Stock Returns: Cyclicity, Prediction and Economic Consequences (NY: Nova Science Publishers) 133-156.

[16] Nagayasu, J. 2010. Regional Inflation (Price) Behaviors: Heterogeneity and Convergence, MPRA Paper No. 25430, University Library of Munich, Germany.

[17] Obstfeld, M. 1994. Are Industrial-country Consumption Risks Globally Diversified? In L Leiderman and A Razin eds., Capital Mobility: the Impact on Consumption, Investment and Growth. Cambridge: Cambridge University Press.

[18] Obstfeld, M. 1995. International Capital Mobility, In Peter B. Kenen ed., Understanding Interdependence: The Macroeconomics of the Open Economy. Princeton: Princeton University Press.

[19] Obstfeld, M and K Rogoff. 2000. The Six Major Puzzles in International Macro-economics: Is There a Common Cause? In B Bernanke and K Rogoff, eds., NBER Macroeconomics Annual 2000, 15, The MIT Press, 339–390.

[20] Pesaran, M. H. 2004. General Diagnostic Tests for Cross Section Dependence in Panels. University of Cambridge, Faculty of Economics, Working Papers in Economics No. 0435.

[21] Sinha, T and D Sinha. 2004. The Mother of All Puzzles Would Not Go Away. Economics Letters 82, 259-267.

[22] Sinn, S. 1992. Saving-investment Correlations and Capital Mobility: on the Evidence from Annual Data. Economic Journal 102, 1162-1170.

[23] Tachibanaki, T. 2005. Confronting Income Inequality in Japan, Cambridge: MIT Press.

[24] Taki, T. 2008. Indicators of Financial Integration: Tests Based on Country and Japanese Regional Data. Osaka Economics Papers 58(3), 41-61.

[25] Yamori, N. 1995. The Relationship between Domestic Savings and Investment: the Feldstein-Horioka Test Using Japanese Regional Data. Economics Letters 48, 361-366.

[26] Yu, I-W, K-P Fung and C-S Tam. 2010. Assessing Financial Market Integration in Asia–Equity Markets. Journal of Banking & Finance 34, 2874-2885.

Table

Table 1. Definition of Regions

Region	Prefecture
1. Hokkaido-Hokuriku (HH)	Hokkaido, Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima, Niigata
2. Kanto	Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, o Kanagawa, Yamanashi, Nagan
3. Chubu	Toyama, Ishikawa, Fukui, Gifu, Shizuoka, Aichi, Mie
4. Kinki	Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama
5. Chugoku	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi
6. Shikoku	Tokushima, Kagawa, Ehime, Kochi
7. Kyushu	Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima, Okinawa

Table 2. Correlation of Consumption Growth Per Capita

	HH	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu
HH	1.000						
Kanto	0.979	1.000					
Chubu	0.984	0.982	1.000				
Kinki	0.975	0.978	0.978	1.000			
Chugoku	0.989	0.977	0.987	0.977	1.000		
Shikoku	0.984	0.965	0.979	0.966	0.983	1.000	
Kyushu	0.990	0.973	0.987	0.965	0.986	0.987	1.000

Note: Full sample.

Table 3. Cross Sectional Correlation Test for Consumption Growth (Per Capita)

	Δc_i	Δc_{w_i}
Pesaran	32.369 (0.000)	33.014 (0.000)
Friedman	348.119 (0.000)	355.923 (0.000)
Free	6.463 (0.000)	6.814 (0.000)

Note: Full sample. The tests are based on Pesaran (2004), Friedman (1937) and Free (1995).

Table 4. Unit Root Test for Consumption Growth (Per Capita)

	Δc_i	Δc_{w_i}
Original data	-2.515 (0.006)	-2.629 (0.004)
Demeaned data	-5.584 (0.000)	-5.287 (0.000)

Note: Full sample. The Fisher type panel unit root test based on the ADF. The second order lag is chosen on the basis of the Akaike Information Criterion. The null hypothesis is that all data are non-stationary.

Table 5. Granger Non-causality Test

	Excluded explanatory variables		Conclusion
	Δc_{w_i}	Δc_i	
HH	2.337 (0.311)	5.909 (0.052)	Indecisive
Kanto	13.049 (0.001)	3.299 (0.192)	$\Delta c_{w_i} \Rightarrow \Delta c_i$
Chubu	8.998 (0.011)	1.432 (0.489)	$\Delta c_{w_i} \Rightarrow \Delta c_i$
Kinki	8.989 (0.011)	1.629 (0.443)	$\Delta c_{w_i} \Rightarrow \Delta c_i$
Chugoku	4.255 (0.119)	5.811 (0.055)	Indecisive
Shikoku	0.529 (0.767)	2.061 (0.357)	Indecisive
Kyushu	5.633 (0.060)	3.844 (0.146)	Indecisive

Note: Full sample. The Chi^2 tests are provided with p-values in parentheses, based on VAR(2).

	Exp variable	Coef.	Std. Err	p-value	Chi2	p-value
f	$f(1)$	0.263	0.147	0.074		
	$f(2)$	0.642	0.150	0.000		
HH	f	0.002	0.001	0.000		
	c_{w_i}	1.052	0.024	0.000	4.790	0.029
Kanto	f	-0.004	0.001	0.000		
	c_{w_i}	0.945	0.031	0.000	3.100	0.078
Chubu	f	0.000	0.001	0.622		
	c_{w_i}	0.985	0.013	0.000	1.460	0.226
Kinki	f	-0.002	0.001	0.016		
	c_{w_i}	0.956	0.022	0.000	3.850	0.050
Chugoku	f	0.002	0.001	0.001		
	c_{w_i}	1.030	0.021	0.000	2.000	0.158
Shikoku	f	0.004	0.001	0.000		
	c_{w_i}	1.035	0.038	0.000	0.840	0.358
Kyushu	f	0.004	0.001	0.000		
	c_{w_i}	1.050	0.034	0.000	2.080	0.149
V(HH)		4.4E-05	9.2E-06	0.000		
V(Kanto)		3.8E-05	9.5E-06	0.000		
V(Chubu)		5.0E-05	9.8E-06	0.000		
V(Kinki)		8.7E-05	1.8E-05	0.000		
V(Chugoku)		4.2E-05	8.7E-06	0.000		
V(Shikoku)		4.8E-05	1.1E-05	0.000		
V(Kyushu)		4.1E-05	9.9E-06	0.000		

Note: Sub sample (1955-2007). The second order dynamic factor model. The Chi2 test examines the null of $c_{w_i} = 1$.

Table 7. Impacts on Regional Consumption

1955-2007	
a) $\lambda(f_1) = \lambda(f_2) = ... = \lambda(f_7)$	Chi2(6)=36.78 (0.000)
b) $\phi(\Delta c_{w1}) = \phi(\Delta c_{w2}) = ... = \phi(\Delta c_{w7})$	Chi2(6)=11.41 (0.076)
c) $\phi(\Delta c_{w1}) = \phi(\Delta c_{w2}) = ... = \phi(\Delta c_{w7}) = 1$	Chi2(7)=13.22 (0.067)
1965-2007	
a) $\lambda(f_1) = \lambda(f_2) = ... = \lambda(f_7)$	Chi2(6)=30.16 (0.000)
b) $\phi(\Delta c_{w1}) = \phi(\Delta c_{w2}) = ... = \phi(\Delta c_{w7})$	Chi2(6)=11.81 (0.066)
c) $\phi(\Delta c_{w1}) = \phi(\Delta c_{w2}) = ... = \phi(\Delta c_{w7}) = 1$	Chi2(7)=12.56 (0.084)
1975-2007	
a) $\lambda(f_1) = \lambda(f_2) = ... = \lambda(f_7)$	Chi2(6)=56.34 (0.000)
b) $\phi(\Delta c_{w1}) = \phi(\Delta c_{w2}) = ... = \phi(\Delta c_{w7})$	Chi2(6)=5.370 (0.497)
c) $\phi(\Delta c_{w1}) = \phi(\Delta c_{w2}) = ... = \phi(\Delta c_{w7}) = 1$	Chi2(7)=6.700 (0.461)

Note: The test (a) examines the equi-impact of the common factor in all region. The (b) tests the equi-impact of c_{wi} in all regions, and (c) exames capital mobiltiy in all regions. The numerals (1 to 7) correspond to the numbered region in Table 1.

Table 8. Determinants of the Common Factor

	Para	Std Error	p-value
$f(1)$	0.109	0.104	0.301
$f(2)$	0.796	0.107	0.000
$\Delta food$	-3.503	1.856	0.067
$\Delta beverage$	-0.489	0.615	0.433
$\Delta agrraw$	0.936	1.417	0.513
$\Delta metal$	0.464	0.882	0.602
$\Delta gold$	0.985	0.844	0.251
$\Delta goil$	-0.838	0.440	0.065
$\Delta nikkei$	-1.270	0.584	0.036
Dyagnostic test			
AR	F(2,33)=	0.523	0.597
ARCH	F(1,42)=	1.113	0.298
Normality	Chi^2(2)=	3.345	0.188
Hetero	F(18,25)=	0.668	0.810

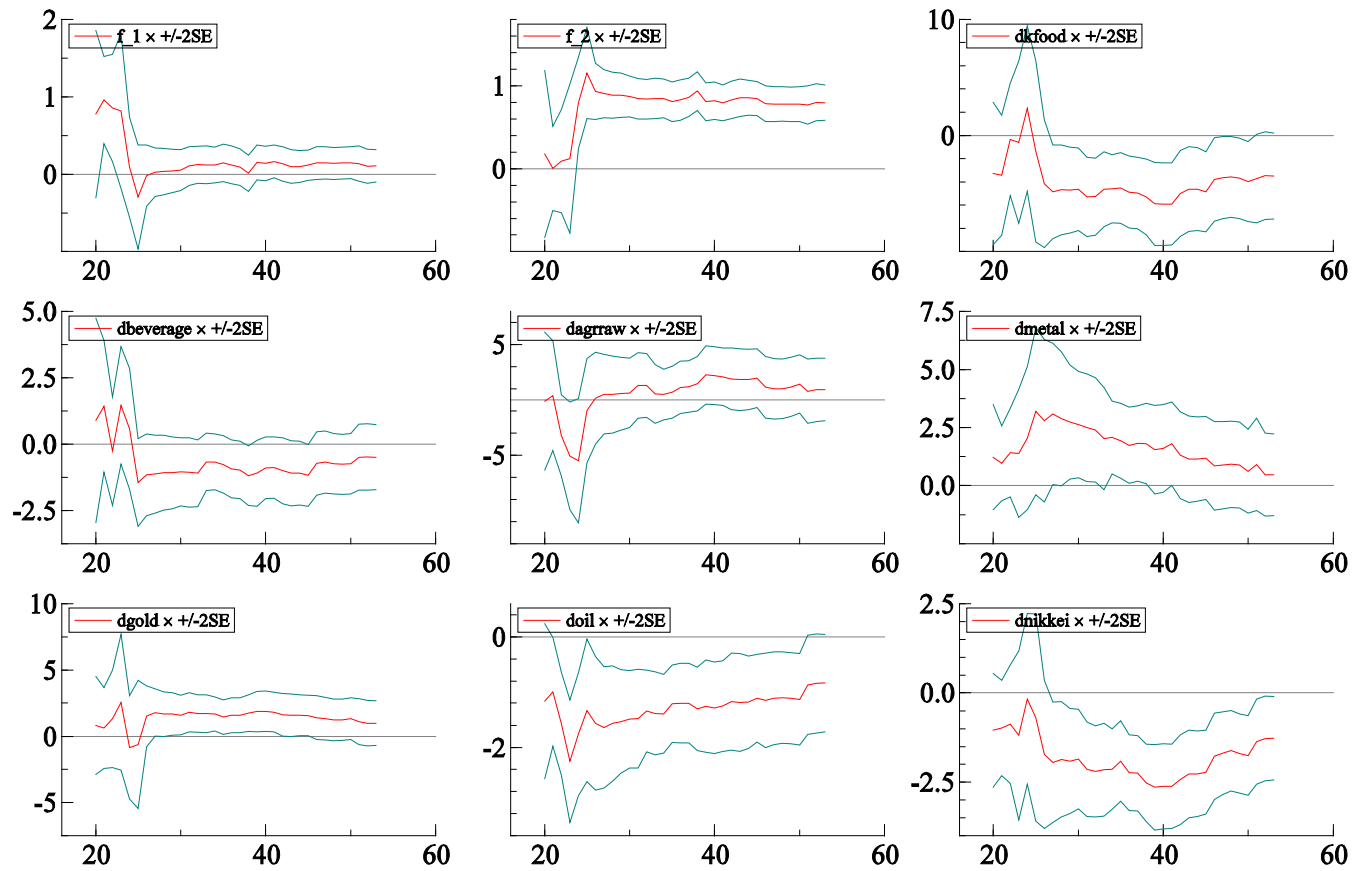Note: The number in parentheses next to variables is the lag order.
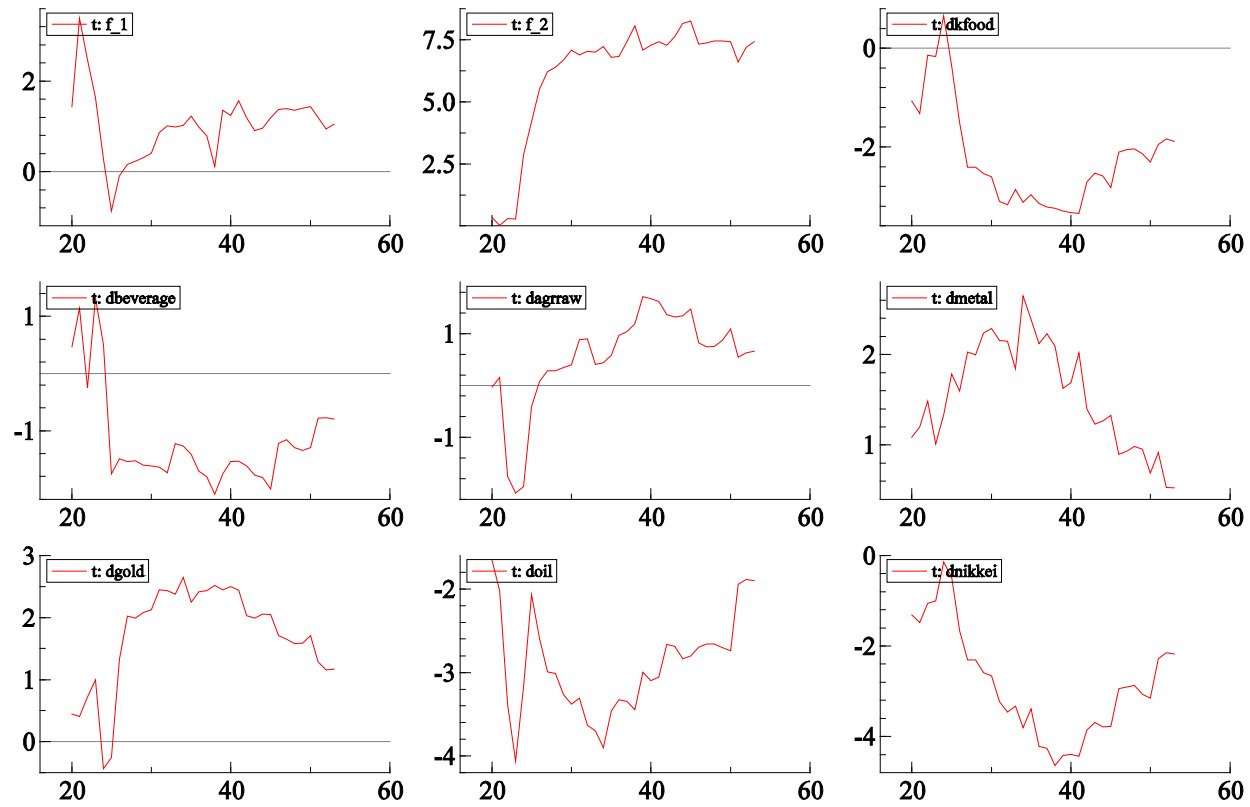
Figures

Figure 1. Consumption
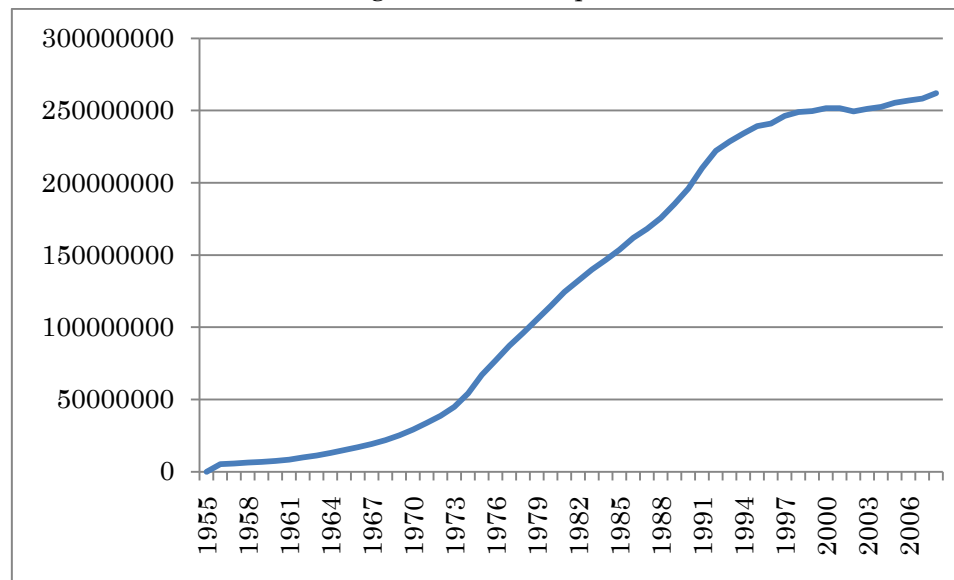
Note: Aggregate consumption from 1955-2007. Units are one million yen.

Figure 2. Parameter Stability

Note: A 'd' before variables indicates the first difference. The first and second order common factors are denoted as f_1 and f_2 respectively.

Figure 3. T-Values

Note: A 'd' before variables indicates the first difference. The first and second order common factors are denoted as f_1 and f_2 respectively.