Regional inflation and industrial structure in monetary union

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Abstract:
It is often argued that an optimal currency area requires homogeneous regional inflation. However, previous empirical studies point out heterogeneity in sectoral inflation and geographical concentration of industries within a monetary union. It follows that there must be a difference in regional inflation in such a union. We examine this view using regional data from Japan which has experienced a period of rapid change in industrial structure, and show that economic structure is closely related to heterogeneous regional inflation. This study suggests that heterogeneous inflation can be a prevailing and long-lasting phenomenon in a monetary union.

Keywords: Regional inflation, Monetary union, Optimal currency area, Industrial structure
JEL classification: F4, E5, R1

1. Introduction

This paper empirically analyzes the behavior of time-varying correlations of regional inflation in a monetary union; in particular we focus on its relationship with industrial structure. Mundell (1961) argued that an optimal currency area requires homogeneous regional inflation in order to avoid asymmetric effects of a single monetary policy and exogenous shocks to the regions. Furthermore, homogeneous inflation is expected to prevail in a monetary union, due to the increased economic integration after forming the single currency area. The presence of homogeneity in regional inflation in a monetary union is thus widely accepted by researchers and policymakers and is included in the Maastricht Treaty as a prerequisite for joining the euro area.

However, there is increasing evidence of heterogeneous regional inflation within a monetary union using the comprehensive coverage of price data like the Consumer Price Index (CPI).[1] Kocenda and Papell (1997), Homes (2002), and Busetti et al (2006) reported evidence of inflation convergence in the pre-euro period. However, this trend has changed since the introduction of the euro, and regional inflation is diverging, forming two convergence clubs in the European Monetary Union, EMU (Busetti et al 2006).[2] Similarly, Nagayasu (2011) presented evidence of heterogeneous inflation and non-convergence of prices using Japanese regional data.

There are some economic explanations for heterogeneous regional inflation. Recent studies (e.g., Aoki 2001; Fuchi and Watanabe 2001; Altissimo et al 2007; Leith

1 There is more evidence in favor of inflation (price) convergence from studies utilizing product-specific data. For example, Golberg and Verboven (2005) show that both levels of and changes in car prices are converging in Europe.

2 Inflation divergence and price convergence can take place simultaneously in the process of monetary integration since a low-price region may experience higher inflation to catch up with a high-price region. In this connection, Faber and Stokman (2009) showed a declining trend in price dispersion among members of the EMU, but there is no evidence that this price adjustment accelerated after the introduction of the euro (Cuaresma et al 2007; Faber and Stokman 2009). Thus it seems that price and inflation convergence was not achieved prior to 1999.

and Malley 2007; Imbs et al 2011) have underlined different levels of inflation persistence and of inflation itself across industries. Among economic sectors, the service sector tends to exhibit higher inflation persistence. When sectoral inflation persistence and thus sectoral inflation rates are different, there must be differences in regional inflation because there is evidence of dissimilarity in the industrial structure in the European Union (EU) (Brulhart 2001). Thus these studies imply that in the absence of convergence in industrial structure, regional inflation rates do not converge even after the establishment of monetary union.

Against this background, we focus on two main issues. First, we analyze if there is any difference in industrial structure using regional data from Japan. In the nearly 70 years since the end of the war, the industrial structure has changed dramatically. Nowadays the tertiary (rather than the secondary) sector is dominant in the country, while the primary industries have been stagnating and play an insignificant role in total economic activities. Second, if there are indeed significant differences in industrial structure among regions, then we examine whether it can explain the correlations of regional inflation. Thus this study will fill a gap between research in the areas of international trade, monetary economics and international finance.

This study is also rather distinctive because of our area choice. The Japanese regions are believed to be relatively homogenous in terms of culture (e.g., language, religion, race, and political and legal systems) by international standards. Furthermore, there are no trade barriers such as tariffs on tradable goods nor legal barriers to free movement of labor between regions. Findings from regions that are likely to meet the conditions of an optimal currency area will have significant policy implications for countries becoming or wishing to become members of a single currency union.

2. Regional inflation

We study regional inflation from 1976Q4 to 2008Q4 measuring annual changes ($\triangle p_t = \ln(p_t / p_{t-4})$) in the Consumer Price Index (CPI (p)). This sample period begins when data from Okinawa, which was returned to Japan in 1972, became available, and the end-of-period is determined by the data availability of our explanatory variables which will be discussed later. Our dataset consists of 10 regions; Hokkaido, Tohoku, Kanto, Hokuriku, Tokai, Kinki, Chugoku, Shikoku, Kyushu and Okinawa, following the classification methodology used by the Ministry of Internal Affairs and Communications which is responsible for compilation of the CPI. The appendix describes the data and summarizes the definition of the regions in which all 47 prefectures are included.

Figure 1 shows a very similar movement of regional inflation with occasional deflationary episodes; a relatively high level of inflation in the 1970s and early 1980s in response to the oil crises, and low inflation in more recent periods reflecting weak economic recovery after the bursting of the bubble in the financial and real estate markets. While inflation rates and their volatility look very similar across regions (Table 1), Okinawa, which lags behind other regions in terms of economic development, has experienced the lowest inflation. Furthermore, F tests in this table suggest that regional inflation is indeed different, a result consistent with Nagayasu (2011). While the difference in regional inflation is at most 0.4% (Table 1) and seems insignificant compared with one in Europe,[3] we confirm statistically significant heterogeneity in regional inflation even in this country with a relatively small landmass and similar

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[3] During 1999-2010, the difference between the maximum and minimum inflation rates was 4.1% in the euro area (Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovak Rep. and Spain). This figure drops to 3.2% when Greece is removed from the sample.

culture—a result consistent from other countries/monetary unions (e.g., Busetti et al 2006).

While we shall go into details later on, our result is also in line with heterogeneous economic structure among regions. Heterogeneous sectoral inflation in a monetary union is observed worldwide; for example, Fuchi and Watanabe (2001) and Altissimo et al (2007) showed from Japanese and European data respectively that there is a significant difference in sectoral inflation within a region/country, and services tend to exhibit higher inflation persistence than industrial goods. In the presence of industry concentration in a certain region, there likely exists heterogeneous inflation.

Furthermore, in order to show interaction between regional inflation, its variance is decomposed using the method suggested by Diebold and Yilmaz (2009). For presentation purposes, Table 2 summarizes the results according to the size of regional economies measured by the GDP and reports evidence of inflation spillovers. This variance decomposition is carried out using the residuals from the 4th order 10 variable Vector Auto-Regressor (VAR): $x_t = \varphi_1 x_{t-1} + \varphi_2 x_{t-2} + \varphi_3 x_{t-3} + \varphi_4 x_{t-4} + \varepsilon_t$ or $x_t = A(L)u_t$ in the moving average form, where L is a lag operator. The Cholesky decomposition method is employed to calculate the contribution of region i's inflation variance to the 4-step-ahead forecasting residual variance of region j ($i \neq j$, $i=1,\ldots,10$ and $j=1,\ldots,10$). In short, spillover effects are calculated as:

$$Spillover = \frac{100 \times \sum_{h=0}^{4} \sum_{i,j=1}^{10} a_{h,ij}^2}{\sum_{h=0}^{4} trace(A_h A'_h)} \tag{1}$$

where $a_{h,ij}$ is an element of A: $A = \begin{bmatrix} a_{h,11} & a_{h,12} & \cdots & a_{h,110} \\ a_{h,21} & \ddots & & a_{h,210} \\ \vdots & & \ddots & \vdots \\ a_{h,101} & a_{h,102} & \cdots & a_{h,1010} \end{bmatrix}$ for a h-step ahead forecast. Thus equation (1) is a ratio of the total spillover to the variation of the total forecast error.

Table 2 shows that regional inflation in Kanto which includes Tokyo (the nation's capital) is least affected by other regions, and is mostly generated by Kanto itself. While other regional inflation is also generally most affected by itself, influence from other regions is substantial. Interestingly, like Kanto, Okinawa is also less affected by inflation in other regions.[4] In short, countrywide inflation is dominated by the inflation in Kanto.[5]

Finally, the moving-window correlations of regional inflation are calculated with a different window size (5, 10 and 20) in order to check the sensitivity of our final results to the window size. Figure 2 plots correlations from a window size of 10 and shows that it is time-varying and has a high value (often more than 0.5). But correlations tended to be low when there were large economic shocks such as banking problems with high non-performing loans (2000) and Lehman Shock (2008). Table 3 presents the average of correlations for each pair of regions. The highest correlation can be obtained between Kanto and Kinki—industrial regions with the present and former capital cities. The lowest level is found between Hokuriku and Okinawa, and interestingly all pairings with Okinawa are listed in the low correlation group. This again characterizes the unique position of Okinawa. In order to better understand the characteristics of regions, we shall look into their industrial structure next.

3. Diversification of Industrial structure

Production concentration is important in our study since recent studies of inflation in the

[4] In general, the result remains unchanged even if the order of variables in the specification has altered.

[5] The dominance of Kanto declines slightly in forecasting models with longer time horizons.

New Keynesian framework emphasized differences in the persistence of sectoral inflation. When inflation persistence and thus inflation rates are different among industrial sectors and if regions specify production of goods and services, monetary union likely faces long-lasting heterogeneous regional inflation.

There are several economic theories which would lead one to expect a country (region) to specialize in the production of particular goods and services. For example, David Ricardo proposed the concept of comparative advantage in order to explain international trade, and predicted that a country specializes in the production of products according to technological differences. In contrast, Heckscher-Ohlin model pointed to differences in factor endowments in countries as an engine of international trade. A country will specialize in the production of products that utilize economic factors that are internationally more affluent.

Marshall (1920) and Krugman (1991) provided three further theoretical explanations of high localization of industries. First, the proximity of firms in the same industry creates a labor market pool. Since these firms seek similar types of skilled workers, the labor market pool helps reduce the possibilities of mismatching and functions to introduce flexibility into the labor market. Second, the agglomeration of similar firms creates a more efficient market since firms can have easier access to specialized intermediate inputs and services. Third, firms can benefit more from knowledge spillover by locating close to each other. In this regard, Yamawaki (2002) reported that Japanese small firms consider, among other things, the location of leading firms nearby and the availability of relevant skilled workers as key factors in their decision-making about location.

Here we analyze changes in industrial structures for each region using value-added shares[6] and the classification method of the Cabinet Office, Government of Japan (i.e., the primary, secondary and tertiary sectors). Table 4 shows the proportion of all three sectors across the regions. The primary sector is relatively more important in the northern regions (Hokkaido and Tohoku) which are known to produce agricultural products, but the secondary sector plays a more significant role throughout Japan, in particular Tokai where the headquarters of Toyota are located. However, it is the tertiary sector which has the highest ratio to GDP, particularly in Okinawa. Thus although Japan may often be regarded as a manufacturing country with many internationally competitive firms, it is the service sector which contributes most to overall economic activity.

Furthermore, the proportion of the tertiary sector has been increasing over time, matched by a decline in that of the primary and secondary sectors (Figure 3). (This figure shows the trend of each sector at the national level.) More specifically, while some industries such as the semiconductor as well as the processing and assembly industries (e.g., cars, semiconductors, general electrical machines) expanded rapidly until the 1980s, the secondary sector has shown a steady decline during our period, and the decline accelerated in the 1990s during the economic slowdown. Despite a slow adjustment due to the rigidity in the labor market however, there have been notable advances in the information and technology industry, an area which is closely related to the tertiary sector. Therefore, it is expected that in the future the tertiary sector will maintain its significant presence in the Japanese economy.

We study if there is divergence in production specialization in Japanese regions

[6] Industrial structure can also be calculated on the basis of employment. However, consistent industry-specific employment data are not available on a regional basis.

using the β convergence criterion often used in economic growth literature.[7] This criterion suggests that convergence in industrial structure takes place, for example, when a region with a low contribution from the primary sector experiences higher growth in the ratio of the primary sector's activities-to-GDP than a region with a high contribution from this sector. The concept of β convergence can be summarized as:

$$(y_{it} / y_{it-1}) = \alpha - \beta(y_{it-1}) + u_{it} \tag{2}$$

where y_{it} represents the ratio of real sectoral GDP to total GDP for region *i* at time *t* and the residual *u* has zero mean with a constant variance. Parameter α captures a steady-state value and thus here is cross-sectionally constant (i.e., absolute convergence). The condition of convergence requires $0 < \beta < 1$ which indicates a negative correlation between changes in *y* and lagged *y*. A more general form can be written as:

$$(y_{it} / y_{it-1}) = \alpha + \delta(y_{it-1}) + \sum_{j=1}^{4} \eta_j (y_{it-j} / y_{it-j-1}) + u_{it} \tag{3}$$

where $\delta = -\beta$ and the lagged endogenous variable is included in order to deal with autocorrelation. The convergence condition thus becomes $-1 < \delta < 0$. Since our data are from the same country and are thus expected to be highly correlated with one another, we shall estimate equation (3) by the Seemingly Unrelated Regression (SUR) method in order to capture the cross-sectional correlation in the residual terms a la Breuer et al (2001). For presentation purposes, we also present results from replacing α with α_i (conditional convergence) in equations (3) with and without the lagged endogenous variable.

[7] See Barro and Sala-i-Martin (1999) for a comprehensive review of empirical studies of economic growth. We also considered the σ convergence criterion also suggested by them. The results are not reported here since we have only 10 regions, but are consistent with our conclusion from the β convergence criterion.

Table 5 presents parameter δ and fixed terms α and α_i estimated for each sector along with the standard errors based on the bootstrap method since statistics do not follow a conventional distribution. In general, we can observe convergence in the primary sector regardless of the specification of the steady-state, and divergence in the secondary and tertiary sectors. This observation is supported by the signs and statistical significance of our estimates. Parameter δ is positive for the tertiary sector which implies $\beta < 0$. While δ is negative for the secondary sector, this parameter is statistically insignificant. These findings support non-convergence of industry structure for these sectors. In contrast, δ is negative and significant for the primary sector, raising evidence of convergence in its sector. This is consistent with the fact that activities in the primary sector like agriculture, which contributes least to overall economic activity, has been decreasing throughout Japan. In contrast, the manufacturing and service sectors seem to be concentrated in certain (often rural) areas. This conclusion remained unchanged even when the different size of lag orders (j=1 to 4 in equation (2)) is used.[8]

The non-convergence of industry structure is observed in trade unions in Europe too. For European countries, Brulhart (2001) for example looked at the manufacturing industry in 13 European countries over the period of 1972-1996, and reported that sectoral employment specialization has been increasing over time. Gugler and Pfaffermayr (2004) showed that for 14 EU countries over the period 1985-98 while there is evidence of convergence in productivity, industry structure remains unchanged. Similarly, Brulhart and Traeger (2005) showed that there was no significant change in the geographical concentration of employment and market services between 1975-2000

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[8] We also consider equation (3) with the a priori assumption of homogeneous α_i (i.e., $\alpha_1=\alpha_2=\ldots\alpha_{10}$) and heterogeneous δ_i. The general conclusion remains the same as those from the assumption discussed in the text.

in the EU, but there was evidence of convergence in the manufacturing sector. In the international context, Rodrik (2011) argued about the importance of the investigation into economic convergence at the sectoral level; the conclusion of convergence is sensitive however to the choice of industries.

4. Empirical relationship

Here we shall examine the relationship between the correlations of regional inflation and economic factors including the industrial structure of the regions. More precisely, we consider economic variables such as deposits and demographic changes which are expected to capture the unique characteristics of each region.[9]

The Japanese economy and the society cannot be discussed without considering demographic changes. Japan has experienced a rapid increase over recent years in the aged proportion of its population. With a low birthrate (less than 2% since 1975) and longevity, there is a relatively small workforce in the country. This was recently exacerbated by the retirement of the baby-boom generations. This phenomenon has had serious economic and social impacts on the society, putting further pressure on the national budget, due to increased outlay from the social security system and the social safety net, which are already in a rather fragile state.

Demographic changes have affected living patterns, and underpopulation (*Kasoka*) has become a common phenomenon throughout Japan. At the national level, underpopulated cities (including villages and towns) have increased from 38.3% in

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[9] We also considered geographical proximity in this section by introducing to equation (4) a dummy variable (one if regions are adjacent to each other, and zero otherwise). However, this is found to be statistically insignificant in all cases, and thus these results are not reported here. But please note that a simple regression with only this dummy as an explanatory variable shows the statistical importance of space, we interpret industrial structure contains similar information included in this spatial dummy. The distance can be regarded, at times, as a proxy of transportation costs.

1990 to 45% in 2011.[10] Furthermore, such cities are unevenly distributed across the country and, while a majority of prefectures have experienced further underpopulation, there are 5 out of 47 prefectures which have improved their situation during this period.[11] Increases in job opportunities as well as 'while still expensive more affordable' living environments motivated residents in rural areas to move to big cities. As a result, a high dependency ratio (i.e., a high proportion of retirees and children) is often seen in the countryside.

Finally, the size of bank deposits is considered in order to capture similarity across regions. Generally, large economies including Kanto and Kinki regions tend to have high bank deposits. This variable is closely related to demographic changes; recent studies (Horioka 2010) pointed out that there is a negative relationship between bank deposits and the proportion of dependents. In particular, retirees have started 'dis-saving' (spending) their deposits to cover their living expenses.

Using these data and the correlation of regional inflation ($Corr(\Delta p_{ijt})$) calculated with several window sizes, we estimate the following general specification for panel data:

$$\begin{aligned} Corr(\Delta p_{ijt}) = \alpha + \beta_1 \,|\, Ind_{it} - Ind_{jt} \,| + \beta_2 \,|\, Work\_pop_{it} - Work\_pop_{jt} \,| \\ + \beta_3 \,|\, Deposit_{it} - Deposit_{jt} \,| + \beta_4 t + u_{ijt} \end{aligned} \tag{4}$$

where *Ind* is a change in a proportion of industrial structure for a particular sector (e.g., real GDP for the primary sector/Total GDP), *Work_pop* is a change in a demographic ratio using the definition of workforce as from 15 to 65 years old (i.e., Workforce/Population), and *Deposits* is a change in demand deposits, Subscripts *i* and *j*

[10] See http://www.kaso-net.or.jp/index.htm for definition and further information about underpopulation in Japan. Among other conditions a city is considered underpopulated when more than a certain number of residents have moved away.

[11] These 5 prefectures are Miyagi, Ibaraki, Aichi, Hyogo and Tokushima.

represent region ($i \neq j$). The absolute value of these ratios is examined in order to capture the proximity of regions: the regions are said to be similar, when this absolute value becomes small (approaches zero). In order to take account of endogeneity issues, equation (4) will be estimated by the Generalized Method of Moments (GMM). Davis et al (2011), for example, showed that industrial structure is affected by inflation in OECD countries, a direction of causality opposite to (4).

Table 6 summarizes our empirical results and also lists the instruments used in the 2-step GMM estimation. The standard errors (SE) in this table are robust to heterogeneity and autocorrelation. We used only the secondary and tertiary sectors in this analysis since the primary sector is insignificant in size and is converging within a country. Generally the results are consistent with our expectations; all key variables have a correct sign often with statistical significance. Namely, regional differences in industrial structure, demographic factors and deposits are negatively correlated with regional inflation. Thus, we confirm that a similar level of regional inflation can be observed among similar regions in terms of these three criteria. This result is generally unchanged even when correlations with a different window size are employed.

This is also consistent with our preliminary analysis of the data. Due to its heavy reliance on services (e.g., tourism) for geographical and historical reasons, Okinawa had a rather distinctive profile with the lowest and highest ratios for the secondary and tertiary sectors respectively (Table 4). This distinguishing factor seems to contribute to the low correlation of inflation with other regions.

Since industrial structure shows no sign of convergence in general, we expect the low correlations of regional inflation among heterogeneous regions in future too. Thus heterogeneous regional inflation is not a transitory but a long-term phenomenon even among the Japanese regions which are often considered, by international standards, to be homogenous in many respects.

The GMM results are known to be sensitive to the choice of instrumental variables, and recent studies emphasize the importance of checking both the order (i.e., the number of instruments greater than the unknown parameters) and rank conditions in order to see the appropriateness of instruments. In this connection, the under-identification (Kleibergen and Paap 2006) and weak identification (Stock and Yogo 2005) tests are implemented in this study.[12] All these tests in additional to the conventional Hansen J test confirm that our instruments are statistically appropriate and thus our results are reliable.

Finally, we consider extra variables which capture the financing costs of firms since there is evidence that regional inflation responds differently to exogenous shocks which are common to regions (Nagayasu 2011) and firms respond heterogeneously to increases in financing costs (Berman et al 2009; Dhyne and Druant 2010). Furthermore, studies on Pricing-to-Market give rise to evidence of partial exchange rate pass-through into import prices in advanced countries although this pass-through effect has been declining in recent years (Warmedinger 2004, Campa and Golderg 2005, Otani et al 2006). In this regard, we use the call rate (R) and a nominal effective exchange rate (EER) which is expressed in terms of yen.

The results are summarized in Table 7. Again, the model is estimated by the GMM, and instrumental variables are explained in the table. Increases in financial costs are represented by a rise in R and a decline in EER (i.e., yen depreciation). In such circumstances, we expect a low level of inflation correlation and thus a negative

[12] These tests examine the null hypothesis of under-identification and weak instruments respectively.

(positive) relationship between inflation correlation and the call rate (the exchange rate). Using the growth rates of these variables, our data confirm this theoretical expectation; at times of tight monetary policies and yen depreciation, heterogeneities become more apparent in regional inflation. In terms of statistical significance, the exchange rate is reported to be more influential over inflation correlations. With respect to variables in the absolute value, the results remain the same as before and indicate high inflation correlation among similar regions.

5. Summary and Discussion

This paper empirically investigated the relationship between regional inflation and industrial structure using Japanese regional data, and reported mainly two findings. First, industrial structure has been changing in Japan; while the primary sector has been diminishing throughout Japan, there is evidence of non-convergence in the secondary and tertiary sectors which dominate the economy. Second, given this, we found that there is a strong link between the correlations of regional inflation and changes in industrial structure. Since there is no sign of convergence in the key sectors among regions, the phenomenon of heterogeneous inflation is likely to prevail in years to come. Third, our data suggest that inflation correlations tend to decline at times of increasing financial cost, which also reflects the different economic structures in each region.

While this study focuses on Japanese regions, our findings provide potentially useful information for countries considering joining the euro area. Since there is no strong sign of convergence in industrial structure in Europe, our study predicts continuously heterogeneous inflation in the future. If so, economic imbalances must be dealt with by other means such as fiscal transfers—a lack of which likely makes a continued monetary union very difficult to achieve. Nagayasu (2011) discussed that the size of intergovernmental fiscal transfers in Japan (from central to local governments) is one of the highest among the major industrialized nations.[13] Without such a transfer mechanism, prevented in the euro area by the Lisbon Treaty, stronger discipline regarding inflation and price convergence is necessary to maintain the single currency area. In contrast, our findings may have limited policy implications for the Japanese monetary authorities. This is because inflation spillover from the urban (e.g., Kanto area) to other regions is substantial. Such circumstances may justify close monitoring of inflation developments in Kanto, even in order to control inflation in other areas.

[13] More generally, the necessity of fiscal transfers is closely related to the lack of factor mobility, a factor preventing the creation of an optimal currency area pointed out by Mundell (1961).

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Appendix. Data Description

Regional classification (based on the Statistics Bureau, the Ministry of Internal Affairs and Communications)

Region	Prefectures
Hokkaido	Hokkaido
Tohoku	Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima
Kanto	Ibaraki, Tochigi, Gunma, Saitama, Chiba, Tokyo, Kanagawa, Yamanashi, Nagano
Hokuriku	Niigata, Toyama, Ishikawa, Fukui
Tokai	Gifu, Shizuoka, Aichi, Mie
Kinki	Shiga, Kyoto, Osaka, Hyogo, Nara, Wakayama
Chugoku	Tottori, Shimane, Okayama, Hiroshima, Yamaguchi
Shikoku	Tokushima, Kagawa, Ehime, Kochi
Kyushu	Fukuoka, Saga, Nagasaki, Kumamoto, Oita, Miyazaki, Kagoshima
Okinawa	Okinawa

Regional CPI: Monthly data are obtained from the Statistics Bureau, the Ministry of Internal Affairs and Communications (MIAC). Quarterly data are based on the end-of-period.

Regional/Sectoral GDP: Annual data are obtained from the Cabinet Office, Government of Japan. Two datasets are combined using year 1999 as a benchmark. Annual data are converted to quarterly data and real data using regional CPI since sectoral price data consistent with our regional classification are not available.

Population/Dependency ratio: Annual data are obtained from the e-Stat organized by the MIAC. http://www.e-stat.go.jp/SG1/chiiki/ToukeiDataSelectDispatchAction.do.

Deposits: Demand deposits are from the Bank of Japan.

Interest rates: call rates from the Nikkei Needs.

Effective exchange rates: nominal effective exchange rates from the International Financial Statistics of the International Monetary Fund.

Table 1. Basic Statistics of Regional Inflation and Industries

No.	Region	Obs	Mean	Std. Dev.
1	Hokkaido	129	0.016	0.023
2	Tohoku	129	0.018	0.025
3	Kanto	129	0.017	0.023
4	Hokuriku	129	0.017	0.023
5	Tokai	129	0.017	0.022
6	Kinki	129	0.016	0.022
7	Chugoku	129	0.017	0.024
8	Shikoku	129	0.016	0.022
9	Kyushu	129	0.017	0.024
10	Okinawa	129	0.014	0.021
F(9,120)			4.130	0.000

Note: F test examines the null hypothesis that inflation rates are equal among region.
The period is from 1976Q4 to 2008Q4.

Tables 2. Regional Inflation

% To	From										
	Kanto	Kinki	Tokai	Kyushu	Tohoku	Chugoku	Hokuriku	Hokkaido	Shikoku	Okinawa	From Others
Kanto	89.0	0.5	0.6	4.5	0.0	0.5	0.4	0.2	0.4	4.0	11.0
Kinki	83.5	6.8	0.5	3.9	0.0	0.7	0.1	0.3	0.6	3.6	93.0
Tokai	81.7	1.5	6.5	4.6	0.3	0.5	0.1	0.2	0.7	3.9	94.0
Kyushu	72.6	2.4	1.0	15.9	0.2	1.2	0.1	0.1	0.9	5.6	84.0
Tohoku	76.9	0.9	1.9	11.1	5.3	0.9	0.3	0.3	0.2	2.2	95.0
Chugoku	75.6	1.5	2.3	8.6	0.6	5.9	0.1	0.2	0.9	4.4	94.0
Hokuriku	74.6	0.8	1.5	6.7	1.3	1.2	8.6	0.3	0.9	4.0	91.0
Hokkaido	71.5	0.7	0.5	9.0	5.4	0.4	0.5	9.1	0.4	2.5	91.0
Shikoku	75.9	1.2	1.8	10.6	0.8	1.2	0.3	0.2	4.8	3.3	95.0
Okinawa	51.7	0.9	0.6	6.7	2.0	1.4	0.6	1.1	0.2	34.9	65.0
Contribution to others	664.0	10.0	11.0	66.0	10.0	8.0	2.0	3.0	5.0	33.0	813.0
Contribution incl. own	753.0	17.0	17.0	82.0	16.0	14.0	11.0	12.0	10.0	68.0	0.8

Note: The order of regions is based on the scale of GDP. Based on the fourth period ahead forecasting model.

Table 3. Correlation Level/levels

Order	Pair	Mean	Std. Dev	Order	Pair	Mean	Std. Dev
1	Kanto-Kinki	0.926	0.071	24	Tohoku-Hokuriku	0.825	0.212
2	Kinki-Kyushu	0.901	0.079	25	Hokuriku-Kyushu	0.819	0.172
3	Kanto-Tokai	0.889	0.157	26	Hokuriku-Kinki	0.812	0.263
4	Shikoku-Kyushu	0.888	0.119	27	Hokkaido-Tohoku	0.811	0.200
5	Tohoku-Kanto	0.886	0.132	28	Tokai-Shikoku	0.808	0.236
6	Tokai-Kinki	0.885	0.136	29	Hokkaido-Kinki	0.807	0.182
7	Kanto-Kyushu	0.882	0.096	30	Hokkaido-Kyushu	0.804	0.173
8	Hokuriku-Shikoku	0.878	0.095	31	Kanto-Okinawa	0.798	0.152
9	Kinki-Chugoku	0.876	0.115	32	Hokuriku-Chugoku	0.795	0.212
10	Chugoku-Kyushu	0.874	0.155	33	Tokai-Kyushu	0.792	0.248
11	Tohoku-Chugoku	0.871	0.159	34	Hokkaido-Tokai	0.790	0.254
12	Tokai-Chugoku	0.871	0.134	35	Hokkaido-Hokuriku	0.787	0.194
13	Tohoku-Tokai	0.866	0.158	36	Hokkaido-Chugoku	0.787	0.216
14	Kanto-Chugoku	0.863	0.135	37	Kinki-Okinawa	0.786	0.205
15	Hokkaido-Kanto	0.863	0.126	38	Hokuriku-Tokai	0.777	0.264
16	Tohoku-Kinki	0.858	0.127	39	Chugoku-Okinawa	0.770	0.157
17	Kinki-Shikoku	0.855	0.152	40	Kyushu-Okinawa	0.769	0.192
18	Chugoku-Shikoku	0.851	0.166	41	Tokai-Okinawa	0.747	0.217
19	Tohoku-Kyushu	0.849	0.141	42	Hokkaido-Okinawa	0.740	0.181
20	Kanto-Shikoku	0.841	0.153	43	Shikoku-Okinawa	0.736	0.202
21	Tohoku-Shikoku	0.836	0.160	44	Tohoku-Okinawa	0.707	0.185
22	Hokkaido-Shikoku	0.836	0.154	45	Hokuriku-Okinawa	0.707	0.229
23	Kanto-Hokuriku	0.832	0.267				

Note: Correlation calculated with a window size of 10.

Table 4. Basic Statistics for Industrial Structures

	Obs	Mean	Std. Dev.
		Primary sector	
Hokkaido	129	0.053	0.020
Tohoku	129	0.056	0.029
Kanto	129	0.011	0.006
Hokuriku	129	0.029	0.015
Tokai	129	0.017	0.007
Kinki	129	0.008	0.004
Chugoku	129	0.023	0.013
Shikoku	129	0.048	0.022
Kyushu	129	0.043	0.019
Okinawa	129	0.033	0.015
F(9, 120)		1932.970	0.000
		Secondary sector	
Hokkaido	129	0.233	0.027
Tohoku	129	0.297	0.018
Kanto	129	0.327	0.048
Hokuriku	129	0.346	0.025
Tokai	129	0.429	0.023
Kinki	129	0.336	0.041
Chugoku	129	0.355	0.019
Shikoku	129	0.310	0.025
Kyushu	129	0.269	0.019
Okinawa	129	0.187	0.031
F(9, 120)		7301.300	0.000
		Tertiary sector	
Hokkaido	129	0.715	0.044
Tohoku	129	0.647	0.035
Kanto	129	0.662	0.053
Hokuriku	129	0.624	0.038
Tokai	129	0.555	0.028
Kinki	129	0.656	0.044
Chugoku	129	0.622	0.028
Shikoku	129	0.641	0.045
Kyushu	129	0.688	0.035
Okinawa	129	0.779	0.043
F(9, 120)		7209.240	0.000

Note: F test examines the null hypothesis that inflation rates are equal among regions.

Table 5. Convergence in Industry Sectors

	Coef.	Std. Err.	P-value	Coef.	Std. Err.	P-value
Primary sector	0 Lag			4 lags		
δ	-1.378E-02	1.432E-03	0.000	-9.210E-04	2.049E-04	0.000
α	2.770E-05	2.810E-05	0.323	6.300E-06	2.910E-06	0.030
δ	-2.265E-02	2.589E-03	0.000	-1.908E-03	3.370E-04	0.000
α1	7.033E-04	1.224E-04	0.000	7.070E-05	1.730E-05	0.000
α2	4.824E-04	1.467E-04	0.001	6.000E-05	2.460E-05	0.015
α3	9.380E-05	2.510E-05	0.000	1.140E-05	2.620E-06	0.000
α4	2.557E-04	6.630E-05	0.000	3.000E-05	1.150E-05	0.009
α5	1.610E-04	4.380E-05	0.000	1.940E-05	4.460E-06	0.000
α6	7.690E-05	1.950E-05	0.000	8.620E-06	2.280E-06	0.000
α7	1.648E-04	5.160E-05	0.001	1.950E-05	6.850E-06	0.004
α8	5.268E-04	1.197E-04	0.000	4.010E-05	1.140E-05	0.000
α9	4.746E-04	1.033E-04	0.000	4.710E-05	1.120E-05	0.000
α10	3.512E-04	7.150E-05	0.000	1.980E-05	1.110E-05	0.074
Secondary sector						
δ	-6.128E-04	9.898E-04	0.536	-6.870E-06	6.620E-05	0.917
α	-5.469E-04	2.602E-04	0.036	-2.300E-05	1.920E-05	0.231
δ	-2.086E-04	2.567E-03	0.935	-1.020E-04	2.456E-04	0.678
α1	-7.786E-04	5.764E-04	0.177	-8.800E-06	5.230E-05	0.866
α2	-2.073E-04	8.041E-04	0.797	9.920E-06	7.020E-05	0.888
α3	-1.108E-03	8.052E-04	0.169	-2.380E-05	7.440E-05	0.749
α4	-6.138E-04	8.954E-04	0.493	-1.080E-05	8.250E-05	0.896
α5	-5.085E-04	1.125E-03	0.651	8.940E-06	1.004E-04	0.929
α6	-8.864E-04	8.648E-04	0.305	-6.680E-06	8.220E-05	0.935
α7	-3.320E-04	8.949E-04	0.711	1.850E-05	9.150E-05	0.840
α8	-8.083E-04	7.913E-04	0.307	-2.120E-05	7.680E-05	0.783
α9	-3.528E-04	7.271E-04	0.628	4.760E-06	6.410E-05	0.941
α10	-6.427E-04	4.649E-04	0.167	-5.300E-06	4.910E-05	0.914
Tertiary sector						
δ	8.200E-04	1.062E-03	0.440	2.108E-04	9.830E-05	0.032
α	4.570E-04	7.780E-04	0.557	-9.960E-05	6.920E-05	0.150
δ	1.187E-03	2.345E-03	0.613	1.261E-04	2.162E-04	0.560
α1	4.727E-04	1.720E-03	0.784	-1.240E-05	1.682E-04	0.941
α2	2.963E-04	1.506E-03	0.844	-1.690E-05	1.516E-04	0.911
α3	5.567E-04	1.602E-03	0.728	-2.420E-05	1.673E-04	0.885
α4	3.563E-04	1.486E-03	0.811	4.470E-08	1.510E-04	1.000
α5	1.542E-04	1.289E-03	0.905	-3.480E-05	1.352E-04	0.797
α6	2.842E-04	1.560E-03	0.855	-3.910E-05	1.576E-04	0.804
α7	3.080E-05	1.475E-03	0.983	-4.520E-05	1.329E-04	0.734
α8	6.823E-04	1.525E-03	0.655	2.990E-05	1.470E-04	0.839
α9	9.930E-05	1.591E-03	0.950	-3.330E-05	1.524E-04	0.827
α10	1.578E-04	1.834E-03	0.931	-2.750E-05	1.666E-04	0.869

Note: The number next to α corresponds to the order of regions shown in Table 1. Based on equation (3).

Table 6. Determinants of Regional Inflation

	Coef.	SE	p-value	Coef.	SE	p-value
Window size=5	Secondary sector			Tertiary sector		
$\|Ind_{it}-Ind_{jt}\|$	-2.178	0.272	0.000	-1.893	0.230	0.000
$\|Work\_pop_{it}-Work\_pop_{jt}\|$	-1.334	0.326	0.000	-0.915	0.204	0.000
$\|Deposit_{it}-Deposit_{jt}\|$	-0.200	0.042	0.000	-2.178	0.042	0.000
Time (t)	0.000	0.000	0.623	0.000	0.000	0.003
Const (α)	0.991	0.023	0.000	0.919	0.015	0.000
R^2	0.889			0.896		
No. obs	5490.000			5490.000		
Under-identification	362.208		0.000	485.871		0.000
Weak identification	85.576			133.861		
Hansen J	0.833		0.659	2.028		0.363
Window size =10	Secondary sector			Tertiary sector		
$\|Ind_{it}-Ind_{jt}\|$	-1.979	0.197	0.000	-1.715	0.160	0.000
$\|Work\_pop_{it}-Work\_pop_{jt}\|$	-0.839	0.154	0.000	-4.481	0.139	0.001
$\|Deposit_{it}-Deposit_{jt}\|$	-0.178	0.028	0.000	-0.193	0.027	0.000
Time (t)	-0.001	0.000	0.000	-0.001	0.000	0.000
Const (α)	1.105	0.017	0.000	1.040	0.011	0.000
R^2	0.944			0.949		
No. obs	5265.000			5260.000		
Under-identification	371.988		0.000	502.664		0.000
Weak identification	88.134			139.629		
Hansen J	1.571		0.456	3.687		0.158
Window size=20	Secondary sector			Tertiary sector		
$\|Ind_{it}-Ind_{jt}\|$	-1.140	0.098	0.000	-1.004	0.079	0.000
$\|Work\_pop_{it}-Work\_pop_{jt}\|$	-0.300	0.079	0.000	-0.099	0.067	0.140
$\|Deposit_{it}-Deposit_{jt}\|$	-0.005	0.010	0.632	-0.013	0.008	0.089
Time (t)	-0.002	0.000	0.000	-0.001	0.000	0.000
Const (α)	1.106	0.009	0.000	1.070	0.006	0.000
R^2	0.988			0.989		
No. obs	4815.000			4815.000		
Under-identification	340.495		0.000	463.725		0.000
Weak identification	78.797			123.312		
Hansen J	1.829		0.401	0.095		0.953

Note: Estimated by GMM. Fixed effects and time dummies are considered in the specification but are not reported here. Included instruments are a regional difference in real GDP growth (the first and third lags), population growth (the first lag), deposits (the third lag) and the working population ratio (the first lag).

Table 7. Determinants of Regional Inflation with Cost Variables

	Coef.	SE	p-value	Coef.	SE	p-value
Window size=10	Secondary sector			Tertiary sector		
$\lvert Ind_{it}-Ind_{jt}\rvert$	-2.062	0.197	0.000	-1.783	0.159	0.000
$\lvert Work\_pop_{it}-Work\_pop_{jt}\rvert$	-0.908	0.154	0.000	-0.542	0.139	0.000
$\lvert Deposit_{it}-Deposit_{jt}\rvert$	-0.183	0.029	0.000	-0.199	0.028	0.000
ΔR	-0.002	0.003	0.576	-0.003	0.003	0.270
ΔEER	0.253	0.025	0.000	0.255	0.023	0.000
Time (t)	-0.001	0.000	0.000	-0.001	0.000	0.000
Const (α)	1.089	0.017	0.000	1.020	0.011	0.000
R^2	0.944			0.950		
No. obs	5265.000			3264.000		
Under-identification	367.688		0.000	499.881		0.000
Weak-identification	72.486			115.763		
Hansen J	2.787		0.426	4.958		0.175

Note: Estimated by GMM. Fixed effects and time dummies are considered in the specification but are not reported here. Included instruments are M1 growth, regional differences in real GDP growth (the first and third lags), population growth (the first lag), deposits (the third lag) and the working population ratio (the first lag).

Figure 1. Regional Inflation

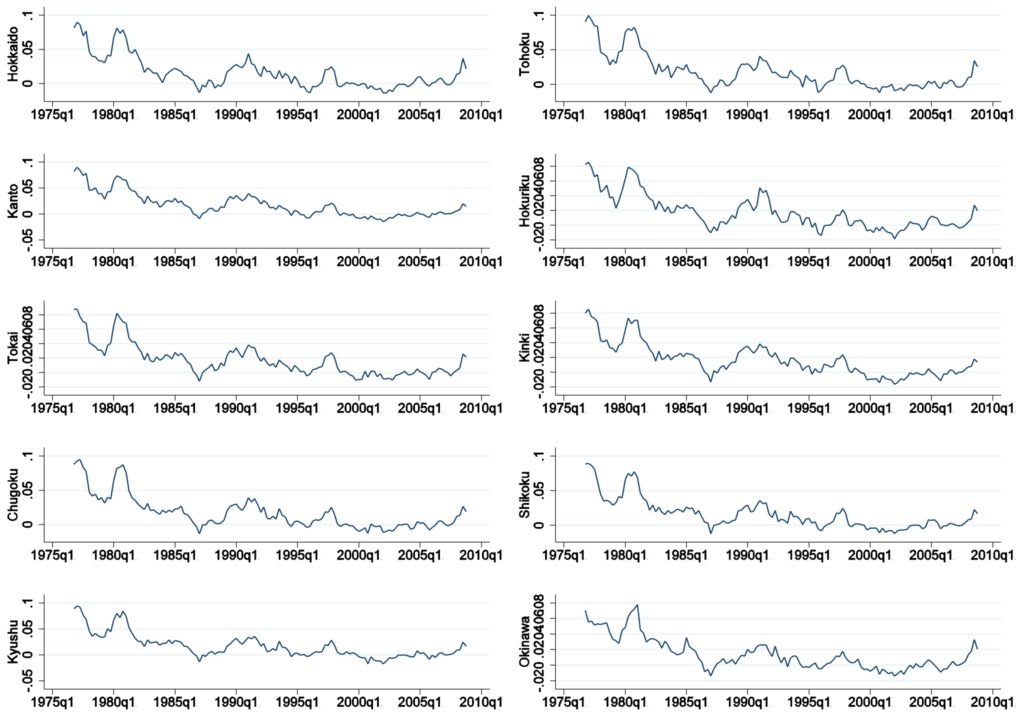
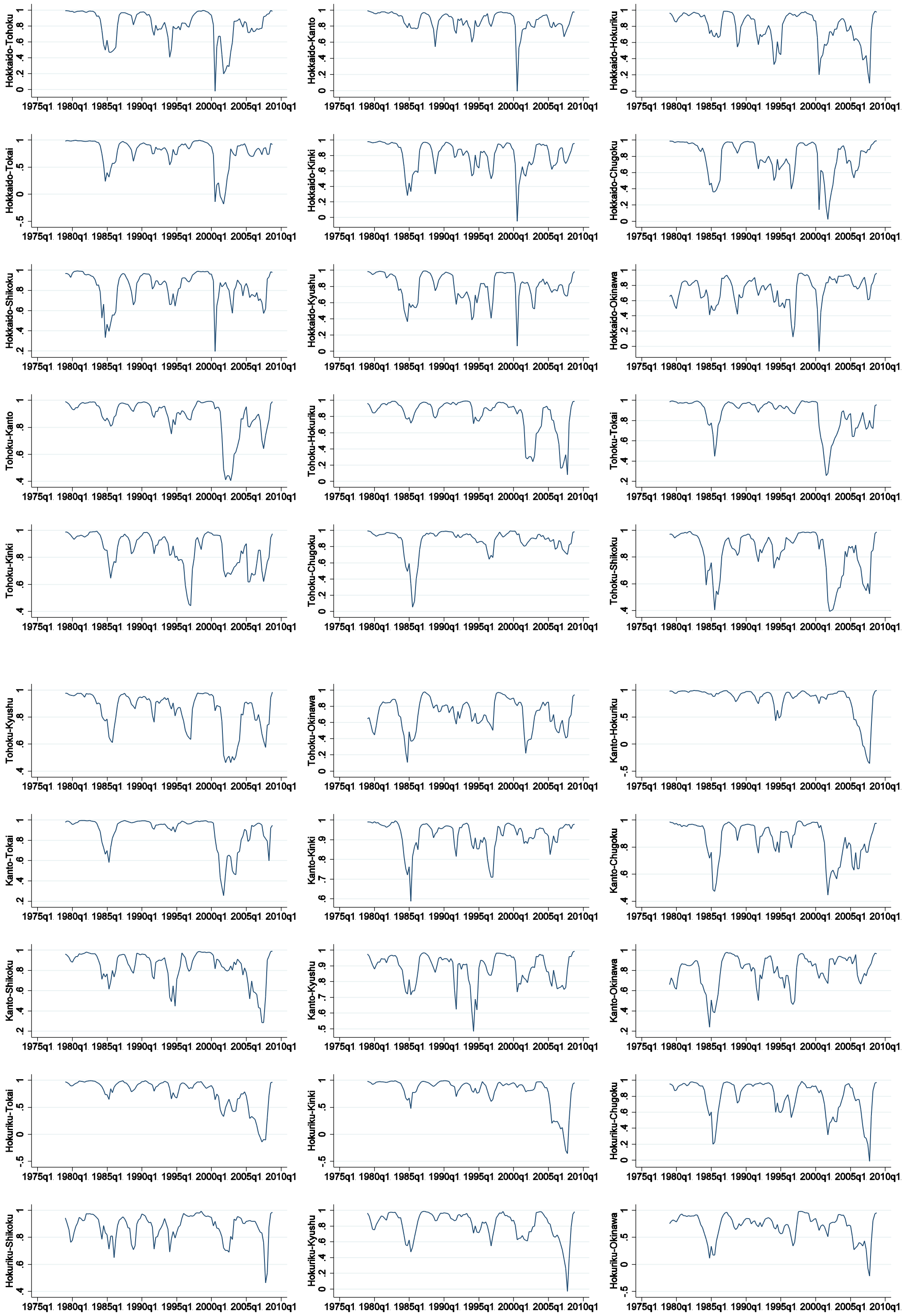


Figure 2. Correlation of Regional Inflation



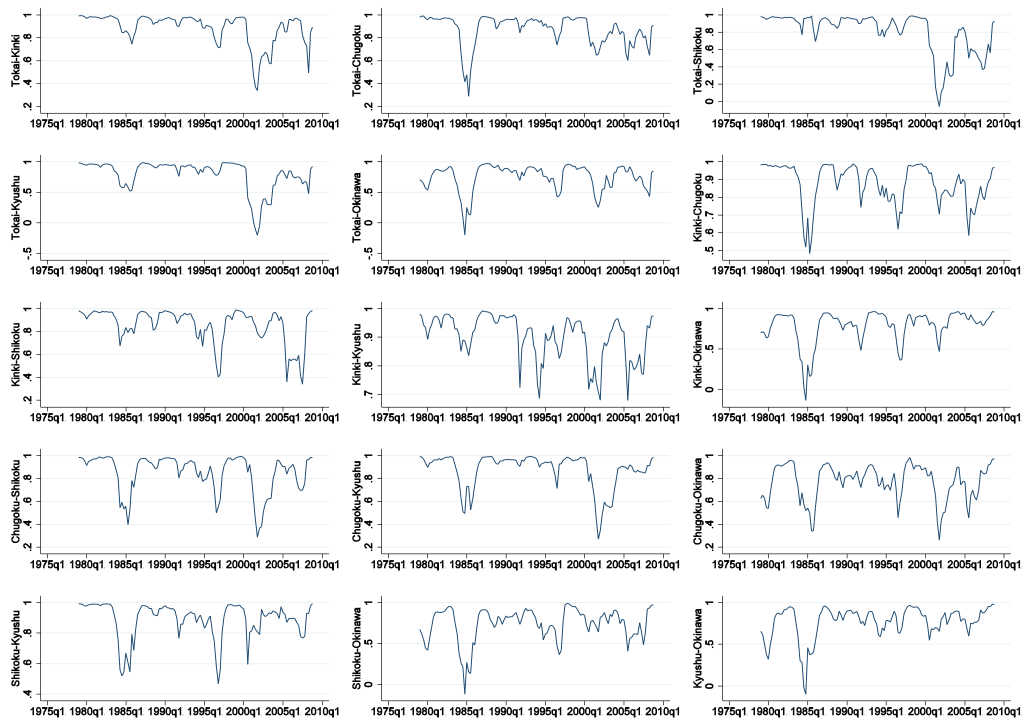
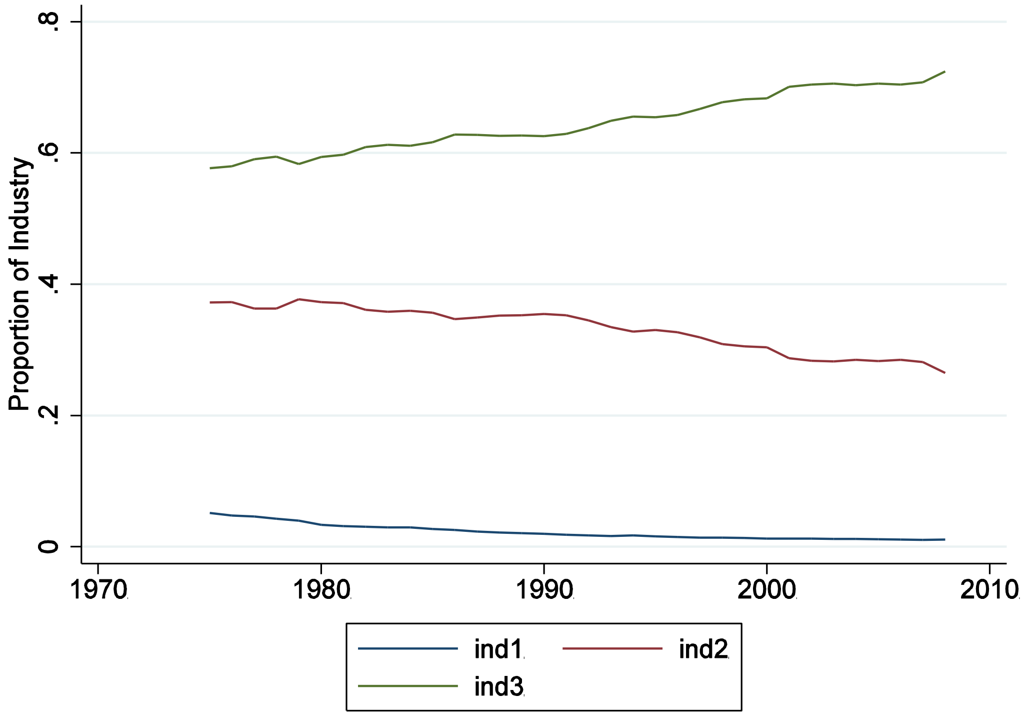

Tokai-Kinki
Tokai-Chugoku
Tokai-Shikoku
Tokai-Kyushu
Tokai-Okinawa
Kinki-Chugoku
Kinki-Shikoku
Kinki-Kyushu
Kinki-Okinawa
Chugoku-Shikoku
Chugoku-Kyushu
Chugoku-Okinawa
Shikoku-Kyushu
Shikoku-Okinawa
Kyushu-Okinawa
1975q1 1980q1 1985q1 1990q1 1995q1 2000q1 2005q1 2010q1

Figure 3. Proportion of Industries



Note: Annual industry specific data are aggregated at the country level. The primary, secondary and tertiary sectors are shown as ind1, ind2 and ind3 respectively.