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Regional Business Cycles in South Korea: An Endogenously Clustered Factor Approach*

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We investigate the economic fluctuations across 16 regions of Korea by decomposing them into a common factor and a cluster factor using an endogenously clustered dynamic factor model. We extract these factors from regional economic activity variables, namely, output, consumption, and investment, and we endogenously determine the clusters based on the characteristics of regions and economic activities. We find that consumption and investment activities and investment volatility are significant determinants of the cluster factors. Our results show that the estimated common factor captures the dynamics of national real GDP and private consumption growth and substantially contributes to the fluctuations in output and consumption. We also note that the output fluctuations in regions with a high sensitivity to the investment cycle are significantly affected by the cluster factor. However, the fluctuations in investment are mainly driven by the idiosyncratic factor.

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I. Introduction

When formulating policies to strengthen regional economic competencies and ensure stability against domestic and international economic shocks, the social and

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economic characteristics specific to each region should be taken into account. The South Korean domestic economy experienced region-specific crises between 2018 and 2021. For example, Gunsan in Jeonbuk was affected by the restructuring of the automotive industry in 2018, while coastal regions were affected by a severe downturn in the shipbuilding industry during the COVID-19 pandemic.[1] Examining the characteristics specific to Korean regional economies in light of these circumstances is important from a policy and academic perspective.

Identifying the factors behind regional economic fluctuations requires a clear understanding of not only the unique industrial structure of a region and its total production and expenditure but also how sensitively the regional economy responds to national macroeconomic impacts. If a common national factor affecting Korea's overall economy is an important cause of fluctuations in regional economies, then policies targeting region-specific economic variables will have limited effects. However, if the factors affected by regional economic events or certain economic activities are the main causes of fluctuations in regional economies, then tailored policies will play a crucial role in stabilizing the regional economy. Understanding the fluctuations in Korea's economy from a macro perspective and identifying the factors causing these fluctuations constitute a good starting point for discussing regional economic policies.

To understand regional differences, the factors that trigger regional economic fluctuations need to be identified. Regional economic condition is determined by common factors at the national level, such as macroeconomic impacts or government regulations and other factors within the region, including the consumption and investment share of regional production, variations in industrial structure, shifts in population structure, and household financial conditions. The nature of fluctuations in the regional economy is also determined by the relative size and direction of the region's response to these factors. Therefore, rather than determining the cause of economic fluctuations in each region as a single factor, the regional impact of various factors that explain the changes in the regional economic situation should be considered. If the factors causing fluctuations in regional economies are determined by focusing on the total production or expenditure in the region yet ignoring the common characteristics of a group of regions and economic activities, then those factors related to such fluctuations may be misidentified, leading to inaccurate policy goals and unintended results.

Given this background, we divide the sources of regional business cycles in Korea into common and clustered factors by applying a dynamic factor model. For our measures of business cycle activity, we use the annual gross regional domestic product (GRDP) and expenditure (private consumption and investment) to

[1] Dong-gu District of Ulsan, the Jinhae-gu District of Changwon, Geoje, Tongyeong, and Goseong in Gyeongnam, Yeongam, Mokpo, and Haenam in Jeonnam, which were affected by the crisis in the shipbuilding industry, were designated as "Special Regions for Industrial Crisis Response".

represent regional economic activities. Following the approach of Francis, Owyang, and Savascin (2017), we endogenously determine a cluster factor based on regional economic characteristics and certain economic activities. This approach allows a cluster factor to share common information not only on regions but also on economic activities. For example, a cluster factor that significantly affects business cycles in industrialized regions might share common information on the investment dynamics in these regions.

Our results show that the dynamics of the common factor align closely with those of real GDP and private consumption. We identify consumption, investment cycles, and investment volatility as significant determinants of the cluster factors, and we find that the endogenously clustered factor approach is superior to the exogenously clustered factor approach based on their statistical entropy scores. According to the variance decomposition of regional business cycles, we identify the common factor as the most significant factor that affects the fluctuations in output and consumption. Meanwhile, the idiosyncratic factor has the greatest influence on the fluctuations in investment.

In terms of regional GRDP growth rates, Seoul and Gyeonggi are strongly influenced by the common factor, while Incheon and Daejeon are influenced by the cluster factor that reflects the GRDP and investment fluctuations in these regions. The Jeonnam region, which is characterized by a high ratio of imports and exports to GRDP and a substantial manufacturing sector, is also influenced by the cluster factor. As for private consumption, the common factor significantly affects Gwangju and Daejeon, whereas the Jeonnam and Gyeongbuk regions are significantly influenced by the cluster factor that is likely to include the consumption fluctuations in these regions. In terms of investment fluctuations, the role of the common factor is relatively subdued likely due to the diversity in industrial structures, the regional biases within sectors, and the varying degrees of specialization across regions, all leading to a marked heterogeneity in investment.

Hwang (2013) breaks down regional economic fluctuations into a common factor and arbitrarily predetermined factors at the regional level based on the Bayesian dynamic factor model and then analyzes the importance of each factor in the variability of regional economic fluctuations. Unlike Hwang (2013), our endogenous cluster factor model endogenously determines the cluster factors that influence regional economic fluctuations by considering the characteristics of regions and economic activities. This approach avoids the model misspecification problem and adds some economic significance to the cluster factors. Against this backdrop, we use variables related to regional economic activities (output, consumption, and investment) or other region-specific characteristics to determine whether the regional economic fluctuations are triggered by a coupling phenomenon with a common national factor or a phenomenon limited to endogenously determined cluster factors.

Several studies have investigated economic fluctuations across regions and countries. For instance, Hwang (2013) highlights the significant role of a common factor in Korea's regional business cycles, especially the fluctuations in output and consumption. Hwang (2013) also emphasizes that the relative importance of nationwide-common versus region-specific factors that explain regional economic fluctuations is determined by the proportion of regional manufacturing production and government spending. Lee (2020) finds that about 10% of GDP fluctuations in Asia can be attributed to a global factor based on the dynamic factor model. Other relevant studies include Kose, Otrok, and Whiteman (2003), who investigate international economic fluctuations at global, regional, and national levels by estimating the dynamic factor model based on Bayesian methodology. In their follow-up study, Kose, Otrok, and Whiteman (2008) investigate the synchronized economic fluctuations between nations. Crucini, Kose, and Otrok (2003) employ a dynamic factor model to comprehensively analyze the macroeconomic factors that cause international economic fluctuations in G7 countries, while Kose, Otrok, and Prasad (2012) analyze the interdependence of global economic fluctuations.

The work of Hamilton and Owyang (2012) serves as the foundation for our adopted methodology. They endogenously determine the expansions or recessions of regions using variables that represent the economic structure of each region in order to study the similarities and differences in economic fluctuations among U.S. states. In addition, to explain economic fluctuations by country, Francis, Owyang, and Savascin (2017) use an endogenously clustered factor model in which the economic fluctuations of each country are determined endogenously according to their characteristics. This model differs from the previous dynamic factor models in which factors are pre-determined by region or economic development.

The rest of this paper is organized as follows. Section 2 describes the basic characteristics of the data used in the model. Section 3 explains the quantitative model and the estimation method. Section 4 presents the results of the estimated model with regional business cycle data. Section 5 summarizes and concludes the study.

II. Data and Regional Economic Activities

2.1. Data

We use the output, private consumption, and investment data of 16 municipal governments, including Seoul Metropolitan City, 6 other metropolitan cities (Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan), and 9 provinces (Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju), to identify those factors that cause regional economic fluctuations in

Korea. We also employ real GRDP to represent regional production, real private final consumption expenditure to represent private consumption, and real gross fixed capital formation to represent investment. We obtain our data from the regional income statistics published by KOSIS of Statistics Korea. Data on real GRDP are available from 1985, while data on private final consumption expenditure and gross fixed capital formation are available from 1995. Given that Gwangju, Daejeon, and Ulsan were designated as metropolitan cities in 1987, 1989, and 1998, respectively, our sample period spans from 1998 to 2019. We use year-on-year growth rates for the analysis.[2]

We analyze the factors related to economic activities (output, consumption, and investment) in each region by dividing the regional business cycles into a nationwide common factor, a cluster factor that reflects the common characteristics of a group of regions and the cycle of a certain economic activity, and an idiosyncratic factor. We use dummy variables for GRDP and expenditure (consumption and investment) to represent the characteristics of economic activities, and we use variables representing a region's economic structure to determine the cluster factor. The following determinants in Table 1 are computed as the average for years 1999–2019: the ratio of private consumption per capita to disposable income per capita (CONSHR), the ratio of government expenditure to GRDP (GOVSHR), the ratio of the GRDP of the manufacturing industry to the total GRDP (MANSHR), the ratio of the GRDP of the service industry to the total GRDP (SERSHR), the volatility of GRDP growth rate (GRDPVOL), the volatility of private consumption to GRDPVOL (CONGRDPVOL), the volatility of investment to GRDPVOL (INVGRDPVOL), and the amount of exports and imports to GRDP (OPENNESS).[3]

[Table 1] Determinants of cluster factors

CONSHR	Private consumption per capita/individual income per capita
GOVSHR	Government final consumption expenditure/GRDP
MANSHR	GRDP of manufacturing industry/GRDP
SERSHR	GRDP of service industry/GRDP
GRDPVOL	Volatility of real GRDP
CONGRDPVOL	Volatility of real private consumption/GRDPVOL
INVGRDPVOL	Volatility of real investment/GRDPVOL
OPENNESS	(Exports+imports)/Real GRDP

Note: Each variable represents a region-specific value. Volatility of economic activities stands for a standard deviation.

[2] Given that data on Sejong City were added only in 2013, we exclude this city from our study.

[3] We collect all data from KOSIS DB of Statistics Korea, and we calculate GRDP per capita using estimated population data from Statistics Korea. Fluctuations in private consumption and investment refer to fluctuations in private final consumption expenditure and gross fixed capital formation, respectively.

2.2. Regional Economic Activities

2.2.1. Dynamics of Regional Economic Activities

Figure 1 compares the dynamics of GRDP growth rate, private consumption, and investment from 1999 to 2019. The first column shows the GRDP growth rates. The dynamics in the capital area are most similar to the nationwide growth rate, whereas the GRDP growth rates of Gangwon and Jeju show significant differences from the national index.[4] In the capital area, the GRDP growth rate of Gyeonggi tends to exceed the national index and exhibit a similar trend. Seoul's growth rate is very similar to that of the rest of the country, except during the years 2003 and 2005.

Gyeongsangnam-do's growth rate is also similar to that of the country until 2011 but sinks below this level thereafter. Moreover, the GRDP growth rate in Ulsan suffers from great ups and downs, including a significant increase in 2004 and a decline to negative rates in 2003, 2008–2010, and 2017–2019. Busan's GRDP growth rate is negative during the 2009 financial crisis, and the same trend continues in 2010. Gyeongsangbuk-do has experienced repeated fluctuations in its GRDP growth rate since 2012. The GRDP growth rate of Daegu City, which represents the Gyeongbuk area, shows a large drop in 2016 followed by a decreasing trend.

In Joella, Jeollanam-do shows minimal growth in 1999, while Gwangju and Jeollanam-do show significant growths in 2010. These areas have contributed substantially to the national GRDP growth. In the Chungcheong region, the GRDP growth rate in Chungcheongbuk-do significantly differs from the national index between 2003 and 2009, while Chungcheongnam-do's growth rate differs from the national index during 2002–2007 and 2013–2019. Meanwhile, the GRDP growth rates in Gangwon and Jeju are the most distinct among all regions when compared with the national trends. Except for Jeju, all regions contribute to a decrease in the national GRDP growth rate in 2009 and an increase in 2010. Jeju frequently shows dynamics opposite to those of the national index. Unlike the national index, which shows no significant fluctuation between 2013 and 2019, most regions show repeated fluctuations during this period.

Contrary to the GRDP and investment growth rates, the private consumption growth rates of these regions tend to comove, showing similar dynamics.[5] For the

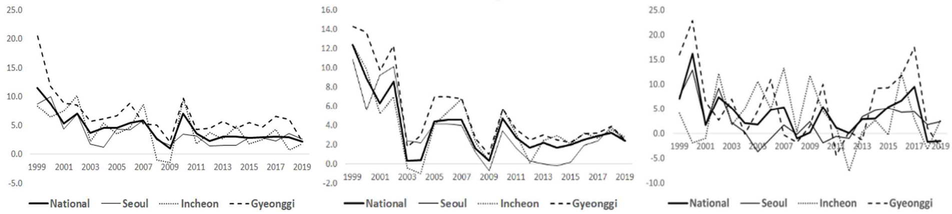
[4] According to Table B1 in Appendix B, the most notable regional GRDP growth rates are reported in Gangwondo and Jejudo due to their low correlations with the other regions (less than 0.5). Specifically, Gangwondo has a low correlation with Ulsan and Jejudo, while Jeju has a particularly low correlation with Chungcheongnamdo, Jeollanamdo, and Gyeongsangnamdo. This result highlights the uniqueness of these two regions.

[5] According to Table B2 in Appendix B, the private consumption growth rate has a generally higher regional correlation than the GRDP and investment growth rates. The regional private consumption growth rate mostly shows a high correlation above 0.5.

[Figure 1] Dynamics of GRDP, consumption, and investment

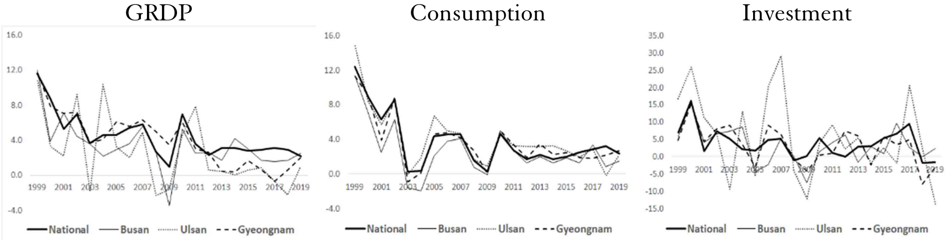
<Figure1A> Capital area

GRDP Consumption Investment



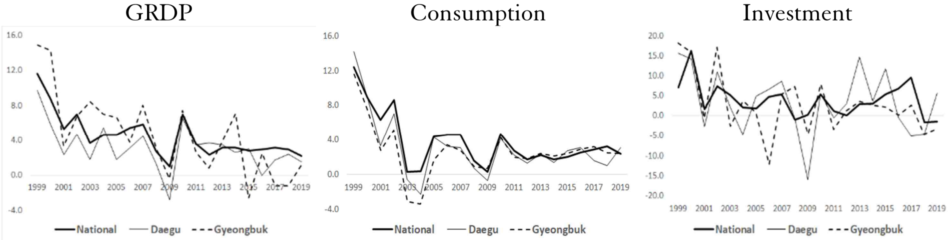
<Figure1B> Gyeongnam area

GRDP Consumption Investment



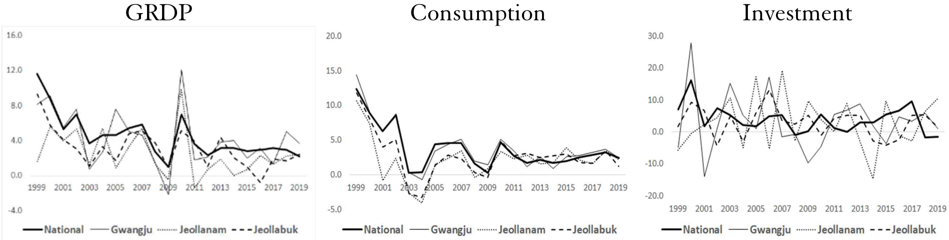
<Figure1C> Gyeongbuk area

GRDP Consumption Investment



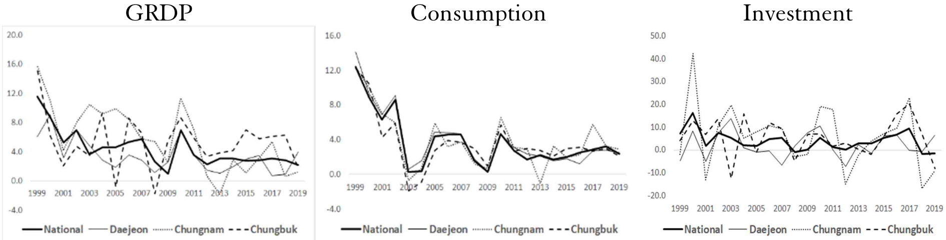
<Figure1D> Jeolla area

GRDP Consumption Investment



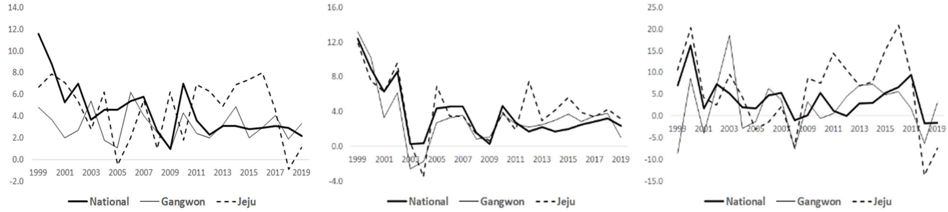
<Figure1E> Chungcheong area

GRDP Consumption Investment



<Figure1F> Gangwon, Jeju

GRDP Consumption Investment



Note: This figure compares the dynamics of regional economic activities for GRDP (leftmost), consumption (center), and investment (rightmost). These figures include the dynamics of the capital area (Figure 1A), Gyeongnam area (Figure 1B), Gyeongbuk area (Figure 1C), Jeolla area (Figure 1D), Chungcheong area (Figure 1E), and Gangwon and Jeju areas (Figure 1F) with the nationwide growth rates (black solid line).

capital area, those periods with dynamics that are least similar to those of the national index include 2012 for Incheon, 2012–2015 for Seoul (which shows a 0% growth rate), 2018 for Busan, Ulsan, and Daegu, 2013 and 2017 for Chungcheongnam-do, and 2012 and 2015 for Jeju-do. The most notable trends are reported during the credit card crisis and the 2008 financial crisis. During the former crisis, a significant difference can be observed in the dynamics between the GRDP and private consumption growth rates, which suggests that the private consumption growth rate during this period may have been driven by a change in consumer preferences and not by a change in consumer income. During the latter crisis, the GRDP growth rate decreases significantly along with the private consumption growth rate, and such co-movement may be due to the known relationship between permanent income and consumption.

In terms of investment growth rate in the capital area, Seoul shows the dynamics most similar to those of the national index. Although Gyeonggi shows a similar trend (except in 2002), larger fluctuations are reported in the area. In the Gyeongnam area, Ulsan's investment growth rate greatly fluctuates from -9.3% in 2003 before reporting a significant increase in 2006 and 2007. In the Gyeongbuk area, Gyeongsangbuk-do's negative growth rate in 2006 and Daegu's negative growth rates in 2009 and 2017 are noteworthy. Gwangju and Jeollanam-do's investment growth rate fluctuations in the Jeolla region are significantly larger than those in Jeollabuk-do. Gwangju suffers from an enormous drop from 27.8% in 2000 to -14% in 2001, while Jeollanam-do reports a negative growth rate in 2014, which is the opposite of the nationwide index. In the Chungcheong area, Chungcheongnam-do's investment growth rate drops significantly from 42.3% in 2000 to -13% in 2001 and shows dynamics similar to those of Gwangju as previously mentioned. Chungcheonbuk-do's investment growth rate in 2003 also moves in the direction opposite to the nationwide investment growth rate. Meanwhile, the fluctuations in the GRDP and private consumption growth rates in Gangwon and

Jeju significantly differ from those of the national index despite showing similar dynamics in their investment growth rates.[6]

[Table 2] Basic statistics: GRDP, consumption, and investment

	GRDP		Consumption		Investment	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Seoul	3.657	2.421	3.276	3.293	2.661	3.899
Busan	3.400	2.849	2.652	2.993	3.281	5.174
Daegu	3.147	2.553	3.052	3.549	3.461	7.852
Incheon	4.214	3.308	3.828	3.290	3.657	5.637
Gwangju	4.242	3.283	3.923	3.439	3.166	9.203
Daejeon	3.471	2.250	3.957	3.412	2.100	5.752
Ulsan	2.547	4.055	4.076	3.433	5.809	12.064
Gyeonggi	6.833	3.924	5.300	4.027	5.747	7.339
Gangwon	3.152	1.440	3.290	3.416	2.457	6.285
Chungbuk	5.342	3.622	3.557	3.147	5.404	8.294
Chungnam	5.838	4.479	3.876	3.323	5.881	14.129
Jeonbuk	3.109	2.233	2.690	3.253	2.933	4.574
Jeonnam	2.552	2.617	2.190	3.060	2.942	8.300
Gyeongbuk	4.576	4.684	2.671	3.109	2.723	7.538
Gyeongnam	4.052	3.117	3.614	3.014	3.276	5.473
Jeju	4.633	2.831	4.247	3.375	5.847	8.839

Note: This table shows the means and standard deviations for regional GRDP, private consumption, and investment growth rates from 1999 to 2019. The data series are obtained from the Korean Statistical Information Service (KOSIS).

2.3. Basic Statistics

Table 2 shows the averages and standard deviations of the regional GRDP, private consumption, and investment growth rates. The average GRDP and private consumption growth rates are the highest in Gyeonggi Province, with Jeju reporting the highest investment growth rate at 5.881 and Gyeonggi reporting the fourth largest growth. By contrast, Ulsan, Jeonnam, and Daejeon report the lowest average GRDP, private consumption, and investment growth rates, respectively. Meanwhile, Gyeongbuk, Gyeonggi, and Chungnam report the greatest standard deviations for GRDP, private consumption, and investment, respectively, while Gangwon, Busan, and Seoul report the smallest standard deviations.

Table 3 presents the averages of the representative variables that determine the clusters at the regional unit level. CONSHR is high in metropolitan areas, including Seoul, indicating a high average consumption tendency. The

[6] According to Table B3 for the correlation of investment growth rate in Appendix B, there are significantly more negative (-) correlations across regions, and its highest value is 0.64, which is a lower correlation compared to the growth rates of GRDP and private consumption.

[Table 3] Basic statistics: Determinants of cluster factors

	CONSHR	GOVSHR	MANSHR	SERSHR	GRDPVOL	CONGRDPVOL	INVGRDPVOL	OPENNESS
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
SEO	0.921	0.103	0.045	**0.826**	2.422	1.360	1.610	0.408
BUS	0.939	0.152	0.169	0.666	2.850	1.051	1.816	0.294
DAG	**0.945**	0.193	0.194	0.661	2.553	1.390	3.076	0.178
INC	0.923	0.139	0.270	0.527	3.309	0.995	1.704	0.694
GWJ	0.933	0.168	0.237	0.618	3.284	1.047	2.803	0.484
DAJ	0.909	0.203	0.161	0.700	2.251	1.516	2.556	0.171
ULS	**0.806**	**0.050**	**0.519**	**0.207**	4.056	0.847	2.975	**1.605**
GGD	0.897	0.130	0.306	0.517	3.925	1.026	1.870	0.503
GWD	0.937	**0.339**	0.087	0.647	**1.440**	**2.372**	**4.365**	0.079
CBD	0.893	0.182	0.368	0.430	3.623	0.869	2.290	0.374
CND	0.912	0.126	0.434	0.304	4.479	0.742	3.154	0.836
JBD	0.891	0.235	0.235	0.505	2.233	1.457	2.048	0.244
JND	0.884	0.182	0.318	0.355	2.617	1.169	3.171	0.832
GBD	0.888	0.146	0.443	0.356	**4.685**	**0.664**	**1.609**	0.655
GND	0.877	0.163	0.380	0.417	3.117	0.967	1.756	0.664
JJD	0.934	0.221	**0.038**	0.638	2.832	1.192	3.122	**0.024**

Note: This table shows the average value of each variable between 1999 and 2019. SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND, and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively. The bold values indicate the maximum and minimum values of each variable. The data series are obtained from the Korean Statistical Information Service (KOSIS).

consumption tendency is also high in Gangwon-do and Jeju-do. The highest GOVSHR of 0.34 is reported in Gangwon-do, indicating that this area has the highest government final consumption expenditure relative to GRDP, while the lowest value of 0.05 is reported in Ulsan. However, Ulsan reports the highest MANSHR—which represents the proportion of the manufacturing industry—at 0.52, while Gangwon-do and Jeju-do have MANSHR values of less than 0.1, indicating a relatively low degree of industrialization. Seoul and Ulsan report the highest and lowest SERSHR values—which represent the proportion of the service industry—of 0.83 and 0.21, respectively. CONGRDPVOL, which represents the volatility of consumption relative to the volatility in GRDP, is highest in Gangwon-do (2.37), which indicates that the consumption in this area might be affected by regional changes in permanent income or consumer preferences. By contrast, the lowest CONGRDPVOL is observed in Gyeongsangbuk-do at 0.66. INVGRDPVOL, which represents the volatility in investment relative to the volatility in the GRDP, is greatest in Gangwon-do (4.37) and lowest in Gyeongsangbuk-do (1.61). OPENNESS is significantly high in Ulsan at 1.61 and is lowest in Jeju at 0.02 followed by Gangwon-do at 0.08, which suggest that Ulsan may have been significantly affected by the changes in external economic conditions, while Jeju-do and Gangwon-do may have been relatively less affected by these changes.

III. Model and Estimation

3.1. Empirical Model

We use the endogenously clustered dynamic factor model proposed by Francis, Owyang, and Savascin (2017), which is a generalized version of the dynamic factor model proposed by Kose, Otrok, and Whiteman (2003, 2008; hereinafter referred to as "KOW"). Unlike the KOW model, which comprises a common factor and a predetermined regional factor, in the endogenously clustered factor model, the clusters are determined endogenously based on the characteristics of regions and economic activities, thereby avoiding misspecification. The model and estimation method explained below are based on Francis, Owyang, and Savascin (2017).

The endogenously clustered dynamic factor model assumes that the observed data in each region can be explained by common and unobserved factors comprising endogenously determined cluster factors. In the analysis, we use M number of regions (16 regions) and N number of economic activity variables (three variables: output, consumption, and investment) that represent regional business cycles with length T. We assume that a regional economic activity variable ($y_{i,t}$, $i=1,\cdots,M\times N$, $t=1,\cdots,T$), which is an observable variable, comprises a linear combination of a common factor (f_t^G), a cluster factor of regional characteristics and economic activities $(f_{r,t}^C)$, and an idiosyncratic factor $(\varepsilon_{i,t})$.[7] The observable $y_{i,t}$ (an economic activity variable for each region) can be expressed as follows:

$$y_{i,t} = \beta_i^G f_t^G + \sum_{r=1}^{R} \gamma_{r,i}^C \beta_{r,i}^C f_{r,i}^C + \varepsilon_{i,t}, \tag{1}$$
$$E\varepsilon_{i,t}\varepsilon_{j,t-s} = 0 \quad \text{for} \quad i \neq j,$$

where r represents a cluster at the level of regions and economic activities, and $\gamma_{r,i}^C$ represents the cluster index. We assume that each regional economic activity i belongs to a unique cluster r. An economic activity belonging to cluster r has a $\gamma_{r,i}^C$ value of 1, while an economic activity outside this cluster takes a value of 0. Therefore, $\sum_{r=1}^{R}\gamma_{r,i}^C = 1$ holds true. According to Equation (1), the economic activities among regions that do not belong to the same cluster are coupled only by

[7] Based on the entropy criterion specified in Francis, Owyang, and Savascin (2017), we set the total number of cluster factors (R) as 7 and consider 3 to 10 cluster factors.

the common factor. However, if the economic activities among these regions belong to the same cluster, then these activities are coupled not only by the common factor but also by the cluster factor of the regions and economic activities. β_i^G and $\beta_{r,i}^C$ constitute a coefficient that represents the sensitivity of the regional economic activity variables to the common factor and the cluster factor, respectively.

To set a cluster factor endogenously, by taking into consideration regional characteristics and economic activities, the probability for each regional activity to belong to a certain cluster can be expressed as the following multinomial logistic function:

$$\Pr[\gamma_{i,r}=1\,|\,Z_{i,r}]\begin{cases}\dfrac{\exp(Z'_{i,r}\delta_r)}{[1+\sum\exp(Z'_{i,r}\delta_r)]} & r=1,\cdots,R-1,\\[2ex] \dfrac{1}{[1+\sum\exp(Z'_{i,r}\delta_r)]} & r=R\ for\ i=1,\cdots,M\times N,\end{cases} \tag{2}$$

where $Z_{i,r}$ denotes a vector of variables that may influence whether a regional economic activity i belongs to cluster r. We set this variable as $\delta_R=0$ for identification.

The idiosyncratic factor ($\varepsilon_{i,t}$) reflects fluctuations or events that are not explainable by the two aforementioned factors, and we assume that this factor follows a normal distribution. Given the potential autocorrelation, we express this variable as Equation (3) and assume that this variable is in line with the AR(p) process.

$$\varepsilon_{i,t}=\phi_{i,1}\varepsilon_{i,t-1}+\phi_{i,2}\varepsilon_{i,t-2}+\cdots+\phi_{i,p_i}\varepsilon_{i,t-p_i}+u_{i,t}\,. \tag{3}$$

When $i=j$ and $s=0$, $Eu_{i,t}u_{j,t-s}=\sigma_i^2$. Otherwise, $Eu_{i,t}u_{j,t-s}=0$.

We structure the unobservable common and cluster factors as Equation (4) under the assumption that they are in line with the AR(q) process.

$$\begin{aligned}&f_{k,t}=\phi_{f_k,1}f_{k,t-1}+\phi_{f_k,2}f_{k,t-2}+\cdots+\phi_{f_k,q_i}f_{k,t-q_i}+u_{f_{k,t}}\,,\\&Eu_{f_{k,t}}u_{f_{k,t-s}}=\sigma_{f_k}^2\,,\\&Eu_{f_{k,t}}u_{i,t-s}=0\,,\end{aligned} \tag{4}$$

for all i, k, and s. The mean of the error term $u_{i,t}$ for $i=1,\cdots,M\times N$, $u_{f_{k,t}}$ for $k=1,\cdots,K$ is 0, and in the absence of any simultaneous correlation, we assume that the coupling among the observed economic activities is determined by factors with an auto-regressive structure.

Given that a factor loading and a latent factor are combined through multiplication in Equation (1), we encounter a methodological challenge in identifying a factor with respect to its sign and scale. To address this issue, prior constraints on the estimated parameters are required. According to previous studies (Sargent and Sims, 1977; Stock and Watson, 1989, 1993; Kose, Otrok, and Whiteman, 2003), one common approach is to fix the sign of an arbitrarily selected factor loading for each group to be positive and to normalize the variance of the error term to 1. However, the restriction on the sign of a factor loading is not applicable in the endogenously clustered factor model because the clusters are not predefined. To address this issue, we follow the method proposed by Francis, Owyang, and Savascin (2017) by setting the sign of the ith extracted factor during the Markov chain Monte Carlo (MCMC) simulation to match that of the i-1th extracted factor, which exhibits the highest similarity. We evaluate the degree of similarity using the mean squared distance. Furthermore, to resolve the issue of scale identification, we set $\sigma_{f_k}^2 = 1$.

3.2. Estimation Method

We estimate our model via Bayesian MCMC simulation (Gelfand and Smith, 1990; Casella and George, 1992; Carter and Kohn, 1994), which estimates the model parameters, latent factors, and cluster composition and then determines the model through Gibbs sampling and the reversible jump Metropolis–Hastings stage.

The basic estimation process involves sampling the parameters from the conditional posterior distribution of a parameter block, which is a combination of the likelihood function and prior distribution. The parameters sampled from the conditional posterior distributions of each parameter block are the same as those sampled from the joint posterior distribution of all parameters. When $g_y(Y|\Theta, F)$ is defined as the likelihood function of the model, $g_f(F)$ as the probability density function of the set of unobservable factors (F), and $\pi(\Theta)$ as the prior distribution of the set of parameters (Θ), the joint posterior distribution of the parameters and unobservable factors can be expressed as follows:

$$h(\Theta, F|Y) = g_y(Y|\Theta, F) g_f(F) \pi(\Theta), \tag{5}$$

where Y is the vector of $MNT \times 1$ observable data, F is the vector of the $(1+R)T \times 1$ dynamic factors (common and cluster factors), and Θ is the parameter set.

The overall MCMC algorithm involves the following stages: (1) extract the index (γ) that represents the cluster and coefficient (β) that in turn represents the factor loadings; (2) extract the variance of the error term σ^2; (3) extract the AR(p) coefficients $\{\varphi_{i,p_i}\}$ of the factor; (4) extract the unobservable factor F; (5) extract the AR(q) coefficients $\{\varphi_{i,q_i}\}$ of the error term; and (6) extract the parameter of the logistic function that determines cluster δ, the variance of the error term in a logistic function λ, and the latent variable ξ. Repeat steps (1)–(6).

We set the lag length of the factor and error term to 1 ($p_i = 1$, $p_k = 1$), the priors of the AR coefficients to $N(0,1)$, and the priors of all factor loadings to $N(0,1)$. Similar to previous studies, we assume that the prior of the error term variance σ_i^2 of the observation equation follows an inverse gamma distribution, $IG(6,0.001)$. We repeat the same process 150,000 times, discard 50,000 samples, and retain 100,000 samples for the analysis.

After the Bayesian sampling step, we calculate the variance decomposition to measure the relative contribution of the common factor, the cluster factor of regional characteristics and economic activities, and the inexplicable idiosyncratic factor. The following equation highlights the variance of the observable variables:

$$\mathrm{var}(y_{i,t}) = (\beta_i^G)^2 \,\mathrm{var}(f_t^G) + (\gamma_i^C \beta_i^C)^2 \,\mathrm{var}(f_{r,t}^C) + \mathrm{var}(\varepsilon_{i,t}) . \tag{6}$$

The variance decompositions of each factor can be expressed as follows:

Variance decomposition for the common factor: $\dfrac{(\beta_i^G)^2 \,\mathrm{var}(f_t^G)}{\mathrm{var}(y_{i,t})}$

Variance decomposition for the cluster factor: $\dfrac{(\beta_i^C)^2 \,\mathrm{var}(f_{r,t}^C)}{\mathrm{var}(y_{i,t})}$

Variance decomposition for the idiosyncratic factor: $\dfrac{\mathrm{var}(\varepsilon_{i,t})}{\mathrm{var}(y_{i,t})}$

The size of the variance decomposition for the common factor reflects the importance of this factor in explaining regional economic fluctuations. In other words, this variance decomposition size represents the degree of coupling of regional economic fluctuations at the national level. Meanwhile, the size of the variance decomposition for the cluster factor represents the degree of coupling of the economic fluctuations at the cluster level. We determine the cluster endogenously to reflect the cycles of production, consumption, and investment, regional industrial structures, and economic environments.

3.3. Model Performance

In this section, we compare the endogenously clustered factor approach with the standard dynamic factor model. We also investigate two other existing models, namely, a model that allows a region-specific factor and a model that allows an economic activity-related factor. The first model consists of (1) a global factor for all variables, (2) a factor common to each region ($f^R_{r,t}$; 16 regional factors), and (3) an idiosyncratic factor for each variable. The dynamic factor model is expressed as follows:

$$y_{i,t} = \beta_i^G f_t^G + \beta_{r,i}^R f_{r,t}^R + \varepsilon_{i,t} . \tag{7}$$

Meanwhile, the second model consists of (1) a global factor for all variables, (2) a factor common to each economic activity ($f^E_{e,t}$; 3 factors for economic activities), and (3) an idiosyncratic factor for each variable. This dynamic factor model can be expressed as follows:

$$y_{i,t} = \beta_i^G f_t^G + \beta_{e,i}^E f_{e,t}^E + \varepsilon_{i,t} . \tag{8}$$

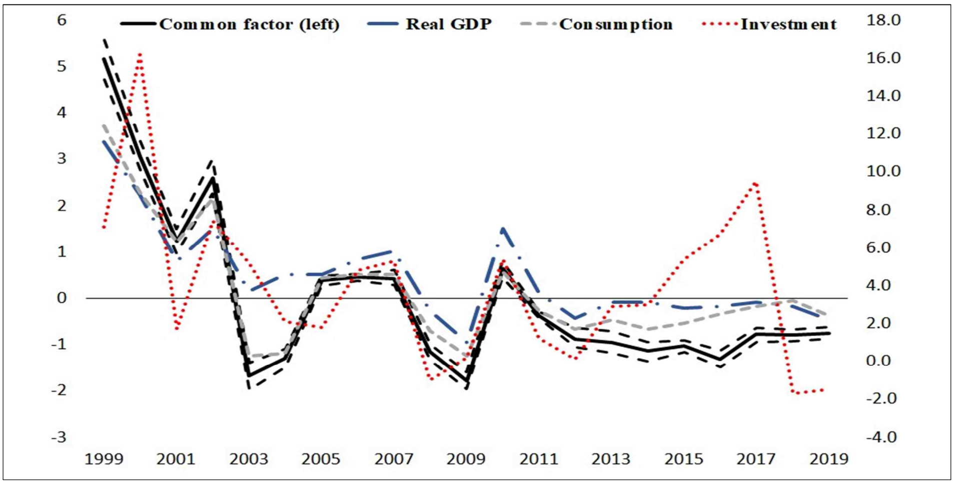
For the model comparison, we calculate the entropy criterion discussed in Francis, Owyang, and Savascin (2017). The entropy measure of the endogenously clustered factor model is 1350, while the entropy measures of the exogenous dynamic factor model with a regional factor and with a factor for economic activity are 1531 and 1537, respectively. These results indicate that the endogenously clustered factor approach is superior to the exogenously clustered factor approach based on their statistical entropy scores.

IV. Results

4.1. Common and Cluster Factors

Figure 2 shows the mean of the common factors extracted through the methodology explained above and the growth rate of the national economic activity variables (real GDP, private consumption, and investment). The estimated common factor and the growth rates of real GDP and private consumption show substantial similarity, and the investment growth rate shows a trend similar to that of the common factor, except in 2015–2017. This relationship becomes more obvious when we examine the correlations with the common factor. Specifically, the correlation between real GDP growth rate and the common factor is 0.94, while that between private consumption growth rate and the common factor is 0.99, both of which are very high. Meanwhile, the correlation between investment growth rate and the common factor is 0.53, which is lower than the previous two but is still high. These results indicate that the estimated common factor contains a great deal of information that often triggers fluctuations in real GDP and private consumption.

[Figure 2] Dynamics of common factor



Note: The black solid line represents the median of the posterior distribution, the black dashed lines indicate the 16th and 84th percentiles, the blue dashed-dotted line represents real GDP, and the gray dashed line and red dotted line represent consumption and investment, respectively.

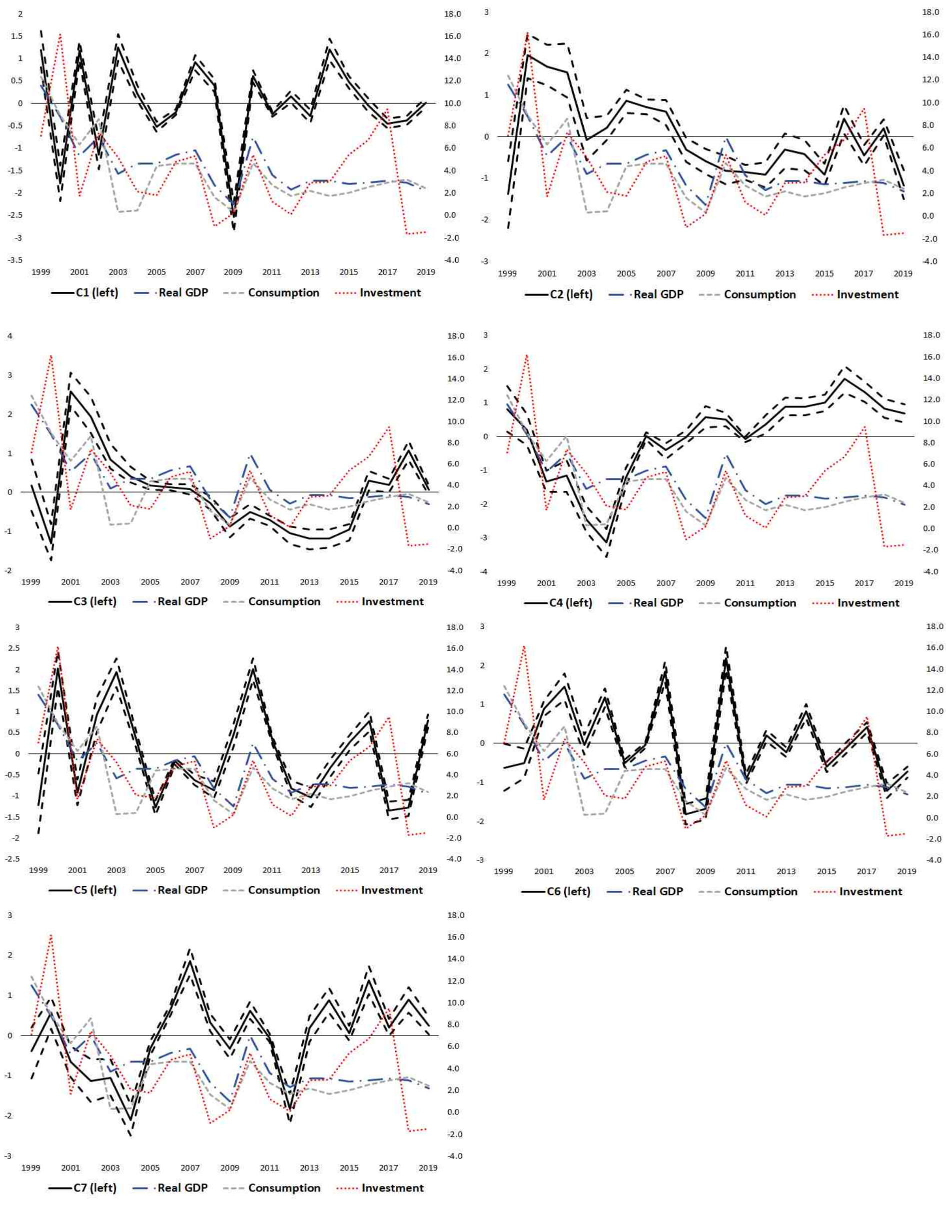
In addition, the estimated common factor represents important past macroeconomic events, which in turn reflect the inflection points in Korea's economic fluctuations, such as the economic recession caused by the 2008 financial crisis. The sharp decline in the common factor during the credit card crisis is largely attributable to the decrease in private consumption than to the changes in real GDP growth rate.[8] The investment growth rate decreases slightly from 7.4% in 2003 to 5.2% in 2004, and the dynamics in 2004–2005 are similar to those of the common factor and private consumption growth rate in 2003–2004, thereby indicating that the investment growth rate lags behind the common factor. Furthermore, during the 2008 financial crisis, the decline in real GDP, private consumption, and investment growth rates affects the decline in the common factor.

The downward trend in the common factor after 2012 has been influenced by the decelerating real GDP and private consumption growth rates due to the weak potential growth rate of Korea's economy. However, the investment growth rate continues to increase after 2012 before dropping sharply in 2018 from 9.5% to -1.7%, which is not reflected in the common factor. Therefore, the cluster factor of regional economic activities and the idiosyncratic factor may significantly impact the investment growth rate. Moreover, the fact that the slowdown in the common factor extracted using regional economic activity variables is more pronounced than the

[8] Unlike GDP growth rate, the common factor estimated using regional GRDP, consumption, and investment data reflects regional characteristics and economic activities and can thus better represent Korea's economic conditions.

overall slowdown in Korea's real GDP growth after 2012 implies that a sluggish regional economy has a greater influence on the common factor than the overall national economic slowdown.

[Figure 3] Dynamics of cluster factors



Note: The black solid line denotes the median of the posterior distribution, the black dashed lines indicate the 16th and 84th percentiles, the blue dashed-dotted line represents real GDP, and the gray dashed line and red dotted line represent consumption and investment, respectively.

[Table 4] Correlations between cluster factor and economic activity

	GDP	Consumption	Investment
Cluster 1 (C1)	0.155	0.000	-0.164
Cluster 2 (C2)	0.286	0.340	0.397
Cluster 3 (C3)	0.189	0.276	-0.093
Cluster 4 (C4)	-.154	0.067	0.091
Cluster 5 (C5)	0.141	-0.032	0.392
Cluster 6 (C6)	0.341	0.180	0.302
Cluster 7 (C7)	0.000	0.080	0.179

Note: This table reports the correlation of each cluster with GDP, consumption, and investment.

Figure 3 shows the trends in the growth rates of the seven estimated cluster factors and national economic activity variables, while Table 4 shows the correlation between the economic activity variables and cluster factors. When examined together, this figure and table show that the real GDP growth rate has a significant correlation with all the cluster factors, except for Cluster 7 and especially for Clusters 2 and 6. Private consumption has a relatively high correlation with Clusters 2 and 3, while investment has a relatively high correlation with Clusters 2, 5, and 6.

By examining the dynamics of individual cluster factors by period, we find that Cluster 1 tends to move in the opposite direction from investment while capturing a significant decline in macroeconomic aggregates during the financial crisis. Meanwhile, Cluster 2 shows an increase in investment growth rate in 2000, which is similar to the private consumption trends from 2003 to 2008. Cluster 3 shares similar trends with the economic activity variables from 2005 to 2012. Cluster 4 tends to co-move with private consumption from 2003 to 2005 and with investment growth rate from 2013 to 2018. Clusters 5 and 6 explain the sharp increases and decreases in investment growth rate from 2014 to 2019, respectively, which cannot be explained by the common factor. Cluster 5 moves similarly to investment growth rate, and they share the same increase or decrease points. Cluster 6 explains the dynamics of investment growth rate for 2008–2011 and 2015–2019. In particular, the high investment growth rate between 2016 and 2017, which reflects a boom in the semiconductor industry, is explained by the movement of Clusters 5 and 6. These two clusters have high correlations at 0.39 and 0.3, respectively, which explain such characteristics. Cluster 7 shows dynamics similar to that of national investment during 1999–2001 and that of all economic activity variables during 2009–2011.

Table 5 presents the logistic coefficients of the determinants of cluster factors. The values in this table are the estimated coefficients of the logistic function for the dummy variables for economic activities and the representative regional variables in Equation 2. A higher value corresponds to a higher possibility for the regional economic activity variables to belong to each cluster factor. When classifying the determinants with high estimated coefficients into clusters, Cluster 2 (C2) includes consumption, investment, and GRDPVOL, Cluster 3 (C3) includes consumption, CONSHR, SERSHR, and CONGRDPVOL, Cluster 4 (C4) includes consumption, MANSHR, GRDPVOL, and INVGRDPVOL, Cluster 5 (C5) includes investment, CONSHR, GOVSHR, SERSHR, CONGRDPVOL, and INVGRDPVOL, Cluster 6 (C6) includes GRDP, MANSHR, INVGRDPVOL, and OPENNESS, and Cluster 7 (C7) includes consumption, GRDPVOL, and OPENNESS. Among the determinants of these clusters, the expenditure (consumption, investment) dummy variables within the region and investment volatility have a statistically significant influence on the composition probability of C4 and C5.

[Table 5] Logistic coefficients

	C2	C3	C4	C5	C6	C7
GRDP	-0.216	-0.368	-0.654	-0.245	0.709	-0.216
Con.	0.117	0.507	**1.121**	-0.570	-0.664	0.333
Inv.	0.046	-0.031	-0.649	**0.967**	-0.166	-0.072
CONSHR	-0.076	0.089	-0.210	0.124	-0.116	0.045
GOVSHR	-0.053	-0.044	0.075	0.070	-0.036	-0.042
MANSHR	-0.011	-0.139	0.267	-0.101	0.076	-0.019
SERSHR	-0.012	0.286	-0.595	0.321	-0.260	0.076
GRDPVOL	0.401	-0.208	0.338	-0.525	-0.109	0.139
CONGRDPVOL	-0.177	0.289	-0.373	0.486	-0.068	-0.125
INVGRDPVOL	-0.571	-0.308	**0.605**	0.504	0.203	-0.477
OPENNESS	-0.038	0.006	-0.033	-0.398	0.480	0.288

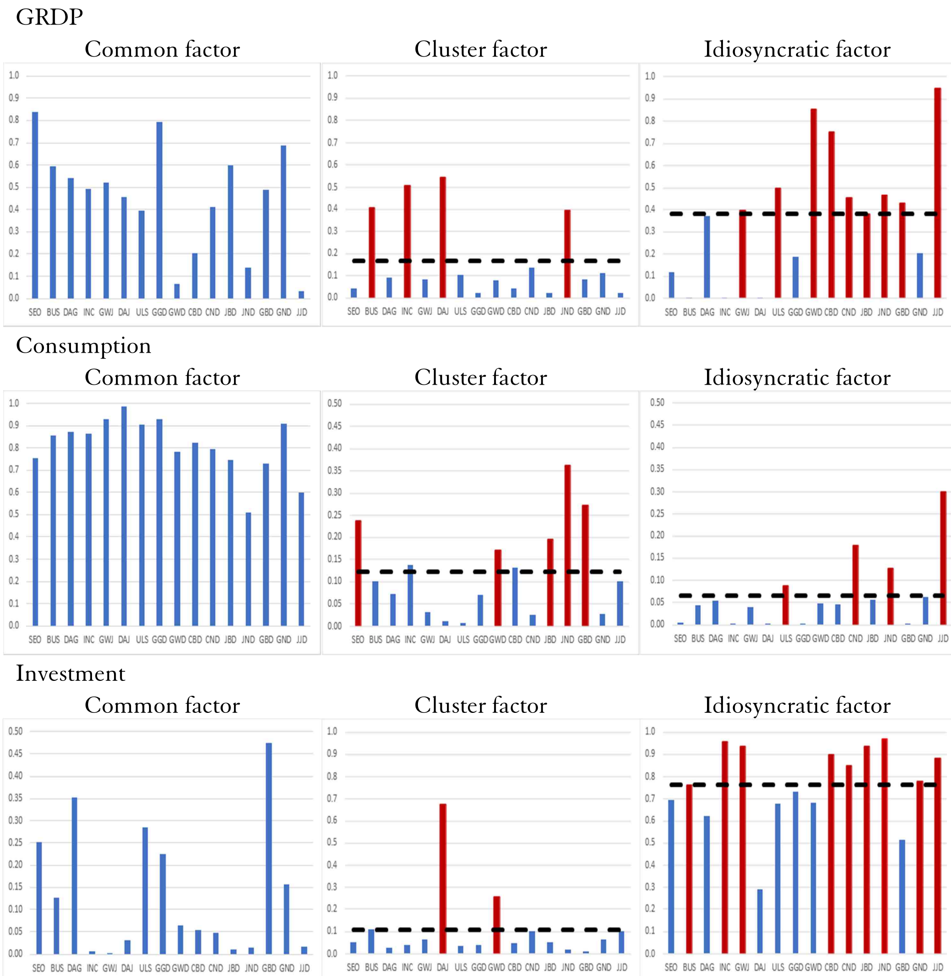
Note: The first cluster covariate coefficients are normalized to 0. Bold values are significant at the 68% credible interval.

4.2. Variance Decompositions

Figure 4 uses the previously discussed variance decomposition to illustrate the explanatory power of the common, cluster, and idiosyncratic factors in explaining the fluctuations in regional macroeconomic aggregates. This decomposition highlights the important role of each factor in the variability of regional economic activity.

The variance decomposition of GRDP reveals the dominant role of the common factor in Seoul, Gyeonggi, and several other regions, with proportions reaching as high as 0.84 in Seoul. However, in Gangwon and Jeju, this proportion is less than 0.1, indicating the prominence of other factors. Cluster factors are particularly significant for Incheon and Daejeon, which are very likely associated with Clusters 6 and 5, respectively. As indicated by the cluster composition in Appendix C, Cluster 5 reflects the fluctuations in GRDP and investment for Daejeon, while Cluster 6 mirrors the GRDP fluctuations of Incheon. Meanwhile, the Jeonnam region, which has a relatively high ratio of imports and exports and a relatively large

[Figure 4] Variance decompositions: 1999–2019



Note: SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND, and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively. The black dashed lines indicate the mean value of the variance decomposition.

manufacturing sector, is influenced by the cluster factor. Idiosyncratic factors are particularly salient in Gangwon, Chungbuk, and Jeju, with proportions reaching as high as 0.95 in Jeju, thereby suggesting unique regional dynamics.

The common factor predominantly explains the fluctuations in private consumption, especially in regions such as Gwangju and Daejeon, whereas the fluctuations in Jeonnam and Gyeongbuk are significantly influenced by the cluster factor. Given the pronounced role of the common factor in determining the variability of RGDP, one might expect a similarly high contribution of the common factor to the fluctuations in consumption. If the common factor of the GRDP fluctuations reflect the movements in nationwide permanent income, thus affecting the national consumption fluctuations, then the common factor of private consumption likely exerts a significant influence on consumption volatility. However, investment presents a contrasting narrative, where the role of the common factor is relatively subdued, and idiosyncratic factors increase in importance across almost all regions, surpassing 0.5 in most. Such increase is due to the differences in industrial structures, regional biases within each sector, and specialization across regions, which result in significant heterogeneity in investment. This result aligns with the findings of Hwang (2013).

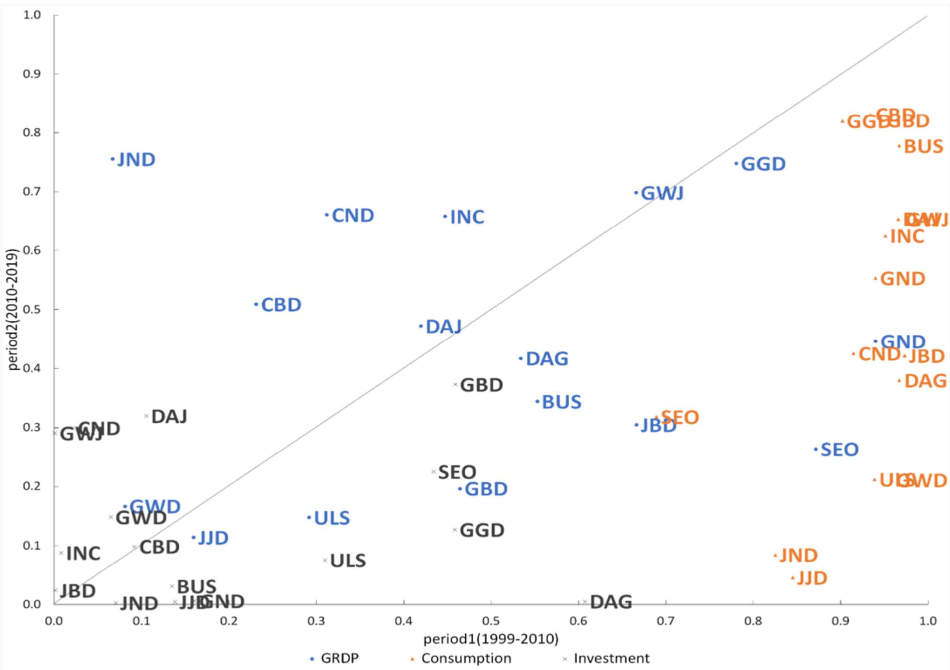
Overall, the common factor is more important for GRDP and private consumption, while idiosyncratic factors are more important for investments. The common factor has a very weak explanatory power in Gangwon and Jeju, which indicates that these regions have special regional characteristics compared with the other regions. Additionally, unlike other regions, the common factor has a stronger explanatory power for GRDP growth than for private consumption in Seoul. Cluster factors have a stronger influence in explaining the investment growth rate in Daejeon. As cluster factors appear to have a greater influence in regions with high investment cycle or investment volatility, these regions require differential policy management.

Figure 5 shows the results of the variance decomposition for the common factors of GRDP, private consumption, and investment for the 16 regions during the first period (1999–2010; x-axis) and the second period (2010–2019; y-axis). First, for GRDP, the relative importance of the common factor increases in seven regions but decreases in nine regions during the second period. Although no significant differences in proportions are observed in Gyeonggi, Gwangju, Daejeon, Daegu, Ulsan, Gangwon, and Jeju, the proportions in Jeonnam, Seoul, and Gyeongnam significantly increase from 0.07 to 0.76, 0.87 to 0.26, and 0.94 to 0.45, respectively. However, the average explanatory power of the common factor for GRDP does not significantly differ between these periods.

Regardless of region, the importance of the common factor in private consumption decreases during the second period. In the first period, all regions have a high proportion exceeding 0.8 except for Seoul, which has the lowest proportion at 0.69. However, in the second period, this proportion drops to varying levels ranging from 0.83 in Chungbuk to 0.04 in Jeju. Meanwhile, in the second period, investment increases in seven regions yet decreases in nine regions. During the same period, Daegu, Jeonnam, Gyeongnam, and Jeju have proportions of less than 0.01, indicating that the common factor exerts nearly no influence during this period. However, in Gwangju and Gyeongnam, the common factor has weak importance during the first period, but such importance increases significantly in the second period. The proportion of the common factor in Daegu is as high as 0.65

during the first period but drops to 0.07 in the second period. All regions, except for Daejeon and Gyeongbuk, show that the common factor has an explanatory power of less than 0.3 for investment in the second period.

[Figure 5] Variance decompositions (common factor): 1999–2010 vs. 2010–2019

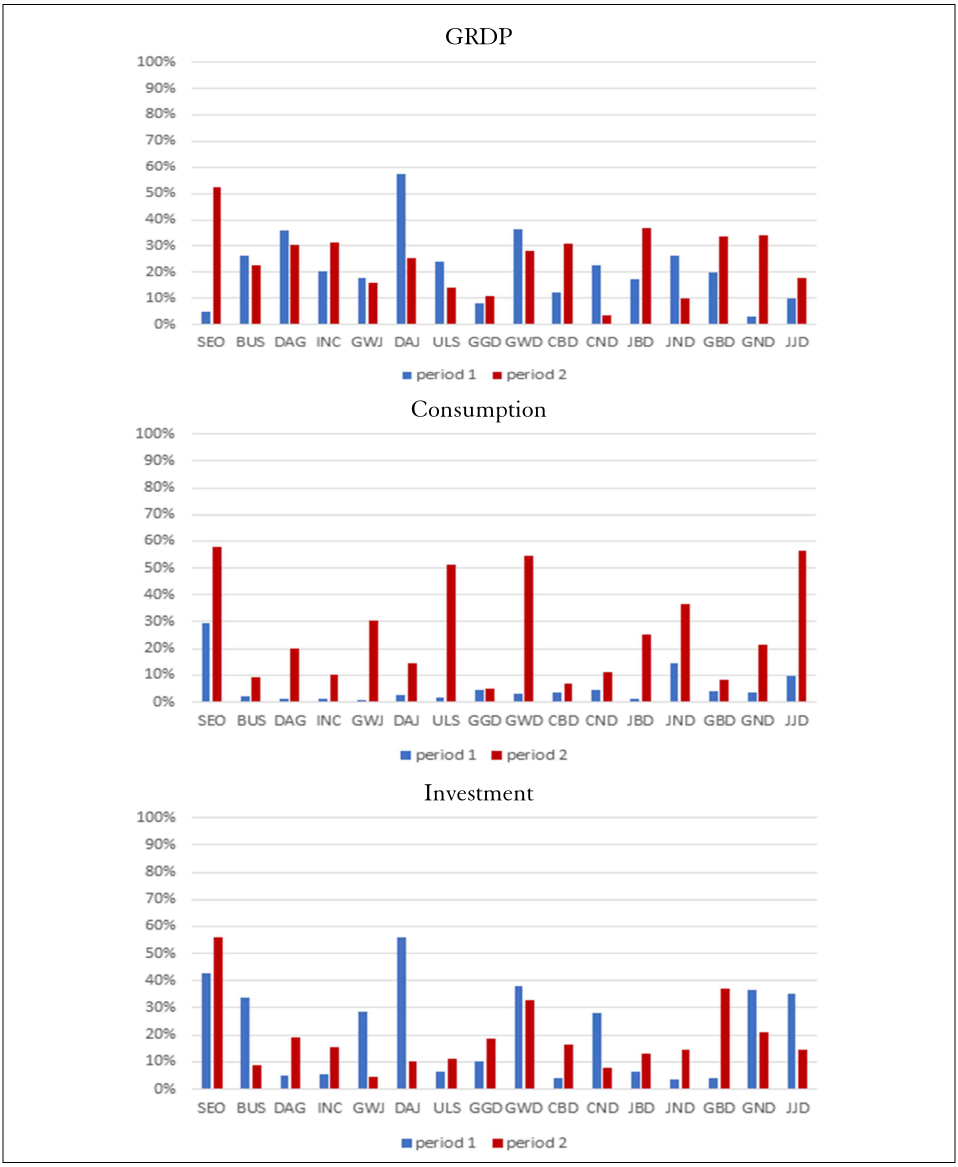


Note: This figure shows the variance decompositions for the common factors of GRDP (blue dots), consumption (yellow dots), and investment (black dots). The X-axis denotes the first period (1999–2010), and the Y-axis denotes the second period (2010–2019) for 16 regions.

Figure 6 shows the variance decomposition of the cluster factor for each economic activity by region and period. Overall, the change per period in the explanatory power of the cluster factor is greatest for consumption growth rate fluctuations, which is in line with the change in the proportion explained by the common factor for consumption fluctuations as shown in Figure 5. While the importance of the common factor for the movements in consumption decreases across all regions during the second period, the importance of the cluster factor increases across all regions. The periodic proportions of GRDP and investment growth rates as explained by the common and cluster factors also move in opposite directions.[9]

[9] With regard to GRDP growth rate, the importance of the common factor decreases while the proportion explained by the cluster factors increases during the second period in Seoul, Gyeonggi, Jeonbuk, Gyeongbuk, Gyeongnam, and Jeju. The contribution of the common factor increases while the explanatory power of the cluster factors decreases in the second period in Gwangju, Daejeon,

[Figure 6] Variance decompositions (cluster factor): 1999–2010 vs. 2010–2019



Note: SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND, and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively.

Gangwon, Chungnam, and Jeonnam. Regarding investment, the importance of the common factor decreases, and the proportion explained by the cluster factors increases during the second period in Seoul, Daegu, Ulsan, Gyeonggi, Jeonnam, and Gyeongbuk. However, the proportion explained by the common factor increases while the proportion explained by the cluster factors decreases in the second period in Gwangju, Daejeon, Gangwon, and Chungnam.

V. Conclusion

We divide Korea's regional economy into 16 municipal governments, including Seoul Metropolitan City, 6 other metropolitan cities (Busan, Daegu, Incheon, Gwangju, Daejeon, and Ulsan), and 9 provinces (Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju), to analyze those factors that trigger regional fluctuations in Korea's economy based on GRDP and expenditures (private consumption and investment) data from 1999 to 2019. We also use an endogenously clustered dynamic factor model for the analysis. We divide those factors that cause economic fluctuations into a common factor, which commonly affects all 16 regions, and an endogenously clustered factor, which considers the characteristics of regions and the cycles of economic activities. We employ a Bayesian estimation method to sample the latent factors and model parameters from the posterior distribution. Based on the model estimation results, we perform variance decomposition to measure the contribution of each factor to the movement of the economic activity variables.

Our estimation results show that the dynamics of the common factor are similar to those of real GDP and private consumption in the national economy. When determining the variables of the cluster factors, we reveal the significant influence of economic activity and investment fluctuations. Moreover, the variance decomposition of the growth rate of the regional economic activity variables shows that the common factor accounts for the largest proportion of fluctuations in output and consumption, while the idiosyncratic factor exerts the greatest influence on investment. At the region level, the influence of the cluster factor on GRDP growth rate is greatest in Busan, Incheon, and Daejeon (likely due to the investment cycle) and in Jeonnam (likely due to its strong manufacturing industry). Regarding the private consumption growth rate, the cluster factor exerts the greatest influence in Seoul, Gyeongbuk, and Gangwon, which may be due to economic activity volatility and investment cycle, and in Jeonnam, which has a relatively high level of manufacturing, exports, and imports. In terms of investment growth rate, the cluster factor exerts the greatest influence in Daejeon and Gangwon due to their high consumption tendencies, high government expenditure shares, and high consumption and investment fluctuations. These results suggest that the factors influencing regional economic fluctuations may vary depending on the economic characteristics of regions. The empirical model and results of this study can be used as a reference when formulating policies for stabilizing regional business cycles.

Appendices

Appendix A. Bayesian MCMC (Bayesian Markov Chain Monte Carlo)

We describe in here the Bayesian MCMC procedure in greater detail. Y denotes the observables, and Θ and F represent the set of parameters and factors, respectively. We let $X_i^* = [1_T, F_G, \tilde{F}_{\gamma_i^*}]$, where 1_T is a $(T \times 1)$ vector of ones, and $\tilde{F} = [F_1, \cdots, F_M]$ is the set of cluster factors. Following Chib and Greenberg (1994), we define $\bar{X}_i^*$ and $\bar{Y}_i^*$ as the quasi-differences of X_i^* and Y_i, respectively.

A.1 Sampling $\gamma, \beta : \gamma, \beta \mid \Theta_{-\gamma,\beta}, F, Y$

We jointly draw β_i and γ_i for each i. γ and β denote the index indicating clusters and the coefficients of factors, respectively. The proposal density can be written as follows:

$$q(\beta_i^*, \gamma_i^* \mid \Theta_{-\gamma,\beta}, F) = q(\gamma_i^* \mid \gamma_{i,} \Theta_{-\gamma,\beta}, Y, F)\pi(\beta_i^* \mid \Theta_{-\gamma}, \gamma_i^*, Y, F),$$

where γ_i^* is drawn from the proposal density function, $q(\gamma_i^* \mid \gamma_{i,} \Theta_{-\gamma,\beta}, Y, F)$, and conditional on γ_i^*, we sample β_i^* from $\pi(\beta_i^* \mid \Theta_{-\gamma}, \gamma_i^*, Y, F)$. This joint pair of (γ_i^*, β_i^*) is either rejected or accepted by the acceptance probability,

$$A_{i,\gamma} = \min\left\{1, \frac{|B_i^*|^{1/2}}{|B_i|^{1/2}} \frac{\exp\left(\frac{1}{2} b_i^* B_i^{*-1} b_i^*\right)}{\exp\left(\frac{1}{2} b_i B_i^{-1} b_i\right)} \frac{\pi(\gamma_i^*)}{\pi(\gamma_i)} \frac{q(\gamma_i \mid \gamma_i^*)}{q(\gamma_i^* \mid \gamma_i)}\right\},$$

where $B_i^* = (B_0 + \sigma_i^{-2} \bar{X}_i^{*\prime} \bar{X}_i^*)^{-1}$, and $b_i^* = B_i^*(B_0^{-1} b_0 + \sigma_i^{-2} \bar{X}_i^{*\prime} \bar{Y}_i^*)$.

A.2 Sampling $\sigma^2 : \sigma^2 \mid \Theta_{-\sigma^2}, F, Y$

Conditional on Y, F, and $\Theta_{-\sigma_i}^2$, we sample σ^2, which is the variance of the error term. We draw σ_i^2 from an inverse gamma posterior,

$$\sigma_i^2 \Theta \mid Y, X, \Theta_{-\sigma_i^2} \sim IG\left(\frac{\nu_0 + \mathrm{T}}{2}, \quad \frac{\Upsilon_0 + \bar{Y}_i - \bar{X}_i\beta_i)'(\bar{Y}_i - \bar{X}_i\beta_i)}{2}\right)$$

A.3 Sampling φ_{i,p_i} : $\varphi_{i,p_i} | \Theta_{-\varphi_{i,p_i}}, F, Y$

Conditional on Y and F, we draw a set of serial correlation coefficients $\varphi_{i,p} = [\varphi_{i,p_1}, \cdots, \varphi_{i,p_\varepsilon}]'$ based on a Metropolis–Hastings step (Chib (1993), Chib and Greenberg (1994)). We sample a candidate $\varphi^*_{i,p}$ from the proposal density, $\varphi^*_{i.p} \sim N(w_\mathrm{i}, W_i)$, where

$$\begin{aligned}
w_i &= W_i(W_0^{-1}w_0 + \sigma_i^{-2}\varepsilon_i'\hat{\varepsilon}_{i,0}), \\
W_i &= W_0 + \sigma_i^{-2}\varepsilon_i'\hat{\varepsilon}_i, \\
\varepsilon_i &= [\hat{\varepsilon}_{i,1}, \cdots, \hat{\varepsilon}_{i,p_\varepsilon}], \hat{\varepsilon}_{i,k} = [\varepsilon_{i,p_{\varepsilon+1-k}}, \cdots, \varepsilon_{i,T-k}]' \\
\varepsilon_{i,t} &= y_{i,t} - \beta_{i,0} - \beta_{i,G}F_t - \textstyle\sum_k^M \gamma_{n,k}\beta_{n,k}F_{k,t}.
\end{aligned}$$

The proposed $\varphi^*_{i,p}$ is accepted with probability,

$$A_{i,\varphi_p} = \min\left\{\frac{\Psi(\varphi^*_{i,p})}{\Psi(\varphi_{i,p})}, 1\right\},$$

where $\Psi(\varphi_{i,p}) = |\Sigma_i|^{-1/2} \exp[-\frac{1}{2\sigma_i^2}(Y_i - X_i\beta_i)' |\Sigma_i|^{-1} (Y_i - X_i\beta_i)]$.

A.4 Sampling φ_{i,q_i} : $\varphi_{i,q_i} | \Theta_{-\varphi_{i,q_i}}, F, Y$

Similar to the case of sampling $\varphi_{i,p}$, we draw a set of serial correlation coefficients of the error term $\varphi^*_{i,q} = \{\varphi_{i,q_i}\}$ from the proposal density $\varphi^*_{i,q_i} \sim N(v_i, V_i)$.

$$\begin{aligned}
v_i &= V_i(V_0^{-1}v_0 + e_i'\hat{e}_{i,0}), \\
V_i &= V_0 + e_i'e_i, \\
e_i &= [\hat{e}_{i,1}, \cdots, \hat{e}_{i,q_F}], \hat{e}_{i,k} = [e_{i,p_{\varepsilon+1-k}}, \cdots, e_{i,T-k}]' \\
e_{i,t} &= F_{i,t} - \varphi_{i,q_i}(L)F_{q_{i,t-1}}.
\end{aligned}$$

The proposed $\varphi^*_{i,q}$ is accepted with probability,

$$A_{i,\varphi_q} = \min\left\{\frac{\Psi(\varphi^*_{i,q})}{\Psi(\varphi_{i,q})}, 1\right\},$$

where $\Psi(\varphi_{i,q}) = |\Omega_i|^{-1/2} \exp[-\frac{1}{2}\hat{e}_{i,0}' |\Omega_i|^{-1} \hat{e}_{i,0}]$.

A.5 Sampling $F : F \mid \Theta, \varphi_{i,q_i}, Y$

We draw a set of factors from the posterior distribution based on the modified Kalman filter as in Kim and Nelson (1999). For simplicity, we assume that the factors and observation errors have the same lag length p. Let $\tilde{y}_t = y_t - \beta_0$ denote the conditionally demeaned data and $\rho_t = [F_t', \varepsilon_t', \cdots, F_{t+1-p}', \varepsilon_{t+1-p}']'$ represent the state vector. The state-space representation is expressed as

$$\tilde{y}_t = H\rho_t$$
$$\rho_t = G\rho_{t-1} + \widehat{u_t}$$

where $H = [\beta_G \ \gamma\beta \ 1_{N\times N} \ 0_{N\times\bar{N}(p-1)}]$, $G = \begin{bmatrix} G_{[\![1)} & \cdots & G_{[\![p]} \\ 1_{\bar{N}(p-1)\times\bar{N}(p-1)} & & 0_{\bar{N}(p-1)\times\bar{N}} \end{bmatrix}$, and $G_i = diag[\varphi_{G,i}, \varphi_{1,i}, \cdots, \varphi_{M,i}, \psi_{1,i}, \cdots, \psi_{N,i}]$. $\widehat{u_t} = [e_t'\varepsilon_t'0_{\bar{N}(p-1)}']'$, $E_t[\hat{u}_t\hat{u}_t'] = Q$.

Moreover,

$$Q = \begin{bmatrix} diag[\omega_G^2, \omega_1^2, \cdots, \omega_M^2, \sigma_1^2, \cdots, \sigma_N^2 & 0_{\bar{N}\times\bar{N}(p-1)} \\ 0_{\bar{N}(p-1)\times\bar{N}} & 0_{\bar{N}(p-1)\times\bar{N}(p-1)} \end{bmatrix}$$

Given $\rho_{0|0}$ and $P_{0|0}$, we compute the prediction density by propagating the state vector through the transition equation and obtain an estimated state vector at period t conditional on the information available at time $t-1$:

$$\rho_{t|t-1} = G\rho_{t-1|t-1},$$
$$P_{t|t-1} = GP_{t-1|t-1}G' + Q.$$

The Kalman filter also updates the prediction using the new information at time t:

$$\rho_{t|t} = \rho_{t|t-1} + P_{t|t-1}H'(H'P_{t|t-1}H + R)^{-1}(\widetilde{y_t} - H\rho_{t|t-1}),$$
$$P_{t|t} = P_{t|t-1} - P_{t|t-1}H'(H'P_{t|t-1}H + R)^{-1}HP_{t|t-1}.$$

We then draw the factors following the backward smoothing procedure described in Cater and Kohn (1994). Following Kim and Nelson (1999), we define Q^* as the upper $(M+1)\times(M+1)$ submatrix of Q and G^* as follows:

$$G^* = [G_1 0_{(M+1\times N)} G_2 0_{(M+1\times N)} \cdots G_p 0_{(M+1\times N)}].$$

We draw F_T from $N(\rho^*_{T|T}, P^*_{T|T})$. Following a backward smoothing procedure, we recursively draw F_{t-1} from $N(\rho^*_{t|t+1}, P^*_{t|t+1})$, where

$$\rho^*_{t|t+1} = \rho_{t|t} + P_{t|t} G^{*\prime} (G^* P^*_{t|t} G^{*\prime} + Q^*)^{-1} (\rho^*_{t+1} - G^* \rho_{t|t}),$$
$$P^*_{t|t+1} = P_{t|t} - P^*_{t|t} G^{*\prime} (G^* P^*_{t|t} G^{*\prime} + Q^*)^{-1} G^* P^*_{t|t}.$$

A.6 Sampling $\delta : \delta \mid \gamma, \xi, \lambda, Z$

Conditional on ξ_i and λ_i, we draw the slope coefficients δ_i from a standard normal regression model for each i,

$$\xi_i = Z_i \delta_i + \upsilon_i,$$

where $Z_i = [Z_{1,i}, \cdots, Z_{N,i}]'$, $\upsilon_i \sim N(p, \tau_i)$, and $\tau_i = diag[\lambda_{1,i}, \cdots, \lambda_{N,i}]$. The prior distributions of the logistic slope parameters are assumed to follow a normal distribution, $\delta_i \sim N(d_i, D_i)$. Afterward, we draw δ_i from the following posterior:

$$\delta_i \mid \xi_i, \lambda_i, \delta_i, Z_i \sim N(d^*_i, D^*_i),$$

where $d^*_i = (D_i^{-1} + Z_i' \tau_i^{-1} Z_i)^{-1} (D_i^{-1} d_i + Z_i' \tau_i^{-1} \xi_i)$, $D^*_i = (D_i^{-1} + Z_i' \tau_i^{-1} Z_i)^{-1}$.

A.7 Sampling $\lambda, \xi : \lambda, \xi \mid \gamma, \delta, Z$

Conditional on $\lambda_{n,i}$, we draw $\xi_{n,i}$ from

$$\xi_{n,i} \mid \gamma_{n,i}, \delta_i, \lambda_{n,i}, z_{n,i} \sim N(m_{n,i}, \lambda_{n,i}),$$

where $m_{n,i} = z'_{n,i} \delta_i$. Without conditioning, $\xi_{n,i}$ follows a truncated logistic with mean $m_{n,i}$: $\xi_{n,i} \geq 0$ if $\gamma_{n,i} = 1$, and $\xi_{n,i} < 0$ if $\gamma_{n,i} = 0$.

To draw $\lambda_{n,i}$ from the posterior, we draw a candidate $\hat{\lambda}_{n,i}$ from a generalized inverse gaussian distribution following Holmes and Held (2006). Afterward, $\hat{\lambda}_{n,i}$ is either accepted or redrawn.

Appendix B. Correlations of Economic Activities Across Regions

Table B1 shows the correlation of GRDP growth rate across regions. Seoul has a high correlation with Gyeongsangname-do, Gyeonggi-do, and Daejeon and a low correlation with Jeju, Gangwon, Jeollanam-do, and Chungcheongbuk-do. The correlation between Busan and Gyeonggi is 0.81, which is the highest correlation value for GRDP growth rate between regions. Busan has a strong correlation above 0.5 with all regions, except for Daejeon, Gangwon-do, Chungcheongbuk-do, Jeollanam-do, and Jeju-do. Daegu has a low correlation below 0.5 with Jeju, Gangwon-do, and Jeollanam-do, while Incheon has a low correlation below 0.5 with Jeju, Gangwon-do, and Chungcheongbuk-do. Gwangju shows a weak correlation with Gangwon-do and Chungcheongbuk-do and a negative correlation with Jeju-do. Gangwon-do and Jeju-do have the most notable regional GRDP growth rates given their low correlations with the other regions at less than 0.5. Gangwon-do has a low correlation with Ulsan and Jeju-do, while Jeju has a particularly low correlation with Chungcheongnam-do, Jeollanam-do, and Gyeongsangnam-do. These results suggest that Gangwon-do and Jeju are unique compared with the other regions.

Table B2 shows the correlation of private consumption growth rates across regions. As shown in Figure 1, the private consumption growth rate generally has a higher regional correlation (above 0.5) than the GRDP growth rate. Busan, Daegu, Gwangju, and Gyeongsangbuk-do; Incheon and Gwangju; Gwangju and Daejeon; Daejeon, Ulsan, and Gyeonggi-do; Gangwon-do and Chungcheongbuk-do; Jeollabuk-do and Gyeongsangbuk-do; Chungcheongbuk-do, Jeollabuk-do, and Gyeongsangbuk-do; and Jeollabuk-do and Gyeongsangbuk-do have high correlations of above 0.95, while Seoul and Jeollanam-do have a low correlation of 0.39, which implies huge differences in the factors affecting the consumption growth rates in these regions.

Table B3 shows the correlation of investment growth rates across regions. Such correlation is significantly more negative and peaks at 0.64, which is lower than those of the GRDP and private consumption growth rates. Seoul and Gyeongsangbuk-do, Busan and Gyeongsangnam-do, and Ulsan and Chungcheongbuk-do report correlations of 0.62, 0.62, and 0.64, respectively, thereby reflecting the greatest coherence among all regions. However, the correlations between Seoul and Incheon, Daegu and Daejeon, and Incheon and Ulsan are all low, which point to significant differences in the factors affecting their investment growth rates.

[Table B1] Correlations of GRDP across regions

Cor_Y	SEO	BUS	DAG	INC	GWJ	DAJ	ULS	GGD	GWD	CBD	CND	JBD	JND	GBD	GND	JJD
SEO	1	0.618	0.605	0.590	0.670	0.709	0.497	0.758	0.223	0.360	0.587	0.662	0.383	0.676	0.767	0.163
BUS	0.618	1	0.788	0.713	0.628	0.440	0.540	0.810	0.460	0.410	0.573	0.723	0.332	0.652	0.685	0.132
DAG	0.605	0.788	1	0.731	0.693	0.537	0.727	0.787	0.371	0.619	0.592	0.788	0.498	0.688	0.600	0.161
INC	0.590	0.713	0.731	1	0.746	0.587	0.667	0.621	0.374	0.436	0.537	0.566	0.717	0.621	0.596	0.243
GWJ	0.670	0.628	0.693	0.746	1	0.618	0.467	0.660	0.256	0.263	0.522	0.573	0.707	0.608	0.583	-0.160
DAJ	0.709	0.440	0.537	0.587	0.618	1	0.506	0.566	0.331	0.385	0.656	0.461	0.567	0.684	0.649	0.242
ULS	0.497	0.540	0.727	0.667	0.467	0.506	1	0.544	0.035	0.554	0.607	0.585	0.369	0.565	0.608	0.320
GGD	0.758	0.810	0.787	0.621	0.660	0.566	0.544	1	0.386	0.619	0.717	0.783	0.343	0.698	0.754	0.140
GWD	0.223	0.460	0.371	0.374	0.256	0.331	0.035	0.386	1	0.377	0.393	0.411	0.226	0.449	0.151	-0.032
CBD	0.360	0.410	0.619	0.436	0.263	0.385	0.554	0.619	0.377	1	0.435	0.504	0.270	0.345	0.305	0.356
CND	0.587	0.573	0.592	0.537	0.522	0.656	0.607	0.717	0.393	0.435	1	0.584	0.384	0.777	0.767	-0.029
JBD	0.662	0.723	0.788	0.566	0.573	0.461	0.585	0.783	0.411	0.504	0.584	1	0.392	0.679	0.737	0.066
JND	0.383	0.332	0.498	0.717	0.707	0.567	0.369	0.343	0.226	0.270	0.384	0.392	1	0.418	0.423	-0.088
GBD	0.676	0.652	0.688	0.621	0.608	0.684	0.565	0.698	0.449	0.345	0.777	0.679	0.418	1	0.737	0.170
GND	0.767	0.685	0.600	0.596	0.583	0.649	0.608	0.754	0.151	0.305	0.767	0.737	0.423	0.737	1	0.062
JJD	0.163	0.132	0.161	0.243	-0.160	0.242	0.320	0.140	-0.032	0.356	-0.029	0.066	-0.088	0.170	0.062	1

Note: SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively.

[Table B2] Correlations of consumption across regions

Cor_C	SEO	BUS	DAG	INC	GWJ	DAJ	ULS	GGD	GWD	CBD	CND	JBD	JND	GBD	GND	JJD
SEO	1	0.713	0.739	0.773	0.854	0.895	0.783	0.901	0.645	0.667	0.766	0.635	0.394	0.620	0.767	0.648
BUS	0.713	1	0.949	0.944	0.950	0.915	0.911	0.851	0.938	0.945	0.866	0.927	0.853	0.954	0.947	0.789
DAG	0.739	0.949	1	0.931	0.949	0.925	0.931	0.869	0.932	0.939	0.858	0.917	0.849	0.937	0.950	0.846
INC	0.773	0.944	0.931	1	0.952	0.920	0.874	0.908	0.915	0.932	0.871	0.891	0.805	0.913	0.942	0.741
GWJ	0.854	0.950	0.949	0.952	1	0.965	0.905	0.924	0.922	0.929	0.871	0.904	0.781	0.914	0.940	0.792
DAJ	0.895	0.915	0.925	0.920	0.965	1	0.953	0.967	0.875	0.895	0.894	0.856	0.693	0.843	0.946	0.782
ULS	0.783	0.911	0.931	0.874	0.905	0.953	1	0.903	0.857	0.865	0.853	0.827	0.694	0.833	0.932	0.791
GGD	0.901	0.851	0.869	0.908	0.924	0.967	0.903	1	0.827	0.855	0.860	0.789	0.603	0.774	0.924	0.734
GWD	0.645	0.938	0.932	0.915	0.922	0.875	0.857	0.827	1	0.968	0.866	0.964	0.913	0.970	0.908	0.826
CBD	0.667	0.945	0.939	0.932	0.929	0.895	0.865	0.855	0.968	1	0.878	0.960	0.876	0.963	0.936	0.797
CND	0.766	0.866	0.858	0.871	0.871	0.894	0.853	0.860	0.866	0.878	1	0.848	0.720	0.845	0.835	0.764
JBD	0.635	0.927	0.917	0.891	0.904	0.856	0.827	0.789	0.964	0.960	0.848	1	0.908	0.968	0.893	0.861
JND	0.394	0.853	0.849	0.805	0.781	0.693	0.694	0.603	0.913	0.876	0.720	0.908	1	0.923	0.775	0.764
GBD	0.620	0.954	0.937	0.913	0.914	0.843	0.833	0.774	0.970	0.963	0.845	0.968	0.923	1	0.898	0.829
GND	0.767	0.947	0.950	0.942	0.940	0.946	0.932	0.924	0.908	0.936	0.835	0.893	0.775	0.898	1	0.799
JJD	0.648	0.789	0.846	0.741	0.792	0.782	0.791	0.734	0.826	0.797	0.764	0.861	0.764	0.829	0.799	1

Note: SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively.

[Table B3] Correlations of investment across regions

Cor_I	SEO	BUS	DAG	INC	GWJ	DAJ	ULS	GGD	GWD	CBD	CND	JBD	JND	GBD	GND	JJD
SEO	1	0.556	0.421	0.003	0.256	0.261	0.305	0.552	0.261	0.290	0.362	-0.177	-0.271	0.622	0.475	0.436
BUS	0.556	1	0.325	-0.161	0.447	0.098	0.419	0.383	0.242	0.259	0.428	-0.188	-0.190	0.505	0.619	0.505
DAG	0.421	0.325	1	-0.088	0.312	0.002	0.347	0.284	0.211	-0.116	0.254	-0.071	-0.041	0.543	0.542	0.181
INC	0.003	-0.161	-0.088	1	-0.267	0.171	-0.014	-0.028	0.084	0.277	0.217	-0.265	0.226	0.081	-0.109	0.011
GWJ	0.256	0.447	0.312	-0.267	1	0.258	0.266	0.292	0.534	0.042	0.535	0.416	-0.181	-0.028	0.531	0.187
DAJ	0.261	0.098	0.002	0.171	0.258	1	-0.419	0.176	0.514	-0.129	0.484	-0.229	0.085	0.051	0.100	0.231
ULS	0.305	0.419	0.347	-0.014	0.266	-0.419	1	0.420	-0.114	0.636	0.402	0.287	-0.219	0.334	0.592	0.218
GGD	0.552	0.383	0.284	-0.028	0.292	0.176	0.420	1	0.162	0.415	0.576	0.141	-0.334	0.347	0.472	0.508
GWD	0.261	0.242	0.211	0.084	0.534	0.514	-0.114	0.162	1	-0.149	0.462	0.059	0.128	-0.156	0.507	0.420
CBD	0.290	0.259	-0.116	0.277	0.042	-0.129	0.636	0.415	-0.149	1	0.290	-0.040	-0.218	0.188	0.288	0.280
CND	0.362	0.428	0.254	0.217	0.535	0.484	0.402	0.576	0.462	0.290	1	0.077	-0.101	0.297	0.544	0.542
JBD	-0.177	-0.188	-0.071	-0.265	0.416	-0.229	0.287	0.141	0.059	-0.040	0.077	1	0.092	-0.385	0.214	-0.155
JND	-0.271	-0.190	-0.041	0.226	-0.181	0.085	-0.219	-0.334	0.128	-0.218	-0.101	0.092	1	-0.155	-0.096	-0.209
GBD	0.622	0.505	0.543	0.081	-0.028	0.051	0.334	0.347	-0.156	0.188	0.297	-0.385	-0.155	1	0.365	0.270
GND	0.475	0.619	0.542	-0.109	0.531	0.100	0.592	0.472	0.507	0.288	0.544	0.214	-0.096	0.365	1	0.553
JJD	0.436	0.505	0.181	0.011	0.187	0.231	0.218	0.508	0.420	0.280	0.542	-0.155	-0.209	0.270	0.553	1

Note: SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively.

Appendix C. Cluster Compositions

We calculate the posterior probability for each regional economic activity included in a cluster. Referring to the probabilities of belonging to specific economic activities or regional clusters as illustrated in Figures C1–C3, Cluster 2 encompasses investment activities centered on regions such as Busan, Incheon, Ulsan, Gyeonggi, Chungbuk, and Gyeongbuk, all of which exhibit significant GRDP fluctuations. Notably, Gyeonggi's consumption activity is categorized under Cluster 2.

Cluster 3 represents consumption activity and mainly includes Seoul and Daejeon, which are characterized by their high consumption tendencies and significant service industry proportions. Cluster 3 also does not correlate with GRDP but emerges in areas with considerable consumption variability, thereby suggesting that consumer preferences significantly impact this cluster.

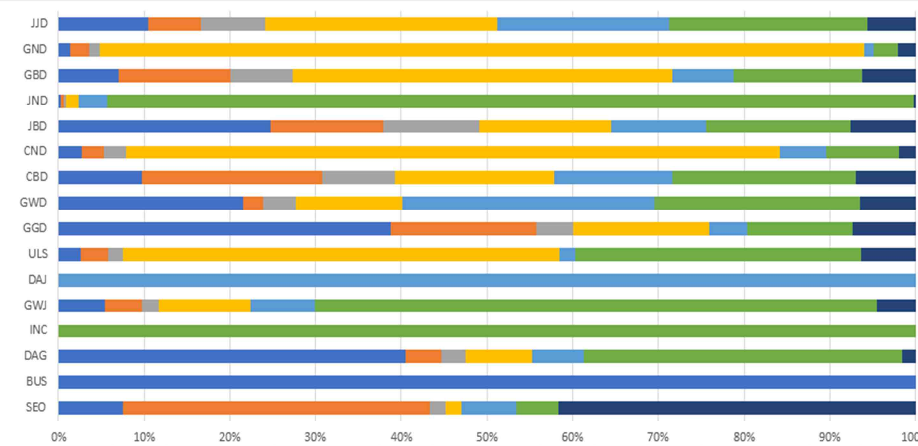
Cluster 4 is influenced predominantly by consumption activity and includes regions that are known for their strong manufacturing sectors and significant consumption and investment volatilities, including Ulsan, Gyeonggi, Chungnam, and Gyeongbuk. This cluster's formation highlights its role in influencing consumption fluctuations across most regions. Cluster 4 also includes regions with a significant manufacturing presence, thereby implying a strong influence from the manufacturing sector. Some areas in this cluster have a high output volatility, which may be driven by the precautionary savings of economic entities.

Cluster 5 is best described as an investment cycle that involves regions such as Seoul, Busan, Daegu, Daejeon, and Gangwon. While Daejeon and Gangwon are distinguished by their high consumption patterns, significant government spending, and considerable consumption and investment volatility, Seoul, Busan, and Daegu are known for their high consumption tendencies and dominant service sectors.

Cluster 6 emerges predominantly around metropolitan cities known for their manufacturing or trading capabilities, such as Incheon and Gwangju, and extends to regions such as Chungbuk and Jeonnam.

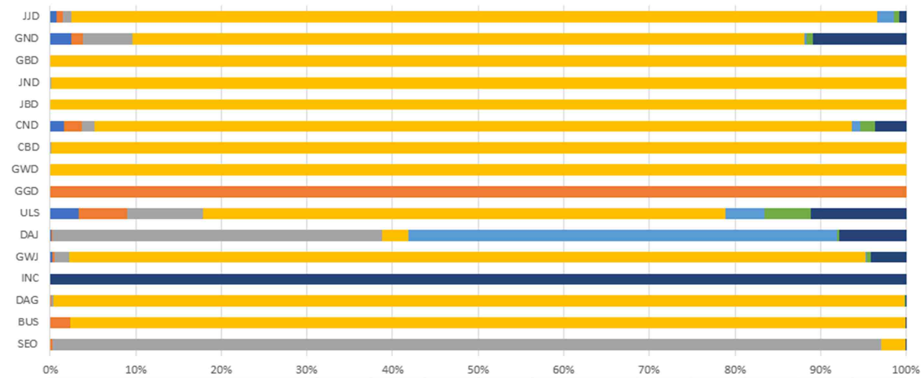
Cluster 7 encapsulates consumption and investment activities. This cluster is prevalent in areas such as Incheon, Ulsan, Gyeonggi, Gyeongbuk, and Gyeongnam, which are well-known for their high export and import capacities. This cluster is also indicative of the GRDP fluctuations observed in Seoul.

[Figure C1] Cluster compositions: GRDP



	SEO	BUS	DAG	INC	GWJ	DAJ	ULS	GGD	GWD	CBD	CND	JBD	JND	GBD	GND	JJD
Cluster1	0.07515	1	0.40477	0	0.05448	0.00E+00	0.02603	0.38801	0.2156	0.0976	0.02669	0.24772	0.0026	0.06998	0.0138	0.10439
Cluster2	0.35779	0	0.04228	0	0.04282	0.00E+00	0.0318	0.16912	0.02295	0.20959	0.02613	0.13164	0.0034	0.13028	0.02173	0.06147
Cluster3	0.01921	0	0.02781	0	0.01974	0	0.01731	0.04367	0.03897	0.08498	0.02579	0.11186	0.00254	0.07299	0.01308	0.07568
Cluster4	0.01754	0	0.07727	0	0.10729	0.00E+00	0.50912	0.15873	0.12375	0.18664	0.76274	0.15372	0.01528	0.44345	0.89212	2.70E-01
Cluster5	0.06492	0	0.06073	0	0.07516	1.00E+00	0.01927	0.0435	0.29411	0.13698	0.05403	0.11102	0.03262	0.07059	0.01096	0.20108
Cluster6	0.04851	0	0.37163	1	0.65576	0.00E+00	0.33314	0.12414	0.24007	0.2145	0.08504	0.16807	0.94183	0.15056	0.02848	2.31E-01
Cluster7	0.41688	0	0.01551	0	0.04475	0	0.06333	0.07283	0.06455	0.06971	0.01958	0.07597	0.00173	0.06215	0.01983	0.05566

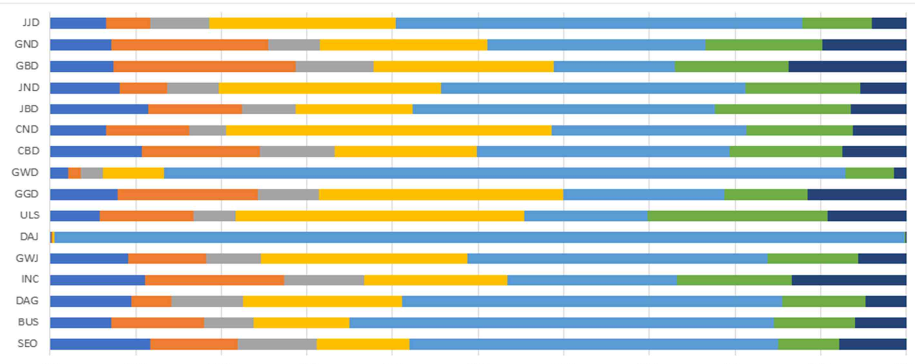
[Figure C2] Cluster compositions: Consumption



	SEO	BUS	DAG	INC	GWJ	DAJ	ULS	GGD	GWD	CBD	CND	JBD	JND	GBD	GND	JJD
Cluster1	0.00033	3.00E-05	3.50E-04	0	0.00226	0.00082	0.03375	0	1.00E-05	2.00E-05	0.01583	0.00E+00	0	0	0.02512	0.00737
Cluster2	0.00224	2.36E-02	1.56E-03	0	0.00287	0.00154	0.05595	1	1.00E-05	0.00E+00	0.02121	0	0.00059	0	0.01275	0.00706
Cluster3	9.69E-01	0.00048	0.00181	0	0.01736	0.38494	0.0892	0	2.70E-04	0.00129	0.01437	0	4.50E-04	0	0.05819	0.00968
Cluster4	0.02755	0.97578	0.99376	0	0.9298	0.0312	0.61045	0	0.99969	0.99869	0.8849	1	0.99887	1	0.78471	0.94177
Cluster5	0.00027	0.00E+00	0.0004	0	0.00113	0.50046	0.04511	0	0.00E+00	0.00E+00	0.0096	0	0	0	0.00304	0.02043
Cluster6	0.00012	0.00E+00	0.00138	0	0.00505	3.06E-03	0.05393	0	2.00E-05	0.00E+00	0.0177	0	9.00E-05	0	0.00735	0.00577
Cluster7	9.50E-04	1.40E-04	0.00074	1	0.04153	0.07798	0.11161	0	0	0.00E+00	0.03639	0	0	0	0.10884	0.00792

Note: SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND, and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively. The value indicates the posterior probability of each regional economic activity included in a cluster.

[Figure C3] Cluster compositions: investment



	SEO	BUS	DAG	INC	GWJ	DAJ	ULS	GGD	GWD	CBD	CND	JBD	JND	GBD	GND	JJD
Cluster1	0.11669	0.07139	0.09477	0.11144	0.09083	0.00134	0.05836	0.07873	0.02118	0.10762	0.0657	0.11486	0.08166	0.07441	0.07162	0.06477
Cluster2	0.10199	0.10853	0.04717	0.16198	0.09182	0.00068	0.1087	0.16332	0.01424	0.13747	0.09632	0.10976	0.05541	0.21244	0.18267	0.05243
Cluster3	0.09217	0.05778	0.08356	0.09279	0.06333	0.00107	0.04945	0.07201	0.02614	0.08739	0.04345	0.06214	0.05958	0.09081	0.06076	0.06845
Cluster4	0.10942	0.11246	0.18503	0.1679	0.24137	0.00198	0.33768	0.28475	0.07171	0.16572	0.38018	0.13685	0.26008	0.2106	0.1958	0.21796
Cluster5	0.43064	0.49523	0.44425	0.19851	0.35134	0.99283	0.14385	0.1893	0.79583	0.29585	0.22766	0.3528	0.35599	0.14129	0.25501	0.47471
Cluster6	0.07095	0.09428	0.09827	0.13426	0.1048	0.00117	0.20989	0.09726	0.05625	0.132	0.12403	0.15877	0.13383	0.13354	0.13587	0.08215
Cluster7	0.07814	0.06033	0.04695	0.13312	0.05651	0.00093	0.09207	0.11463	0.01465	0.07395	0.06266	0.06482	0.05345	0.13691	0.09827	0.03953

Note: SEO, BUS, DAG, INC, GWJ, DAJ, ULS, GGD, GWD, CBD, CND, JBD, JND, GBD, GND, and JJD denote Seoul, Busan, Daegu, Incheon, Gwangju, Daejeon, Ulsan, Gyeonggi, Gangwon, Chungbuk, Chungnam, Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju, respectively. The value indicates the posterior probability of each regional economic activity included in a cluster.

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우리나라 지역 경기변동 요인 분석: 내생적 클러스터 요인모형 접근법*

정 다 정** · 이 슬 기*** · 노 산 하****

초 록 본 연구는 내생적 클러스터 동적요인모형을 이용하여 한국의 16개 지역에서 발생하는 경기변동 요인을 공통 요인과 클러스터 요인으로 분해하여 분석한다. 각 요인은 지역별 경제활동 변수인 생산, 소비, 그리고 투자 변수를 이용하여 추출한다. 클러스터는 지역 및 경제활동 변수의 특성에 기반하여 내생적으로 결정된다. 본 연구는 소비와 투자 활동, 그리고 투자 변동성이 클러스터 요인의 중요한 결정 요인임을 발견하였다. 추정된 공통 요인은 국내 실질 GDP와 소비 증가율의 움직임을 잘 포착한다. 또한, 생산과 소비의 지역별 변동을 설명하는데 공통 요인의 기여가 큰 것으로 나타난다. 더욱이, 투자 사이클에 대해 높은 민감도를 가진 지역에서 생산의 변동은 클러스터 요인에 의해 상당한 영향을 받는 반면, 투자의 변동은 주로 개별적 요인에 의해 주도되는 것으로 나타난다.

핵심 주제어: 베이지안 MCMC, 클러스터 요인 모형, 지역 경기변동

경제학문헌목록 주제분류: C11, C32, E32

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