Doctoral Dissertation

Long Term Demographic Predictions Considering the Spatial Distribution of Population

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Graduate School of Engineering

Hiroshima University

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We hereby recommend that the dissertation by Ms. SEBAL OO entitled "Long Term Demographic Predictions Considering the Spatial Distribution of Population" be accepted in partial fulfillment of the requirements for the degree of Doctor of Engineering.

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ABSTRACT

Japan has been depopulation since 2009. Declining fertility rate with a super-aging society and massive urban agglomeration occurs due to the emigrations from rural areas, which results in rural–urban disparities. Population decrease causes the labor force shortage which directly threatens the economic and demographic sustainability. To meet the need of Japan‘s labor force and the social problems in the depopulated areas, in the recent years, labor force shortage has been mitigated by an acceptance of foreign migrants to Japan. The foreign migrants and its spatial distribution significantly change as the acceptance of specialized and technical skills workforce from overseas. The presence of foreign workforce is a crucial to stabilize aging society. However, the social and economic divisions between rural areas and urban areas is increased by urban agglomeration with rural depopulation as a result of internal and international migration, the government faces difficulty in maintaining infrastructure and social services. In order to preserve the social sustainability for both the domestic and foreign residents, it is essential to understand the agglomeration and long-term population distribution among the Japanese municipalities.

In regional planning, population prediction with the demographic transition is one of the attentive methods that gives fundamental information for decision-making in regional planning. Population prediction is mainly based on the (latest) past trends, and many socioeconomic factors influence on population dynamics. The relationships between the various socioeconomic factors are complex and its exact causal structure is not well-known. Therefore, most of the population prediction methods depend on rational

or tractable assumptions. The national population prediction method in Japan is Cohort-Component Analysis (CCA) that requires minimum demographic information assuming simple dynamics for each cohort. However in CCA, migration is a difficult component since the geographical heterogeneity behind them is complex and correlated. While CCA has well defined structure, the population prediction in smaller areas such as municipalities still relies on trend extrapolation due to the limited availability of demographic and migration data.

Since population distribution at municipality scale often shows the spatial clusters of agglomeration or depopulation, the spatial dependency among the contiguous regions should not be neglected since the daily activities are not closed in the spatial boundary of given dataset. In order to clarify the significance of spatial dependencies in migration phenomena, this dissertation applied the statistical model with spatial dependencies to the migration phenomena in Japan. The proposed population prediction approach can give not only the future population distribution but also the workforce agglomeration in municipality scale. As the acceptance of the foreign migrants would have a significant contribution on the future demographic structure of Japan, this dissertation also focuses on the transition of foreign residents' characteristics in recent years and observes the structural breaks in the migration trend. With better understanding of future population structure in local areas for both domestic and foreign residents, some of the progressive policies for regional sustainable development will be discussed. Also, the effects of incentives to attract the workforce from the industrial zones in urban areas to local communities with innovative technologies-based business entities will be demonstrated by the proposed approach. A brief description of each chapter in this dissertation is as follows.

Chapter 1 provides the background of depopulation by declining fertility rate with the super-aging society and population studies focusing on the migration phenomena. Based on the background, the research motivation and objectives of this study are discussed. In Chapter 2, literature about the demographic studies, population predictions, spatial demography, demographic transition of both domestic and foreign residents, economic development and urbanization are reviewed. The following sections are discussing about the current situation and issues of study area.

Chapter 3 focuses on the methodology applied in the following chapters and data collection with those characteristics. This study consists of four main methodologies. First is as an existing population prediction method, Cohort Component Analysis (CCA) is explained the second part is about our proposed methodology; integration of CCA with spatial statistic model (spatial autoregressive model, SAR) to analyze the distribution of the population, migration and prediction of future demographic structure. Third part is about nonnegative matrix factorization model (NMF) implies the transition of foreign residents' cohorts decomposed into some different patterns and geographical potential of migrants. Final is about the multiple linear regression model setting to test the structural break among the transition of foreign residents' internal and international migration. The data collection and data setting for this dissertation are explained in the following part. According to the data availability for foreign residents in cohort structure and migration, third and the final models will focus on the prefecture data and the discussion will be made on the 8 regions over 47 prefectures of Japan, for simplicity.

Following Chapter 4 to Chapter 7 are about the discussions of research contributions and findings. Chapter 4 examines the inter-regional migration prediction for economic development by considering the spatial dependencies using SAR. This chapter clarifies the significance of spatial dependencies in migration phenomena with industrial indices for Japanese municipalities. The results give strong evidence to include the spatial dependencies in population prediction, which is possible by integrating CCA with SAR. According to the findings, the simulation analysis of the future population following to the proposed approach will be tried. Since the distribution of industries is spatially agglomerated, population prediction with the interaction between industrial location and migration of each cohort will result in more severe demographic disparities among the municipalities, comparing with a conventional CCA.

In order to confirm the remarks of Chapter 4, Chapter 5 observes the long-term impact of inter-regional migrants on population prediction by considering the spatial distribution of urbanization indices. In this chapter, the estimation of natural increase and decrease are calculated with CCA, and the migration phenomena is modeled by using SAR approach introduced in the previous chapter. By applying recursive estimation, the prediction of the population distribution and migration with cohorts' structure are carried out. The proposed approach gives the higher populations among the middle-aged cohorts than those populations by a conventional CCA in 2040, which would be brought by foreign migrants from overseas. The results show that the future Japanese populations will become more concentrated in urban areas with a lower fertility, and the migration from overseas which also tend to concentrate in urban area. Furthermore, the manufacturing employees will be attracted to metropolitan areas or to the regions with industrial agglomeration, and that the number of retailers will undergo changes over time, even in urban areas.

The findings of Chapter 5 clarify that foreign resident's migration has a positive contribution on the future demographic structures of Japan. Therefore, following Chapter 6 aims to analyze the transition of foreign residents' characteristics, in order to clarify the policy making for foreign migrants by local government. Nonnegative matrix factorization model (NMF) is applied to the cohort data of foreign residents in 47 Japanese prefectures in 2010, 2015 and 2020. This chapter proves that due to the policy change about the foreign labor force acceptance to Japan, the trend of foreign migration from 2010 to 2020 has several structural breaks. The results show the cohort transition for foreign migrants with infants or child are significantly different especially between Tohoku and Kyusyu regions from 2010 to 2020. Elderly cohort also has a significant change in Tohoku region from 2015 to 2020. Since the regions highlighted in this analysis include many depopulated areas and the capacity of those local government for the policy building would not be enough, they should be supported by the national government.

Chapter 7 focuses to clarify the structural break of foreign residents' domestic and international migration in Japan. A constrained multiple linear regression models designed for OD matrix structure are estimated to find some structural breaks. The data set used for this analysis is foreign residents' annual migration data in Japan with 47 prefectures from 2010 to 2020 and an oversea category is inserted. The proposed models fit well for all the periods, so, then the residual test about spatial dependency can be used to find the structural breaks. The findings show that the foreign resident's domestic migration is significantly changed among all the Japanese prefectures in observed period. The structural break of foreign residents' migration occurs four times from 2010 to 2020. These breaks are observed for immigration but only a break is observed for emigration in

2020. This finding suggests that the immigration is unstable, while the emigration is stable except in 2020.

Chapter 8 is about the conclusion remarks of this dissertation. In this chapter, overall summary is described with various policy recommendations based on the outcomes from the dissertation. At the end of this chapter, contributions, limitations and some suggestions for future studies are brought out.

As a student of Taoyaka program, I got a chance to participate in the Taoyaka team project which consisting of two team members from different backgrounds. The team project was fully supported by Taoyaka program and guided by a mentor, Associate Professor Ayami NAKAYA from the Graduate School of International Cooperation and Development. The team report was presented in Taoyaka Onsite Team Project Workshop, and I here proudly added individual report of the team project as an appendix of the dissertation.

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Chapter 1 Introduction

1.1 Background

In the developed countries, depopulation has become a global phenomenon over the last decades. It is no longer a concern, but an actuality. In South Korea and most of European countries, the combination of low fertility and emigration have led to the country depopulation (World Bank, 2019). Additionally, the depopulation will begin in Europe around 2020–25, in Asia around 2055–60 and in Latin America and the Caribbean around 2060–65, according to the population forecasting a scenario with medium fertility variant by United Nations, Department of Economic and Social Affairs, Population Division (World Population Prospects 2022, Summary of Results).

The primary cause of depopulation is a decrease in total fertility, which occurs in a process known as demographic transition (Lutz and Gailey, 2020). The fertilities in the developed Eastern Asian countries have fallen to extremely low levels such that Japan dropped to 1.36 in 2020. The fertility rate in England and Wales hit the lowest record of 1.58 in 2020, although the majority of Western countries have not yet experienced such the sharp fall. Since 1950, fertility rates for all women cohorts have also declined in developing countries (World Population Data Sheet 2021). Declining fertility has the drawback of reducing population among the young generation. Due to a decline in the younger age group, a country with low fertility may experience a constrictive population pyramid structure which will eventually lead to further depopulation.

Current demographic trends in developed countries are also leading to super aging society. According to UN world population ageing report 2015, a higher proportion of elderly means more population to be economically dependent, so then relatively fewer people in the working-age cohorts have to support them. Japan is denoted as a super-aged society with recorded 26% of over-65 cohorts in 2015 and it is higher than Italy and other most aged countries in Europe according to United Nations Population Division (UNPD). Elder people experience various social problems in daily activities. In contrast, the aging problem than other countries became in Europe and the United States apparent earlier and it was regarded as part of a public concern mainly in the low-income group (Swinburn et al. 2004; Wrigley et al. 2003). As shown in the formal reports, concerning with elderly population is a definitely essential issue in the population study for economic development and for social sustainability.

Population study ranges over demography, sociology, economics and industrial or infrastructure planning. Among them, demography to focus on the population prediction provides some possible scenarios of future population for decision-making in socio-economic planning, such as maintaining the public and private infrastructures or a design of social services, etc. A population prediction requires future fertility, motility and migration of population based on their past and present conditions (Lutz et al., 2019; United Nations, 2019). Since Malthus proposed the well-known mathematical model for growth estimation under unlimited resources in 1798, many models with more tractable structures have been developed to meet the requirements in regional planning. Although simple time-series regression models provide adequate population prediction in a stationary state (Abel et al., 2013), they cannot reflect the demographic mechanism behind the transition of population subgroups. On the other hand, cohort component analysis (CCA) has advantages of simplicity and of tractability, and it is used as a standard model for regional population prediction in the U.S., Japan, and other countries (Wilson and Rees, 2005; Chi, 2009; Smith et al., 2013). Cohort is a special population group, often defined by sex and age. Cohort study was originally developed in medical, demographic and generational studies because it allows to describe the dynamics of a specific group of interest, such as place of residence, occupation, or environmental exposure (Doll, 2001). Smith et al. (2013) conducted a population prediction under acceptable parameter assumptions using several sources of data. For instance, Vanella and Deschermeier (2020) proposed a probabilistic CCA that uses simulation techniques based on stochastic models for fertility, mortality and migration to forecast the population by cohort group.

CCA is a reliable and de-fact standard tool for population prediction when the target area is relatively large because higher reliability in its parameters is required (George et al., 2004; Smith et al., 2013). On the other hand, the population prediction in small area is often made by trend extrapolation methods due to the limited availability of demographic and migration data. However, population projections in smaller areas such as sub-national or municipality level are necessary for appropriate design of a long-term planning. Addition to the practical needs, small area population prediction also deserves more academic attentions because it is essential to achieve rationality and tractability through the aggregation of population (Wilson, 2015). Some previous literatures on small area population prediction (Bell, 1997; Wilson and Rees, 2005; Wilson, 2011; Smith et al., 2013) cover a variety of cohort-component model. However, all these studies adopt the assumptions about directional, no-directional migration being constant over the predicted periods.

CCA is an effective population prediction method since the fertility and mortality can be rationally estimated, while the migration in CCA is the more difficult to be set or estimated. In conventional CCA, migration rate is assumed to be constant over the predicted periods for simplicity. However, migration is far from a stable phenomenon in municipality level. Migration in municipality level can be a primary factor to cause regional heterogeneity (Shryock and Siegel 1973). In early CCA studies, migration was ignored for simplicity; for example, two studies on poverty reduction in India have ignored the role of remittances, possibly underestimating the poverty impact of urban-based economic growth (Ravallion and Datt, 1996; Besley et al., 2004). According to Skeldon (1997a), migration trends to be a source of regional development. For example, the emigration from rural to the others was continuously increasing during the rapid-growth-era in Japan. And also, migration is attracted to the areas where economic activities agglomerate and where the investment in private capital and in infrastructure concentrates. All those pulling factors causes the out-migration from rural to urban areas which are also serious concerns for local governments with depopulation (Sato and Yamamoto, 2005).

Migration can be split into international and internal movements. Most of the previous migration studies mainly focused on international migration by voluntary for employment, or by forced as refugee. Until the last decade, international migration has gotten considerable attentions while more recently, interregional migration becomes much focused on by many researchers (Luca, 2015). Under a low birthrate, interregional migration in a country or in the geographically “closed” areas is the primary demographic process shaping national patterns of human settlement (Jorge and Francisco, 2018). According to the World Bank (2016), there were approximately 247 million people living outside of their country, which amounted approximately 3% of the global population, UN estimated that 763 million internal migrants living away from their hometowns, but within their country. Deshingkar and Grimm, (2005) pointed out that in 2001 the number of interregional migration in China and India was double of global international migrants. The number of internal migrants in China stood at more than 100 million because of migrant workers who left their hometown and worked in other provinces. According to the Indian census in the same year, more than 300 million people were classified as domestic migrants because of the bulk of labor mobility (Deshingkar, 2006). These studies suggested that interregional migrants outnumber international migrants by over three to one. So then, migration should not be negligible in population study.

Hugo and Alegret (2008), Wulff et al. (2008), Stillwell and Hussain (2010) , Collantes et al. (2014) and Bell et al. (2017) pointed out that international and internal migration would shape the regional demographic structure. These studies suggested that immigrants have revitalized the local community of the aged country and have acquired access to a variety of employment in labor-intensive industries such as agriculture, construction and social services in order to compensate for locals who have left the local labor market. The mobility of labor force also affected the regional employment structure in different regions of the national settlement system (Frey, 2015). These studies focused on the internal and international migration of the Western developed countries, which played an essential role in country urbanization and has contributed to a decrease in the demographic disparity among the regions. These studies pointed out that the beginning of urbanization and immigrating to urban area from other areas occur due to the demand of labor, economic growth and safe space for humans, give a verity of reasons in migration. As regional labor markets are clearly interdependent through the migration phenomena, there is a need to study migration impacts in wider societal context, and to see how migration process works as an integrated components of long-term population prediction.

1.2 Research Motivation

Most of the population studies in domestic migration have been primarily focused on the characteristics of a target area but not on those of the surrounding regions. Looking on the distribution of population, spatial dependencies are often observed. For example, work opportunities and about life related factors of the surrounding regions are the factors in which people to migrate from one region to another would consider the characteristics not only of the target area but also of the surroundings. The spatial impact of migration shapes human settlement pattens, but few attempts have been made to measure systematically the extent of population redistribution with systematic viewpoint (Philip Rees et al., 2017). Previous study by Chi and Ventura (2011) pointed out that population transition itself exhibits the spatial spillover effects and that population growth is affected by surrounding areas, no matter whether it is of turnaround migration, renewed metropolitan growth, or rural rebound. Most of the conventional population models isolate local area-specific effects with ignoring the effects from its surroundings, however, an appropriate modeling in the correlations between the geographically closed areas are then likely to improve the quality of local estimates of population (Pascal et al. 2018). Hence, demographic and economic factors of neighbors should not be neglected. These studies indicate that population distribution considering the spatial dependencies should be one of the major focuses in population studies.

According to Thuku and Gideon (2013), population growth and economic growth are correlated and that an increase in population impacts the economic growth in the country. The study of Kotavaara et al.(2014) showed that a careful selection of economic variables of a region can make the population prediction accurate since the strong influence of economies activities on population change. Therefore, population changes and economic development are mutually dependent and reinforcing. However, the connection between interregional migration and industrial structures has not yet been explored and studied in demographic point of view even it is quite essential how those factors effect on industrial structures and labor markets.

Additionally, the labor force shortage mainly occurs in rural areas rather in the larger cities, while many local governments still lack the capacity to accept migrant workers (Chi, 2020). Despite the lack of support from the national government, some local governments have begun to promote their own policies on accepting the foreign migrants to sustain the labor force in their regions. In order to revitalize the local labor force market, local governments must find out how to incorporate with foreign migrants. Hence, it is necessary to examine the government policies about accepting migrants, foreign residents and legislation in order to figure out the local governments' initiatives to adapt the aging society and to sustain the local community.

In order to build effective public plans against the depopulation with declining fertility, the transition of population should be appropriately simulated for a rational prediction of population dynamics. A better understanding of population transition in local areas requires the study focusing on both domestic and foreign residents because of their substantial contribution to labor force supply. While the increasing fertility requires a long-term to increase population, accepting the foreign migrants can improve the demographic structure for productive cohorts in rather short term. On the other hand, the increase of migrants inevitably accompanies the community problems as how to accommodate those "strangers" or new commers into the local society. In order to construct inclusive society for the domestic and the immigrated people (Clemens, 2014), it is essential to develop a prediction method for analyzing the demographic transition to yield a realistic picture of a probable future development of a population. In the above study, the characteristics of each region with its neighborhood as spatial dependencies should be considered.

1.3 Objectives of Study

The objectives of this dissertation are as follows. The conventional CCA is combined with a migration model that includes spatial dependencies of migration relationship between the industrial indices of the regions and working cohorts and with the resolution at the municipality level. The proposed model can statistically test the significance of spatial dependency in migration and can discuss the effects of working opportunities and of daily life convenience on migration (1). The characteristics of the proposed approach and the conventional CCA are compared regarding the population prediction for the projected period (2). The performance of the proposed model is clarified about the workforce agglomeration (3). The recent trend of demographic in Japan is affected not only by domestic people but also by foreign residents. Hence, the transition of foreign residents' cohort characteristics is analyzed by Non-negative Matrix Factorization model (NMF) (4). The structural break test for the foreign migrants in Japan is made to clarify the impacts of various implemented immigration policies (5).

With better understanding of future population structure in local prefectures and municipalities for both domestic and foreign residents, this dissertation will point out the solution for the progressive policies making regarding with the regional sustainable development. Also, the effects of incentives to attract the workforce from the industrial zones in urban areas to local communities with innovative technologies-based business entities can be demonstrated by the proposed approach.

1.4 Composition of the Thesis

This dissertation consists of seven chapters. **Chapter 1** provides the background of the depopulation by declining fertility rate with a super-aging society, population studies focusing on the migration phenomena and importance of spatial dependencies in the migration prediction. Based on the research background, research motivation and objectives of the study are discussed. In **Chapter 2**, the literatures about the demographic studies, population predictions, spatial demography, demographic transition, economic development and urbanization are reviewed. Following part summarizes the existing studies and clarifies the issues of study with data collection. **Chapter 3** focuses on the explanation of the methodology of the study and data collection procedures. This chapter consists of four main contents. First is about the reviewing methodology: conventional Cohort Component Analysis (CCA) and the second is about our proposed methodology:

integration of CCA with spatial statistic model (spatial autoregressive SAR model) to analyze the distribution of the population, migration and to predict the future demographic structure. Third is about nonnegative matrix factorization model (NMF) which is applied to the data about foreign residents' cohorts' trends with the different patterns and geographical potential of migrants. The final is for the explanation of the multiple linear regression model setting to observe the transition of foreign residents' internal and international migration. The data collection and data setting for this dissertation are explained in the following part.

Chapter 4 to **Chapter 7** are about the discussion of research contribution and findings. **Chapter 4** examines the inter-regional migration prediction for economic development by considering the spatial dependencies based on spatial statistic model (SAR) to discuss the job opportunities and daily life conveniences. **Chapter 5** observes the long-term impact of inter-regional migrants on population prediction by considering the spatial distribution of urbanization indices. This chapter states the trends in population, share of the cohorts in total population and policy discussion according to the predicted population structure. A comparison of the projected future population by the proposed model with that by the existing CCA. Since the treatment of migration phenomena is different in those approaches, the above comparison clarifies the impact of migration modeling on population transition. **Chapter 6** analyzes the transition of foreign residents' characteristics for clarify the policy building to foreign migrants by local government. **Chapter 7** mainly purposes to clarify the structure break of foreign domestic and international migration in Japan from 2010 to 2020. The study explores how year to year migration of foreign residents were shifted based on spatial characteristics in different time series under various implemented immigration policies.

Chapter 8 is about the conclusion remarks of the study. In this chapter, overall summary is described will various policy recommendations based on the outcomes from the dissertation. At the end of this chapter, contributions, limitations, and some suggestions for future studies are brought out. The following Figure 1.1 is the structure flow of this dissertation.

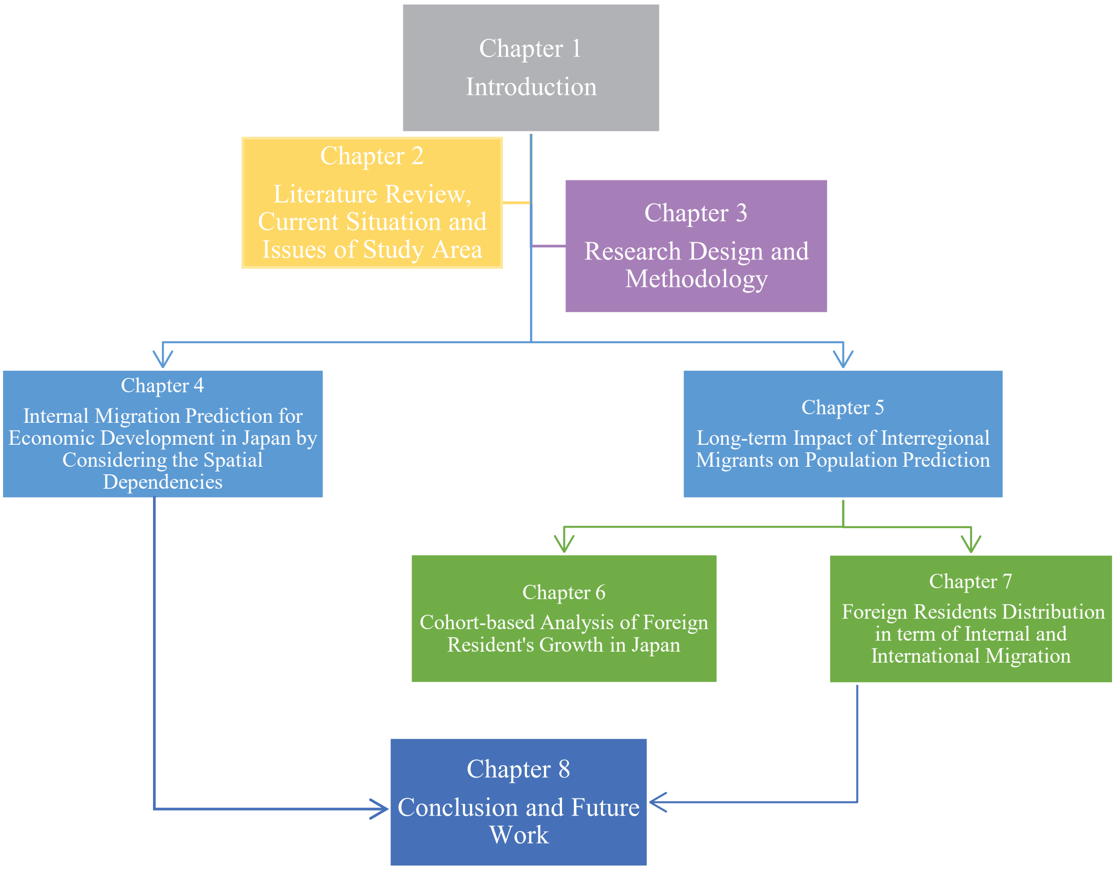


Figure 1.1 Chapter Structure of Dissertation

Chapter 2 Previous Studies and Study Area

2.1 Literature Review

2.1.1 Demographic Studies

Pyrialakou et al. (2016) suggested that population change is caused jointly by demographic, social, economic, political, geographic and cultural factors. In a quantitative approach for population prediction, a careful selection of socio-economic factors can improve the prediction accuracy of the model. Since demography is inherently spatial social phenomena (Voss 2007; Matthews and Parker, 2013), spatial distribution of population depends on the neighbors of a target area (Wilson et al., 2021). A possible mechanism behind the dependency is that the labor force demand of local industries in an area often requires some commuters beyond the area. However, it is also possible for a reverse causal relationship, such that the available workforce in an area or in its neighbors would effect on the locations of the industries. Thus, the causal relationships between economic or social factors and migration or population is rather bidirectional.

Developing a population prediction method that incorporates the spatial dependency on migration and industrial distribution into CCA would yield probable future dynamics of population and industry with their spatial distribution due to the recursive structure of CCA. Spatial models describe spatial dependencies among the neighbors, and the recent developments in statistics and computing resources have allowed for the explicit modeling of spatial dependencies (Schaub and Kéry, 2012). Among these spatial statistical models, spatial autoregressive (SAR) model is the most appropriate for including spatial dependencies (LeSage and Robert, 2009), since SAR can affect the global average (constant) of the regression model. The existing knowledge-based regression approach for population forecasts typically models the relationships between the population changes and its causal factors in the estimation period, and then applies the estimated parameters for population projection. The regression approach for population forecasting is increasingly used in urban planning, climate change and infrastructure systems (Chi and Wang., 2017).

Previous studies about Japanese demography are mainly focused on larger geographic units—at the national or prefecture level (Matanle, 2017). However, in recent years, an interest in the migration phenomenon has changed for much smaller spatial units, so as to consider the spatial heterogeneity. Smaller spatial units of demographic studies have been conducted by Stawarz et al. (2021) for domestic migration relevant to the locals in Germany and the population prediction in the Southern California is made by Feng et al. (2020). There are a couple of studies focusing on interregional or domestic migration with respect to the demographic studies in Japan. For example, Sekiguchi et al. (2019) focused on the relationship between the motivation to migrate and individual characteristics with their living environments across the prefectures by applying a tree decision analysis. This study provided policy recommendations to promote the U-turn migration for domestic residents. Note that, these studies only focus on the Japanese residents. According to the literatures, there are no studies applying a statistical analysis for migration phenomena in population prediction with rather the smaller spatial units in Japan, such as the municipality level.

With respect to the international migrants, the acceptance of foreign residents and workforce in Japan was discussed from social aspects such as living condition, cultural influences, social interactions in Japanese society. Previous studies about international and internal migration, commonly concluded that the foreign immigrants have revitalized local industries especially in the labor-intensive sectors such as agriculture, construction and social services. The foreign immigrants were introduced for a compensation of domestic labors who have left or retired their job (Hugo et al., 2008; Stillwell and Hussain 2010; Collantes et al., 2014). Additionally, there were significant links between internal and international migration in global cities via domestic labor substitution (Sassen, 1984). The internal and international migration among Western developed countries played an essential role in the urbanization of those countries and contributed to a convergence of regional demographic disparity. The lack in similar approach in Japan supplies a motivation to start a study on the labor force transition including foreign migrants.

2.1.2 Demographic Changes, Economic Development and Urbanization

Earlier study by Ravenstein (1885) pointed out that local labor markets are clearly interdependent on the surrounding region and its neighbors, which sometimes cause migration to compensate the imbalance of labor supply. Following to his work, migration studies had developed and those studies clarified some essential factors to migrate. Castelli (2018) discussed that there were 'macro' and 'micro' factors to influence on an individual decision to migrate. The 'macro factors' were political, demographic, socio-economic and environmental situations, while the 'micro factors' were education, religion, marital status, and personal attitude. While international migration gathers a lot of attentions due to the economic or social conflict of migrants with the inhabitants, the amount of domestic migration is actually larger than that of international migration. Even though domestic migrants can go without the difficulties that the international migrants face, the imbalanced population distribution in a country is a matter to threaten social stability. Recently, many studies such as Luca (2015), Rodríguez-Vignoli and Rowe (2018) focused upon the domestic migration considered as a primary demographic process to shape national patterns of human settlement.

The migration driven by economic motivations or other individual reasons is referred as “push” or supply factor of labor force, while the migration attracted by job opportunities is referred as “pull” or demand factor of labor force (Lee and Hoshino, 2017). However, the connection between domestic migration and industrial structures has not been deeply explored in migration studies. Todaro (1980), Rosenzweig and Stark (1997) or Lucas (1997) proved that more job opportunities and more income at the destination of migration than those in the current location is available, the more migrants occur if the gap is larger enough to compensate for the costs of migration. The difference in regional economic growth influences on a distribution of population since the employment opportunities are main factors to cause migrants for job-searching (Zuo, 2018). The domestic labor migration can change the population growth in a region, especially the regions where the natural increase of population is lower. Domestic migration also promotes regional innovation (Zhao and Li, 2021). Matanle (2017) pointed out that the industrialization and urbanization occurred in Japan throughout the post-World War II era was accompanied with rapid economic growth. Domestic migration has long-term impacts on regional economic prosperity; it acts as a regulating valve, helping to achieve the efficient allocation of human capital across the domestic regions. According to these studies, population transition, migration and economic development are mutually dependent and reinforcing.

Composition of regional industries is an important factor for the national economic development. Looking on qualitative or quantitative characteristics among the industrial composition and economic development, it is found that local industrial structures, whether it is diverseified or specialized, provide various effects on migration. A major factor underlying regional disparities in the employment market is the uneven geographic distribution of industries with significant employment absorption capacity. Ito et al. (2008) described that the tertiary industry like wholesale and retail expand in the region where few employment opportunities and accumulation of manufacturing enterprises is sparse. This suggests that labor force transition should not be underestimated especially in the region of depopulation.

2.1.3 Spatial Demography

The spatial dependency possibly occurs in the context of population distribution as with a following exampled mechanism. In region A, there is a new industry operated and this could provide several employment opportunities. The inflow of new labors and their families to region A would increase population of region A. Some new employees and their families may choose to live in region A's neighbor as region B, where housing prices are relatively lower and well connected with public transport services. In that case, population growth in region B is owing to population growth in region A, but it has nothing or less to do with region B's characteristics. The only reason that region B receives this benefit is because region B is geographically close to region A. In addition, the spatial regression approach could further include the impacts of driving factors in neighboring geographic units.

As demonstrated above, the spatial dependency among regions is an essential phenomenon to be modeled in the context of an inter-regional migration and industrial development. The spatial dependency can be modeled by using spatial statistic models with given spatial-dependent structures. Recent developments in statistics and computing capacity allow an explicit modeling of spatial relationships, rather than removing them by careful study design (Kéry and Schaub, 2012). Among spatial statistic models, spatial autoregressive (SAR) models give a base to consider in the effect of spatial dependency on the regional outcome. The model is applicable for any datasets about the observations on geographical areas or on the units with a spatial representation. Spatial dataset might be recorded with the sample unit in countries, states, counties, regions, municipalities or alternatively, the nodes of a social network. A typical continuous outcome variable is incidence of disease, output of farms or crime rate. Those are modeled with the objective variable to be explained. For cross-sectional data, each variable has one observation for each spatial unit. For panel data, multiple observations for different cross-sections are available for each spatial unit. In order to fill the poor information about the spatial dependency, the former model requires a spatial dependent structure.

The spatial dependent structure assumed in SAR and other spatial statistic model's spatial weighting matrix. The spatial weighting matrix is often made by the inverse distance or nearest neighbor to share the boundary of spatial unit. Generally, the concept of the spatial autoregressive model means that neighboring regions have more influence on each other than on the regions located far away. The regression approach for population forecasting is increasingly used in urban planning since the model can clarify the relationships between population change and possible driving factors (Chi, 2016).

The existing regression approach for population forecasts typically estimates the relationship between population and its causal factors in the estimation period and then applies the estimated parameters to the projection period. The simplest forecasting model is the standard ordinary least squares (OLS) regression, which can consider a variety of driving factors of population change (e.g., Chi, 2009), while a spatial regression model can include the impact of population growth in neighboring geographic units (e.g., Chi and Voss, 2011).

Spatial filtering models and spatial error models are appropriate in the situations where spatial interdependence is a nuisance rather than a main concern of the analysis. Spatial autoregressive models can incorporate a specification of spatial interdependence not in the error term but in the fixed or predicted part of the regression equation (Anselin, 2003). It is useful to distinguish between two following cases, one in which the hypothesized spatial interdependence runs from the independent variables in nearby areas of the focal area, while the other in which the hypothesized spatial interdependence runs from the dependent variable in nearby areas of the focal area. The former can model by an ordinal spatial statistic model if the spatial correlation can be captured by the independent variable's spatial correlation, while the latter required an integration of time-series dependence with the spatial dependence. Therefore, a novel model structure to consider the bilateral relationship should be developed for the dependence of population and industries.

The model with lagged independent variables is sometimes not specifically referred as a spatial regression model because it seen to be estimated with OLS technique. However, spatial statistic model proved that such the shortcut approach, i.e., to apply OLS to spatial regression equation leads a biased or wrong estimation of the model. Heitgerd and Bursik (1987) demonstrated that local delinquency rates in a community were influenced by racial changes in adjoining communities through a spatial model. More recent example of this approach was Bernasco and Luykx (2003), who explored whether burglary rates in a reference neighborhood were affected by concentrations of burglars' residences in adjacent neighborhoods. Mears and Bhati (2006) explored whether the number of homicides in a neighborhood was affected by resource deprivation in adjacent neighborhoods, or not. As previous studies with various research backgrounds aimed to identify spatial association patterns (spatial dependence and heterogeneity) in socioeconomic phenomena, the spatial dependency for public and private policies should not be neglected.

2.2 Situations and Issues of Study Area

2.2.1 Urbanization, Depopulation and Aging Society of Japan

Japan has two historical periods for rapid urbanization and industrialization. The first period between 1910 and 1930 had a series of significant political and economic changes leaded by the Meiji government. Leaders during the Meiji period concentrated industrialization efforts in existing large urban centers, especially Tokyo and Osaka's commercial hub, where, for instance, the first railroad systems developed by the national government were built. Large urban areas, including Osaka, Tokyo, Kitakyushu, and Nagoya became Japan's industrial and economic hubs during this period, accounting for more than half of the country's industrial production in the 1920s, with Osaka accounting for 27% of that total (Menju, 2019).

The second period of the urbanization and industrialization was started from post-World War II in the 1980s. During this period, the growth around Tokyo resulting in the Tokyo mega concentration problem which was an acute condition of political, economic, and socio-demographic activities converging in Tokyo at the cost of other areas. However, the growing disparity became a national big issue by those marginalized in regional and peripheral prefectures throughout Japan during both periods. As industrialization and urbanization progressed, social and economic divisions between urban and rural spheres in Japan become increasingly more pronounced.

Since the late 1980s, Japan has faced rural-urban disparity. During the urbanization eras, rural-urban migration was occurred, and people were relocated from rural communities to urban centers as a result of bubble economy or so-called industrialization. Because of urbanization and industrialization, Japan faced economic, income and employment inequalities between urban and rural areas, wealth inequality due to the land prices and most important infrastructure disparities occurred between metropolitan areas and rural regions.

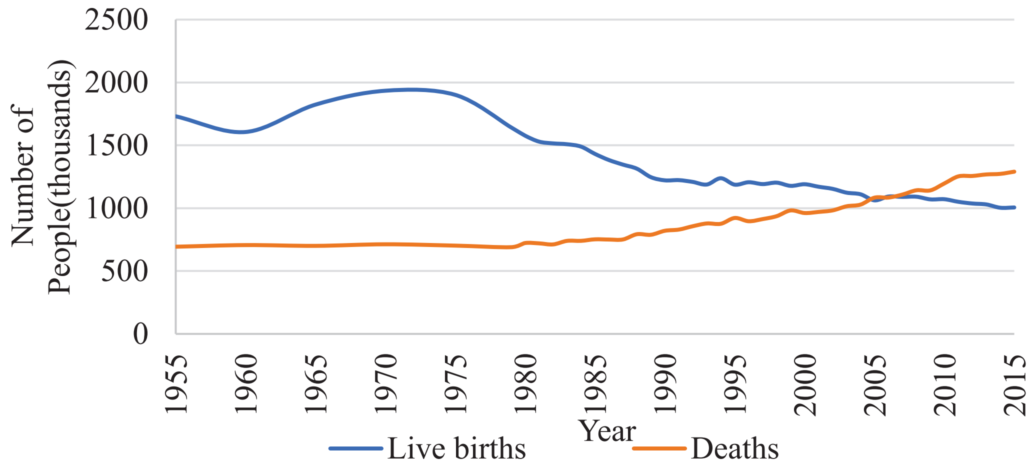


Figure 2.1 Live Births and Deaths for Japanese Population

In Japan, emigration from rural regions to larger cities has continued since 1950s, and the total population of the country has decreased since 2009, because of a declining number of births. According to Figure 2.1, the annual number of births in Japan has drecreased from 1.9 million in 1970s, called the "secondary baby boom," to 1.01 million in 2015, and the number of deaths has continuously increased from 1980 to 2015. In Japan, the total fertility was below 2.0 in 1975, and it continuously decreased and bottomed out at 1.26 in 2005 since World War II. In 2015, the fertility increased to 1.46 however, its level is still far below the level of replace of population. Among the Japanese prefectures in 2015, Okinawa had the highest fertility of 1.94, while Tokyo had the lowest fertility of 1.17 (Population Census, 2015).

Japan has also been facing a rapid aging over recent decades, and it will become more intense when the second baby-boomer generation reaches their 60s in 2040. According to the OECD Regional Statistics, while the working-age population in Japan declined by 8.5%, the elderly population increased by 32%, accounting for over a quarter of the Japanese population in 2014. Rural areas in Japan are aging faster than urban areas.

Almost 30% in rural areas is over 65 years old, while it is under a quarter of the population in urban areas. In a depopulated society, economically active/working-age groups face particular tension. They must foster and educate younger generations while they also support older generations with health care or nursing. Moreover, the country will also face the problem of fewer younger generations being able to join the workforce as discussed above. The causes of the steep drop in births in Japan would be as follows; both parents work outside the home social support for families is scarce, and childcare support from retired generations has become difficult because more households are separated from them that is, there are fewer multi-generational households. Because of the pressure to work for economic reasons, many families of reproductive age tend to forgo to have the next generation. Even though the above circumstance is not severe in rural areas to have higher fertility, social migration from rural to urban areas for job searching has continued. This will accelerate the population decline, if the lower fertility in urban areas is not improved.

2.2.2 Interregional Migration Issues in Japan

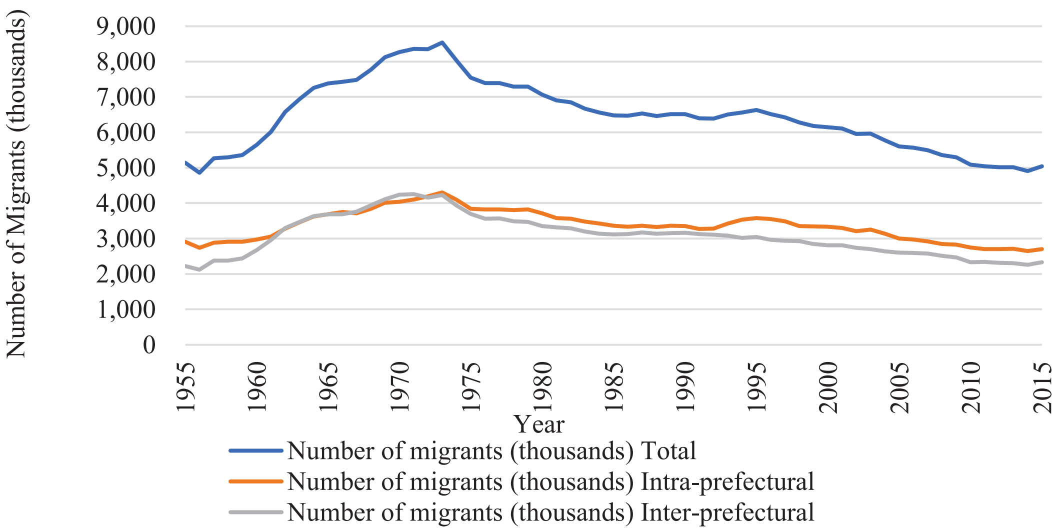


Figure 2.2 Number of Internal Migrants for Japanese Population

As shown in Figure 2.2, the number of annual domestic migrants peaked during the mid-1960s to early-1970s. This is due to industrial development during this period, which accompanies population movements for employment reasons in the industrial sector. After 1972, the number of interregional migrants drastically decreased, due to the severe economic challenges to the industrial sector brought by the oil crisis in 1973. Rapid industrialization and urbanization disrupted the balance of the spatial distribution of the population, and urban areas absorbed this inflow by expanding outward into the suburbs. All the above phenomena in Tokyo metropolitan area makes the area into one of the largest cities in the world, and exacerbated depopulation in the countryside of Japan. The migration rate increased again after 1995, and the number of inter-prefectural migrants increased yet again after 2011. According to the 2015 population census—eight prefectures, including three metropolitan areas (Tokyo, Osaka and Nagoya)—had a positive net migration, while the other thirty-nine prefectures had a negative net migration. This statistic shows that Japanese people are highly mobile from rural areas to urban areas. There are several disadvantages in agriculture, such as lower labor inputs because of mechanization with lower wages and the vulnerability to climate change, then the stable management of agriculture is difficult. Moreover, the reproductive generations in rural areas are deterred by the poor availability of services, including healthcare, education and transportation. These factors make the residents in rural areas push out to urban ones. As rural areas lose population, it becomes difficult for maintaining public facilities, such as schools and hospitals in rural areas. These impacts on living services and built environment supply further reason for younger population to migrate from rural areas to larger cities in pursuit of better education and job opportunities. Such population losses

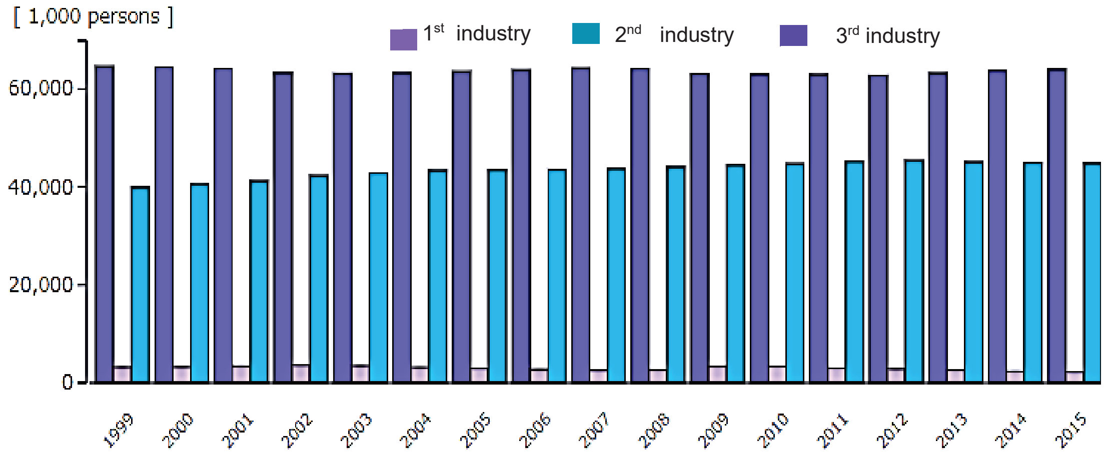


Figure 2.3 Number of workers per industry in Japan (Source: Portal Site of Official Statistics of Japan website (https://www.e-stat.go.jp))

have triggered policy concerns on the economic and demographic sustainability of rural areas in Japan.

In recent decades, all the economies in developed countries have faced slowdowns due to depopulation and aging. An aging and a declining population lead to a decrease in the labor force. As shown in Figure 2.3, the number of labors in first and second industries are continuously declining. This puts further downward pressure on economic growth, such as reduced production caused by the declining labor force, accompanied with an increasing proportion of retired people. The arguments by Matanle and Sato (2010) suggested that the country's industrial structure and workforce distribution are related. This finding indicates that determining the relationship between demographic change and the industrial structure of the country can improve the estimation of population dynamics. Therefore, finding out the relationship between the demographic change and industrial structure of the country is an essential for the prediction of future population.

2.2.3 Foreign Residents International migration and Immigration policies

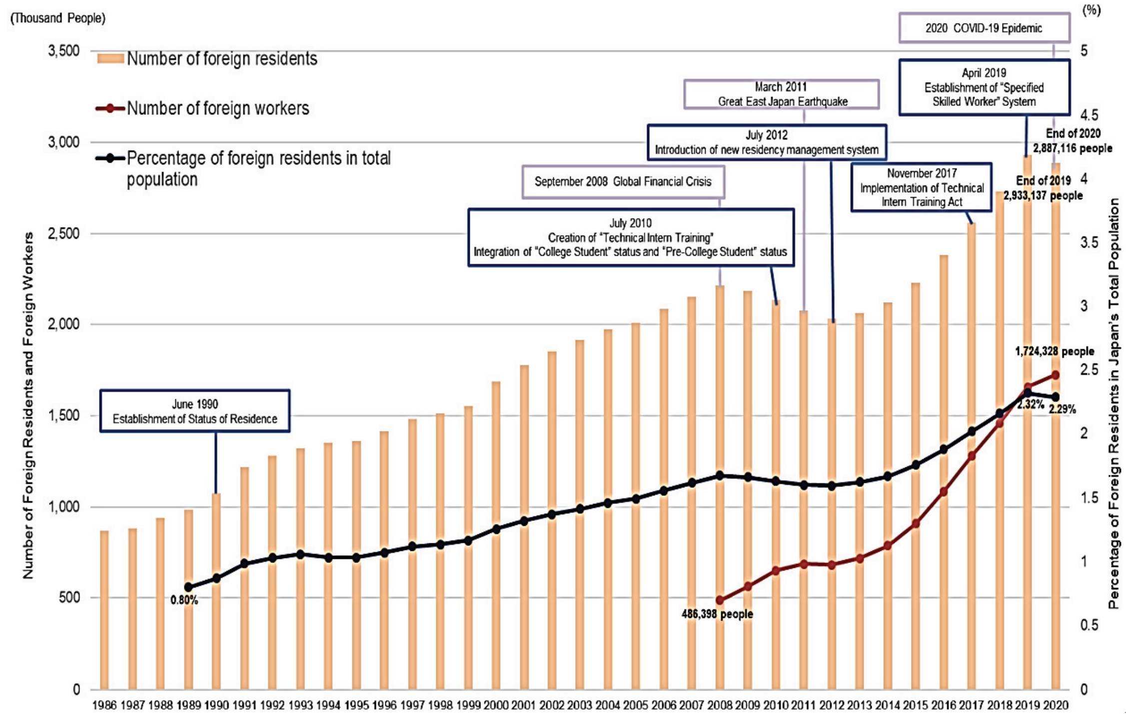


Figure 2. 4 Changes in the Situation of Foreign Residents in Japan (Source: Immigration Services Agency of Japan)

In the recent years, depopulation has been mitigated by the positive contribution of international migration in Japan. Despite the fact that international migration in Japan is smaller than that of other industrialized countries in Europe and North America, the number of immigration and emigration in Japan has gradually increased over the last decades. During these years, the characteristics of international migration and the social structure of foreign residents have significantly transformed and effecting on or affected by the Japanese society (Sato, 2004). Japan's foreign community has been growing about 200,000 annually, even while the population as a whole has been falling by about 500,000 in a year. In 2019, approximately 2.93 million residents of foreign nationality were registered in Japan as 2.3 percent of the total population. According to Japan Immigration

Bureau, the three major foreign migrants to Japan are China for 27.2%, Republic of Korea at 18.8% and Vietnam with 13.4% of the total. The most common status of residence for foreign residents in 2019 were permanent resident with 29.0%, technical intern with 12.5% and students with 8.1%.

According to Figure 2.4, there were several significant policies for foreign migrants in Japan such as creation of Technical Intern Training Program (TITP) to solve the labor force shortage and integration of Collage Students and Pre-College Students status in 2010, introduction of new residency management in 2012, implementation of Technical Intern Training Act in 2017 and establishment of Specified Skilled Worker System in 2019. International migration to Japan was started to increase by the introduction of new residency management in 2012. The foreign workforce immigration has significantly increased after 2015 by the impact of Japan Revitalization Strategy approved in June 2014 which includes "Utilization of Foreign Workers" under the "Employment System Reform/ Strengthening of Human Resources". Under TITP, workers from foreign countries were recruited as interns with its term about one to five years, and they were not permitted to change jobs during their stay. In keeping with the no-immigration policy in Japan, the government has provided with a minimum support to the foreign workers during their stay and the workers were expected to return home at the end of their internship in TITP (Toshihiro, 2020). This leads to the illegal disappearance of the interns from their assigned sites when the intern has an economic need to work in Japan beyond their authorized stay. In order to mitigate the system faults of TITP, Japanese government tried to reform immigration scheme with a legal framework for the admission of foreign unskilled or semi-skilled workers under TITP. In 2019, the statuses of residence as "Specified Skilled Worker" (i) which needs considerable degree of knowledge or experience belonging to 12 industrial fields such as "Nursing care", "Building cleaning management", "Machine parts and tooling/ Industrial machinery/ Electric, electronics and information industries", "Construction industry", "Shipbuilding and ship machinery industry", "Automobile repair and maintenance", "Aviation industry", "Accommodation industry", "Agriculture, Fishery & aquaculture", "Manufacture of food and beverages", "Food service industry" and as "Specified Skilled Worker" (ii) which requires proficient skills belonging to "Construction industry" and "Shipbuilding or ship machinery industry" were established for the acceptance of work-ready foreign nationals to secure domestic human resources (MOJ., 2020b). The number of foreign workers hit the peak after the introduction of Specified Skilled Worker System for semi-skilled workers in 12 industries which identified the serious labor shortages. Even though Japanese immigration policies have been relaxed by the above implementations, there is still a sizable imbalance between inbound and outbound international migration policies which need to be carefully monitored (Saito, 2022).

Novel coronavirus pandemic in 2019 (Covid-19), also affects international migration of Japan. 2019 was the beginning year of the new foreign workforce immigration policy, however, the international and interregional population movements have been severely restricted by the national border closure and its strict control to show out the affected passengers with Covid-19. The foreign residents living in Japan or the work-ready foreigners to be visiting to Japan was damaged due to the suspension or slow-down of production activities. As a result, thousands of foreign workers faced unemployment. The government had allowed them to switch jobs to deal with the pandemic, relocating in Japan along with job change however, was not easy for foreign workers. In addition, the strict boarder control caused many foreign workers being unable to return to their own countries. On the other hand, some prospective trainees had been left on stand by in their home countries due to the border closure. Ministry of Justice and the Ministry of Health, Labor, and Welfare implemented the policy for population movement to prevent from the outbreak of Covid-19. This policy also severely impacted on the domestic migration of foreign residents in 2020. The trend of foreign residents' transition as discussed above was not negligible among the domestic industries that had been accepting foreign workers.

Even though the number of foreign residents in Japan is significantly increasing, the social services and government supports to them are still insufficient and the inequities between domestic and foreign residents are also a social issue . Foreign residents are mainly concentrated in urban, suburban and industrial zones since the Japanese government restricts foreign immigration to only those with specialized and technical skills, so then they tend to concentrate on the area except rural regions. The vast majority of these immigrants are also not allowed to bring their family members and are expected to return to their respective countries over their terms in Japan. Even though accepting foreign residents can solve the workforce shortage in Japan, it will not raise national fertility. Therefore, immigration under the current policy of the Japanese government could lead to even more rapid agglomeration and urbanization in existing urbanized areas and deepen the spiral of community aging and depopulation in rural areas. Therefore, there is an urgent need to construct a comprehensive migration policy that includes immigration control in urbanized area and a foreign residents integration program to Japanese local community, such as support language learning and vocational training of foreigners. To consider the implications for social necessities for foreign residents, it is also essential to understand the foreign residents transition over Japanese prefectures.

2.2.4 Research Gaps

There are several gaps in existing studies. In the society with low fertility rate, migration becomes the most important social phenomena and more significant factor for population dynamics. Even though CCA is a tractable population projection tool with logical components, migration is a difficult component to predict by CCA. Migration assumption in CCA is not quite enough to represent the real group of population based on the simple extension of the past trend. The reliability of migration component in CCA needs to be improved (1). In developed countries, changes in socioeconomic conditions and urbanization are rapid. However, existing population prediction studies generally ignore the potential economic and urbanization indices on population agglomeration phenomena for future demographic shifts (2). With respect to methodological limitations referred in (1), there is a need to develop the population prediction method based not only on the past trend and characteristics of each region but on the neighborhood effects. Spatial models can model the neighborhood effects by the spatial dependences and can stabilize the projection results through the realistic/ much reliable assumption (3). The rapid increase of foreign residents can improve the demographic structure about the labor force and economic growth in a rapid aging and low fertility society. However, the social services and accessible social support in Japan are still insufficient for foreign residents. Therefore, there is an urgent need to construct a comprehensive migration policy about the immigration control and a foreign residents integration program such as support language learning and vocational training of foreigners (4).

In summary, this dissertation attempts to bridge several gaps in existing studies. This study contributes to the population studies by proposing a novel method for modeling future demographic structures which can be one of the fundamental approaches by considering the spatial dependencies among the regions. With better population prediction approach, the model will give an alternative long-term impact of population distribution. In order to deepen the understanding in migration of foreign people in Japan, the demographic transition of foreign residents' cohorts is analyzed with the structural break of the inflow/ outflow of foreign domestic and international migration, and then clarify the supporting policies for foreign residents in Japan are discussed with referring to the findings.

Chapter 3 Research Design, Methodology and Data Collection

The population projection in Japan by CCA gives the size and cohort structure of the population future based on the assumptions on fertility, mortality and international migration rates. The official population projection by Japanese government provides a well-defined range of possible future population developments referring to the latest trend. Projecting the population using CCA requires the following assumptions to be set for each cohort: (1) initial population, (2) future fertility rate and the sex ratio at birth, (3) future survival rate and (4) future international migration rates. Figure 3.1 show the national prediction method (CCA) flow of Japanese government.

3.1 Population Prediction Equations by CCA

The general equation of CCA consists of three components with recursive form denoted as:

$$\boldsymbol{P}(i, t+k) = \boldsymbol{P}(i, t) + \boldsymbol{NC}(i, t) + \boldsymbol{NM}(i, t) \tag{3.1}$$

The general equation of CCA in eq. (3.1) is substituted with the survival rate for the natural increase/decrease in a projection period. The transformed equation is as following:

$$\boldsymbol{P}(i, t+k) = \boldsymbol{P}(i, t) * \mathbf{S}(i, x\sim x+n) + \big(\mathbf{IM}(i, t+k) - \mathbf{EM}(i, t+k)\big) \tag{3.2}$$

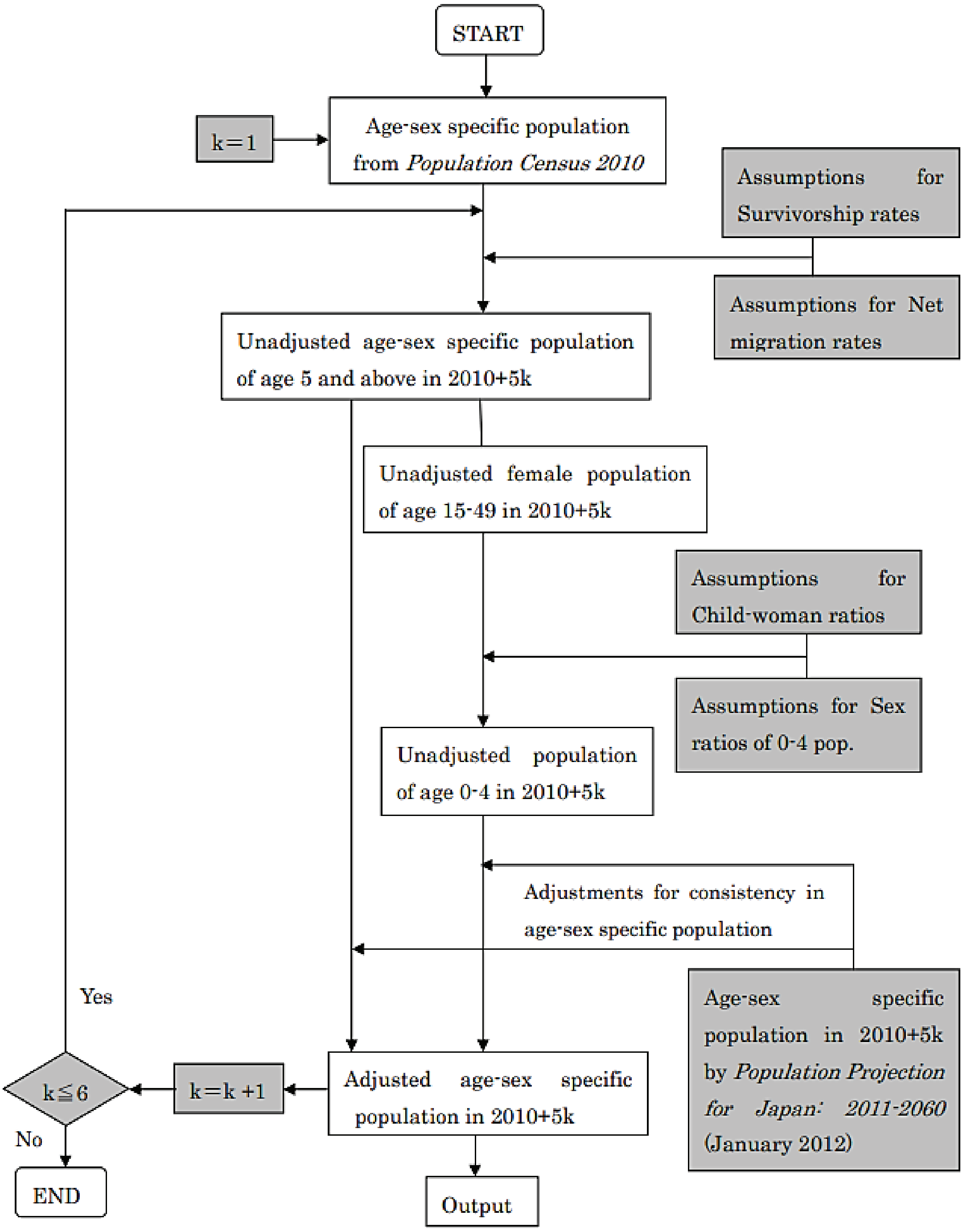


Figure 3.1 National Prediction Method Flow of Japanese Government (Source: IPSS website (http://www.ipss.go.jp))

where $\mathbf{P}(i,t)$ is an initial population of municipality i at initial year t, $\mathbf{S}(i, x \sim x+n)$ is the survival rate of a cohort at the end of a projection interval (ex., n=4 for 5-year age groups) and $\mathbf{IM}(i, t+k)$ and $\mathbf{EM}(i, t+k)$ stand for immigration and emigration in the subsequent period, respectively.

3.2 Parameters Setting for CCA

3.2.1 Initial Population

In this study, the estimation is started from 2010 as initial population from the report of population census of Japan in 2010 by the Statistics Bureau, Ministry of Internal Affairs and Communications. This dissertation predicts the population in 2015 by 5-years-age cohorts with both genders for all the municipalities in Japan. After the estimation from 2010 to 2015, the predicted population in 2015 is set as the initial population for the prediction in 2020 and the above prediction to 5-years ahead is repeated until 2040.

3.2.2 Setting Future Age-specific Survival Rates

In order to project the population from t to $t+n$ period, survival rates of each cohort in the period are needed which can be obtained from the life tables for all the cohorts' in the latest period. Life tables are used to measure mortality, survivorship and the life expectancy of each cohort. In this study, the life table of Japanese population in 2010 is used, where age $x \sim x+4$ is expressed as x years of cohort, and year t=2015, 2020, ..., 2040.

The life table is issued by the National Institute of Population and Social Security Research.

*3.2.3 Children- Women Ratio (***CWR***)*

The child-woman ratio **(CWR)** or fertility refers to the average number of 0-4 cohorts coming from a women cohorts aged in 15-49 for each region. Since the future fertility is uncertain, the national population prediction made by CCA sets the three assumptions such as middle, high and low-variant estimation and gives the population predictions for each assumption. However, for simplicity, this study will only focus on the medium fertility case because the trend of total population transition among the different assumption is not a main concern in this study. The assumptions of medium fertility are following; (i) the average age at first marriage for women varies by cohort and rises gradually from 25.7 years for the 1960–1995 cohort to 28.2 years for the 1995–1999 cohort. Up to the cohort born in 2010, the fertility is kept at almost the same level, and remains unchanged thereafter, (ii) the percentage of women who have never been married rises from 9.4% for the cohort born in 1960 to 20.1% for the cohort born in 1995. Until the cohort born in 2010, the first marriage-age then is kept at almost the same level and remains unchanged thereafter, (iii) the number of births from married couples is affected by the timing of childbearing, marriage and the reproductive behavior of couples. The index for the variations in couples' reproductive behavior, i.e., fertility variation coefficient of married couples drops to 0.920 for the cohort born in 1995 comparing with 1.0 as a benchmark from 1935 to 1954. Up to the cohort born in 2010, it is remained constant and unchanged thereafter. This index and the first marriage behavior described in the above (i) and (ii) are used to calculate the number of births from married couples, which decreases from 2.07 for the cohorts born in the period between 1958 and 1962 to 1.74 for the cohort born in 1995, remaining unchanged thereafter. (iv) based on the number of births from women who had these experiences in marital status, the impact of divorce, bereavement and remarriage on to fertility rates were calculated. As a result, the coefficient of divorce, bereavement, and remarriage falls from 0.962 for the cohort born in 1960 to 0.938 for the cohort born in 1995 assuming the fertility level of first-marriage couples who have finished the birth process to be 1.0 as a benchmark. It also remains unchanged thereafter. As a result of the assumptions (i) to (iv), the total cohort fertility rate of Japanese women falls from 1.808 for the cohort born in 1960 to 1.301 for the cohort born in 1995. It nearly remains constant until the cohort born in 2010 and remains unchanged thereafter. All the above process can convert the cohort age-specific fertility rates into an annual fertility rate.

This study calculated the relative disparities R_i of the municipal child-woman ratio to the national ratio in 2010 and set the future municipal child-woman ratios constant from 2010 to 2040 as in eq. (3.3) and in eq. (3.4).

$$\mathbf{CWR}\ i, t\ (R_i) = \frac{\sum \mathbf{CWR}(i{,}2010{,}x{\sim}x+n\,)}{\mathbf{CWR}\ (2010)}, \text{constant for } t \quad (3.3)$$

For t-year after 2015 as CWR is calculated as follows,

$$\mathbf{CWR}_{i,t+k} = \mathbf{CWR}_{i.t} * \mathbf{R}_{\,i} \quad (3.4)$$

3.2.4 Setting Future Sex Ratios of Age 0-4

To divide the number of births into men and women, the sex ratios of age 0-4 population in 2010 is required. Since this value is almost constant to most of the municipalities according to the past data, the 0 to 4-years-old sex ratio of all municipalities from 2015 to 2040 is assumed to be unchanged with that in 2010.

3.2.5 Newly Born Cohort (0~4) Population

The newly born children for male and female population for t-year after 2015 are calculated by the following equations.

$$\mathbf{P}(i, m, 0\sim4, t+k) \ = \ \mathbf{P}(i, f, 15\sim49) \ * \ \mathbf{CWR}(i, t+k) * \frac{\mathbf{SR}}{(100+\mathbf{SR})} \tag{3.5}$$

$$\mathbf{P}(i, f, 0\sim4, t+k) \ = \ \mathbf{P}(i, f, 15\sim49) \ * \ \mathbf{CWR}(i, t+k) \ * \ \frac{100}{(100+\mathbf{SR})} \tag{3.6}$$

3.2.6 Migration Prediction Assumptions

Migration trends are significantly influenced by the advent of increase in interregional interaction, changes in social situations, policies of government on the international and interregional migration. Furthermore, economic factors for both within and outside of Japan can cause significant changes on migration. As another case, the Great East Japan Earthquake in March 2011 had a substantial impact on Japanese and foreign immigration and emigration in Japan. Also, the outbreak of Covid-19 pandemic which caused the decrease in long range trips and migrants.

There are significant differences in the trend of migration between Japanese and foreign residents in Japan. The population in Japan is influenced by the cohort structure of Japanese residents and foreign residents, the impact of foreign residents on Japanese population is limited because they are still minority in Japan. According to the past statistics, the cohort structure of the Japanese net migration rate by both genders were relatively stable and the trends of foreign domestic and international migration showed great fluctuations due to the outbreak of SARS (2002-2003), the Lehman Crisis (2008) and the Great East Japan Earthquake (2011). For these reasons, the population prediction in this model, the migration of foreign residents will not be focused but treated as same way as Japanese residents. The average age-sex group annual net migration rate of Japanese people between 1986 to 2015 (using 4 cross-sections data, excluding the maximum and minimum to remove random fluctuations) and set the result as the net migration rate of Japanese people for 2016 and onward (Population Projections for Japan 2017 by National Institute of Population and Social Security Research Japan).

3.3 Integration of CCA with the SAR Model

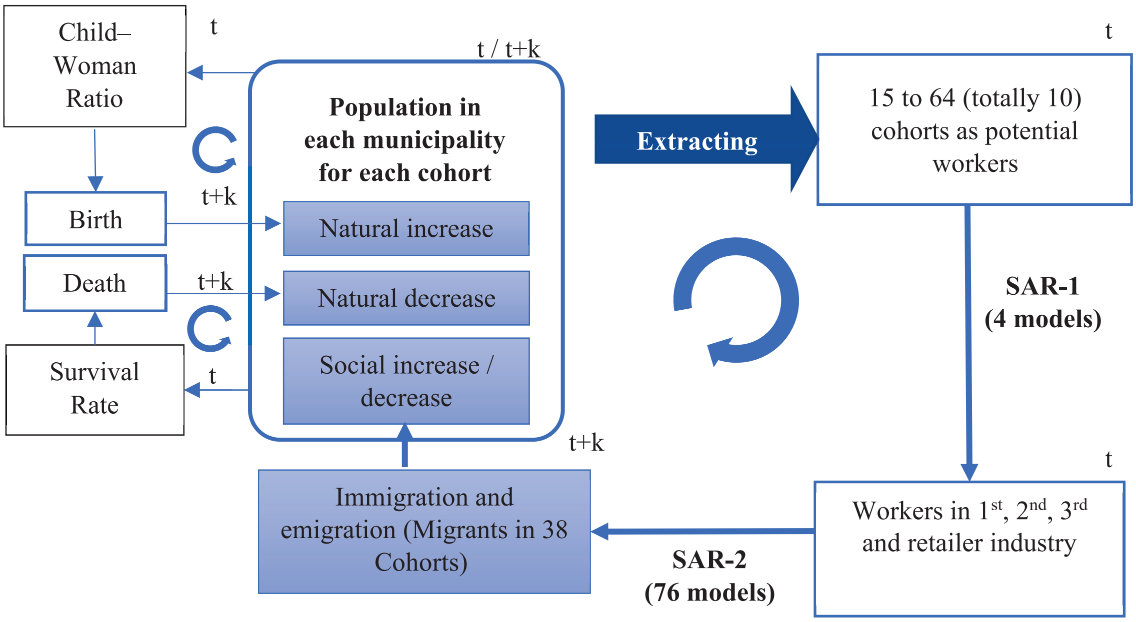


Figure 3.2 Proposed prediction methodology flow (integration of CCA with the SAR model).

In the proposed approach, CCA and spatial statistic model is compined for population prediction. In Figure 3.2, the first step of estimation is started with the cohorts in initial year and to estimate the survived population by calculating age-sex-specific survival rates and children to woman ratio to obtain the number of birth and death at the interval. This step gives the natural increase and decrease for each cohort at initial interval. The second step is to add the natural increase and decrease on each initial cohort to obtain the population at the interval. The third step is to calculate the immigration and emigration of each cohort at the interval by applying SAR model considering the location of industrial workers. The sum of migrants for each cohort is social increase or decrease in each municipality last step. Then the predicted population at the interval is obtained as shown in Figure 3.2, a set of four steps gives the populations in each municipality at the end of interval. All these steps are repeated to reach the target year at last. The proposed methodology mostly follows CCA frame, but the migration and work force are modeled with **SAR-1** and **SAR-2** including the dependency between the workers and the cohort in each municipality and to give immigrants and emigrants for each cohort. In conventional CCA, migration is handled as a ratio of migrants to the cohort population, while its amount is modeled in the proposed approach. In the proposed SAR model, the sum of dependent variable is preserved in the sum of expected (predicted) value of the dependent variable. In the proposed model, the job opportunity and life-related environment at t are treated as an explanatory factor of migration at the end of interval $(t+1)$ in **SAR-2**, and the workforce referred as working cohorts at t is modeled as the explanatory factor of the location of the job opportunity and life-related environment in **SAR-1** at t. Hence the proposed approach models both directions of causal relationship. Additionally, unlike CCA, the dataset used for this study includes domestic and international migration. Such the differences in CCA structure, regression analysis and the data of migration would bring the significantly different distribution of the cohorts over the municipalities. The following gives the details of SAR model calculation for migration prediction.

Generally, the concept of the spatial autoregressive model is that neighboring regions have more influence on each other than on the regions far away. This spatial dependency can be measured through the Moran's I statistics to measure the spatial dependency in a geographical dataset. To examine the necessity of SAR model, an estimation of Moran's I is often used. A higher Moran's I indicates a stronger spatial autocorrelation, or stronger evidence clustering effect. The negative Moran's I indicates also stronger spatial correlations like a checkerboard arrangement of the variable, which is much clearly appearing with low Moran's I. If the Moran test is significant, it is fit to use the spatial statistics models. The spatial regression approach can include some factors to cause geographical correlation with neighboring geographic units, such as the correlation between labor force and the working opportunity.

A SAR model is as follows.

$$\boldsymbol{Y} = \rho \boldsymbol{W}\boldsymbol{Y} + \boldsymbol{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon} \tag{3.7}$$

SAR model can be transferred into an induced form which clearly shows the generating process of the dependent variable as in eq. (3.8). Anselin (1988) noted eq. (3.8) is called mixed regressive or spatial autoregressive model.

$$\boldsymbol{Y} = (\boldsymbol{I} - \rho\boldsymbol{W})^{-1}\boldsymbol{X}\beta + (\boldsymbol{I} - \rho\boldsymbol{W})^{-1}\varepsilon \tag{3.8}$$

Vector $\boldsymbol{Y}$ is a geo-referenced endogenous/dependent variable. Matrix $\boldsymbol{X}$ contains exogenous/explanatory vectors, and the β are associated regression parameter vectors. In eq.(3.8), the model consists in spatial correlation of explanatory variable and that of error term $\boldsymbol{X}\beta$. The reason to use SAR is because the dependent variable $\boldsymbol{Y}$ (number of migration) will be an index of regional attractiveness, or the opportunities of the offered jobs. $\boldsymbol{W}$ is a weighting matrix with neighboring regions, and the associated scalar parameter ρ reflects the strength of spatial dependence. The spatial weight matrix, $\boldsymbol{W}$, is an $n \times n$ nonnegative matrix that has an element of $\boldsymbol{W}_{ij}$, which gives the strength of a bond between location I and j. In this model, $(\boldsymbol{I} - \rho\boldsymbol{W})^{-1}$is non-singular and that the product $(\boldsymbol{I} - \rho\boldsymbol{W})^{-1}$which equals the variance-covariance matrix is positive-definite. The error vector ε in eq.(3.8) shows the dependent structure among the regions. As error term ε is not independent and identically distribute. Therefore, eq.(3.8) cannot be estimated by OLS. An ordinary weighting matrix is defined with the elements of inverse of distance or giving 1 for a range of neighbor and 0 for the others. Choice of $\boldsymbol{W}$ is essential in spatial autoregressive model. In this study, contiguity matrix to indicate spatial correlation among the couple of regions with the shared boundary was used. For contiguity matrices, an element w_{ij} is one of the units *i* and *j* share a common border and is zero otherwise.

$$w_{ij} = \begin{cases} 1 \ \text{ if } i \text{ shares a boundary with } j \\ \qquad 0 \ \text{ otherwise} \end{cases} \tag{3.9}$$

In defining the spatial-weighting matrix, a normalization of the spatial-weighting matrix is necessary for a stochastic stability of spatial process. There are generally two types of normalizations in spatial-weighting matrices. First is traditional row normalization as follows.

$$w_{ij} = \left(\frac{1}{s_i}\right) w_{ij}{}^{*} \text{ where } s_i = \textstyle\sum_j^n w_{ij} \tag{3.10}$$

Second is spectral normalization, which is created by dividing the entries by the absolute value of the largest eigenvalue of the matrix and this normalization is easier to interpret than the traditional row normalization.

$$w_{ij} = \left(\frac{1}{\tau}\right) w_{ij}{}^{*} \tag{3.11}$$

where τ is the largest of the moduli of the eigenvalues of the un-normalized spatial-weighting matrix w^*. In this study, we designed our spatial-weighting matrices based on spectral normalization by eq. (3.11). A sufficient condition with positive-definite variance-covariance matrices are $-1 < \rho < 1$ for row-standardized $\boldsymbol{W}$. When ρ=0, the dependent variable follows the property with identical independent distribution to its neighbors, often called i.i.d.

In spatial statistic models with spatial lags of the dependent variables, interpretation of the parameters is more complicated since the information of the parameter include the effect of its neighbours. This may lead to erroneous conclusions if the direct interpretation of the parameter to link x to z like ordinary linear regression models is made. Previous studies (Kim, Phipps, and Anselin 2003; Anselin and Legallo 2006) suggested a way of interpreting the parameters of the models containing spatial lags of the dependent variable. The decomposition of the effect from x to z into direct effect (any given explanatory variable will affect the region itself) and indirect effects (potentially effects the dependent variable by all other regions) is used in this study, as suggested the above. Note that a direct effect is caused by the change of the variable in the target area while an indirect effect is caused by that in neighboring regions.

In this study, eq.(3.7) is applied to the industrial employee ($\boldsymbol{IE}$) model as **SAR -1** and the immigration ($\boldsymbol{IM}$) and emigration ($\boldsymbol{EM}$) models as **SAR-2**.

SAR (1) is as follows,

$$\boldsymbol{IE}_{(t)} = \rho \boldsymbol{WIE}_{(t)} + \boldsymbol{X}_{(t)} \beta + \varepsilon \tag{3.12}$$

SAR (2) is as follows,

$$\boldsymbol{EM}_{(t+k)} = \rho \boldsymbol{WEM}_{(t)} + \boldsymbol{X}_{(t)} \beta + \varepsilon \tag{3.13}$$

$$\boldsymbol{IM}_{(t+k)} = \rho \boldsymbol{WIM}_{(t)} + \boldsymbol{X}_{(t)} \beta + \varepsilon \tag{3.14}$$

The dependent variable of **SAR-1** is workers by 1^{st}, 2^{nd} and 3^{rd} industries, and the explanatory variables are the working-age cohorts from 15 to 64. To sum up, there are totally 4 models in **SAR-1**. The dependent variables of **SAR-2** are immigration and emigration for each cohort and for each municipality. To sum up, [Migration population (2 types)] × [5-year-old Class (19 class)] × [gender (2 types)] = 76 models are estimated. The explanatory variables are the number of retailers and the number of employees of 1st, 2nd, 3rd and all industries. In the calculation, the effect of parent cohorts on their child cohorts is also considered. The estimation of migration model is made for immigration, emigration, and industrial characteristics (workforce of industries) to clarify the spatially lagged impact of the explanatory variables on the dependent variable. Because of the property of regression model, the expected value of dependent variable is consistent with the data, so then the total number of immigrants / emigrants are also consistent with the data. Therefore, the proposed procedure has a consistency with the control total of data (i.e, sum of migrants) used in the model estimation. In order to summarize the effects of the industrial characteristics on the age composition of migrants, the population pyrmaid charts will be shown. The output of the models are in the form of direct and indirect effect which is the effect from the surrounding regions. The direct and indirect effect are combined as a total effect as the total attractiveness of cohorts on the explanatory variables. Those effects are summerized and averaged over the regions to make figures.

3.4 A model for Transition of Foreign Residents' Cohort Characteristics

As an analytical tool to clarify the cohort structure of foreign residents, a nonnegative matrix factorization model (NMF) can clarify the potential patterns in a dataset with their weights. NMF becomes a popular technique for the analysis of high dimensional data as it extracts sparse and significant characteristics with its weights from a set of nonnegative data vectors (Suykens et.al., 2014). NMF is widely used in various fields such as artificial intelligence, bioinformatics, computational biology and demography. NMF is a kind of technique as an unsupervised cluster analysis, which provides a simplified decomposition of the data matrix by the nonnegativity constraint on its outputs (Yang and Seoighe, 2016). The primary approach of NMF is to estimate matrices W and H as a local minimum of the optimization problem (Paatero and Tapper, 1994) and it became popular by Lee and Seung (1999). The NMF is modeled as follows:

$$\boldsymbol{X} \approx \boldsymbol{W} \times \boldsymbol{H} \tag{3.15}$$

X is set up for n data points with m dimensions $n \times m$, i.e., $\boldsymbol{X} \in \mathbb{R}^{\boldsymbol{m}\times \boldsymbol{n}}$(Linear combination of W and H). By the estimation of NMF the m original dimensions are reduced to k which is the low rank approximation of X (k ≤ min (m, n)) and creates $\boldsymbol{W} \in \mathbb{R}^{\boldsymbol{k} \times \boldsymbol{m}}$ and $\boldsymbol{H} \in \mathbb{R}^{\boldsymbol{n}\times \boldsymbol{k}}$. Each row of W gives weights of basis that appears in some rows of $\boldsymbol{X}$, while each row of $\boldsymbol{H}$ gives the basis made up with the set of column's attributes in

X. In other words, each column vector in ***X*** is approximated by a linear combination of the k**th** row of ***H***, weighted by the corresponding row vector of ***W***. A basic NMF is described in eq. (3.15) where the NMF solutions are not normalized. Given a nonnegative matrix ***X*** and a desired factorization rank k, the objective of the NMF algorithm is to find an approximation *X ~ WH*. After initializing nonnegative matrices ***W*** and ***H*** randomly, they are iteratively updated to minimize a loss function *D (X, WH)* shown in eq. (3.16), specified as a generalized Frobenius distance in eq. (3.17).

$$\underset{\boldsymbol{W},\boldsymbol{H}\geq\mathbf{0}}{\mathbf{Min}}\left[\boldsymbol{D}(\boldsymbol{X},\boldsymbol{WH})+\boldsymbol{R}(\boldsymbol{W},\boldsymbol{H})\right] \tag{3.16}$$

where ***D*** is the objective function to measure the approximation between ***X*** and ***WH*** by Frobenius distance or called a loss function. ***R*** is an optional regularization function which is smoothness or sparsity of the matrices ***W*** and ***H***.

$$\boldsymbol{D}(\boldsymbol{X},\boldsymbol{WH})=\frac{\mathbf{1}}{\mathbf{2}}\sum_{\boldsymbol{i}=\mathbf{1}}^{\boldsymbol{m}}\sum_{\boldsymbol{j}=\mathbf{1}}^{\boldsymbol{n}}\left[\boldsymbol{X}_{\boldsymbol{ij}}-(\boldsymbol{WH})_{\boldsymbol{ij}}\right]^{\mathbf{2}} \tag{3.17}$$

Eq. (3.16) can be optimized by the alternated estimation of *W* and *H* as follows. In each iteration, ***W*** and ***H*** are updated by using the coupled multiplicative update rules as eq. (3.18) and eq. (3.19):

$$\boldsymbol{W}_{\boldsymbol{ik}}\leftarrow\boldsymbol{W}_{\boldsymbol{ik}}\frac{\left(\sum_{\boldsymbol{l}}\frac{\boldsymbol{H}_{\boldsymbol{kl}}\boldsymbol{X}_{\boldsymbol{il}}}{(\boldsymbol{WH})_{\boldsymbol{ij}}}\right)}{\sum_{\boldsymbol{l}}\boldsymbol{H}_{\boldsymbol{kl}}} \tag{3.18}$$

$$H_{kj} \leftarrow H_{kj} \frac{(\sum_l \frac{w_{lk} x_{lj}}{(WH)_{ij}})}{\sum_l w_{lk}} \quad (3.19)$$

Since the optimization of eq. (3.18) and eq. (3.19) is started from an arbitrary matrix with randomized elements, so then the estimated $\boldsymbol{W}$ and $\boldsymbol{H}$ are not unique but robust for most of ordinary data conditions under an appropriate k. If k is not adequate, however, $\boldsymbol{W}$ and $\boldsymbol{H}$ become instable, which causes an interpretation of the estimated basis. To alleviate this problem, some existing methods enforce a simplicity of the basis by adding regularization terms to the NMF objective function (Suykens et al., 2014). Furthermore, in this study, $\boldsymbol{W}$ matrix is standardized as $\boldsymbol{W'}$ whose components of a row of $\boldsymbol{W}$ are divided for each row sum. For $\boldsymbol{H}$ matrix, standardization is done by summing up the entries in each rows and each component (h_{kn}) is divided by its row sum to form $\boldsymbol{H'}$ (influence factors of the corresponding samples). The standardization by eq.(3.20) and eq. (3.21) makes it easier to compare the cluster membership and the interpretation of basis.

W-matrix Standardization:

$$\boldsymbol{W'} = [\boldsymbol{w_{mk}}] \boldsymbol{s.t.},\ \boldsymbol{w_{mk}} \geq \boldsymbol{0}, \sum_n \boldsymbol{w_{mk}} = \boldsymbol{1} \quad (3.20)$$

H-matrix Standardization:

$$\boldsymbol{H'} = [\boldsymbol{h_{kn}}] \boldsymbol{s.t.},\ \boldsymbol{h_{kn}} \geq \boldsymbol{0}, \sum_n \boldsymbol{h_{kn}} = \boldsymbol{1} \quad (3.21)$$

The choice of k is an empirical problem by comparing a set of outcomes obtained by different k settings (Do et al. 2020). In order to simplify the searching k from the viewpoint of interpretation, a set of cohort contribution of male and female in a basis of

H should be basically similar, but some exceptions can be allowed. This criterion is applied after the statistical criterion gives several candidates of k.

3.5 A model for Foreign Residents International and Interregional Migration

In order to investigate the impact of numerous elements connected to foreign migrants' movements from original to destination, many models and approaches have been developed. A major issue in the field of demographic distribution study is the prediction of original to destination (OD) flows. Traditional models like the autoregressive integrated moving average model (ARIMA); (Pan et al., 2012), factorization-based approaches (Deng et al., 2016; Gong et al., 2018), etc., can be used to handle the long-term dependence of OD. However, these models cannot capture complicated interactions effectively and suffers two side correlations; for OD flow data correlations exist in both the origins and the destinations due to poor efficiency.

Multiple linear regression analysis is also one of the models, allowing for exploratory examination of the importance of many different factors in the act of migration. Additionally, it can be applied for forecasting the population movement and observe its structural transition. Its primary application is to examine the relationship between a migration measure and one or more explanatory variables.

The multiple linear models are describing the relation between several random variables $\mathbf{X_1}$, …, $\mathbf{X_i}$ and $\mathbf{Y}$ simple extension of linear model. Eq. (3.22) is the multiple regression model provides a prediction of $\mathbf{Y}$ from the $\mathbf{X}_i$ as follows.

$$\boldsymbol{Y} = \beta_0 + \sum^{i} \beta_i \boldsymbol{X}_i + \boldsymbol{\varepsilon}_i, i = 1, \dots\dots, n \tag{3.22}$$

where $\mathbf{X_1}$ …,$\mathbf{X_i}$ are predictors or independent variables and the response or dependent variable is $\mathbf{Y}$. β_0 is an intercept and β_i are slopes, respectively. The random variable $\boldsymbol{\varepsilon}$ has mean zero and is independent from $\mathbf{X_1}$, …, **i.**

This study applies the regression model for the data in time series from 2010 to 2020 with origin to destination structure. The following model is made to find the structural break of the migration of the above structure. Support the dependent variable as a migration between *i* and *j* in *t* $\mathbf{M}_{ij}^{t}$. If the migration in *t* is almost similar to *t-1*, $\mathbf{M}_{ij}^{t}$is explained by $\mathbf{M}_{ij}^{t-1}$except some errors ε_{ij}. As to simplify the discussion, some of the additional assumptions are introduced which will be shown later regression of migration to find the structural break between *t-1* and *t* is formulated as follows.

$$\sum_{ij=1}^{n} \mathbf{M}_{ij}^{t} = \beta_0 + \sum_{ij=1}^{n} \beta_i \overline{\mathbf{M}}_{ij}^{t-1} + \sum_{ji=1}^{n} \beta_j \underline{\mathbf{M}}_{ji}^{t-1} + \varepsilon_{ij} \tag{3.23}$$

where, $\mathbf{M}_{ij}^{t}$ is a migration flows between region *i* to *j* for the period *t*. β_0 is the intercept, $\overline{\mathbf{M}}_{ij}^{t-1}$ is the row standardized migration flows of region *i* to *j* in the period *t-1* and $\underline{\mathbf{M}}_{ij}^{t-1}$ is the column standardized migration flows between region *j* to *i* in the period *t-1*. ε_{ij} is the residual error term which is used for the global Moran 'I to detect the structural break between *t-1* and *t,* because significant Moran's I indicates the estimated model fails to give the prediction for $\mathbf{M}_{ij}^{t}$ by $\mathbf{M}_{i}^{t-1}$ and $\mathbf{M}_{j}^{t-1}$. The conventional structural break analysis is a test for an unexpected change over time in the parameters of regression models for time-series dataset. It is a test of equality in the coefficients of the parameters of regression, and there is a breakpoint mechanism. However first, this study has only 10 cross-sections with a large number of samples for each cross-section. Second in the regression, the objective and explanatory variables are extracted for the same cross-section and set that the model will be perfect with R-squared 1 and no residual. If the previous year components of row and column (inflow/ outflow) are linearly increase or decrease, the residual will be random. That is why the global Moran' I for the residual can be applied for the structural break test. This is the null hypothesis in this analysis.

The migration from or to oversea region included as an additional row or column, so totally 47 prefectures + 1 oversea = 48 spatial units are defined. Therefore, 48 x 48 OD matrix except 47 intra-prefectures and an intra-oversea migration data is analyzed for each cross-section. In this study, the situation where the intercept coefficient β_0 is set to zero, i.e., the regression lies through (0,0). Additionally, all the regression coefficients β_i or β_j are constrained in our model above 0. Therefore, the linear constraints; a lower bound to be zero to align with the scenarios are given. The objective function is sum of the squared errors, as same as ordinary regression approach.

3.6 Data

The spatial unit dataset should be carefully chosen in the population study. However, currently the demographic data source is quite limited with the spatial unit scale and with the time interval scale. Hence in this study, population prediction of proposed approach by integration of CCA with the SAR model much fine scale (municipality) data is used and the foreign resident's analysis focus much about the categorical fineness with only the available interval dataset. One of the characteristics of this study is that all the four models do not introduce the explanatory factors directly into the models. As this study is the descriptive type, it is quite difficult to describe the phenomena and find direct policy recommendations. Based on the philosophy of the proposed modellings, this study can compressively and briefly understand the phenomena and can guess to make the recommendations based on the current trends.

Chapter 4 uses the initial workforce, immigrants', and emigrants' data from 2010 to predict the workforce in 2015 using **SAR-1** model and the immigrants and emigrants in 2015 using **SAR-2** model. The predicted workforce, immigrants and emigrants of 2015 are applied to predict the population in 2020. This implication is repeated until it reached the final year of 2040. For Chapter 5, cohort-based population data of 2010 is used to predict the population of 2015 and predicted data of 2015 is used to predict the population of 2020. This prediction is repeated until it reached the final year of 2040. Other geographical or industrial data is from Geographic Data (ArcGIS Data Collection 2015, Esri Japan) and statistic from e-Stat of Japan. The regions used in Chapter 4 are 1 prefecture (Fukushima) and 1799 municipalities. For Chapter 5, Fukushima prefecture is substituted with 13 districts and 59 municipalities. Therefore, the total target areas are 1871 municipalities.

The Esri demographic dataset for Japan provides a national statistical database and shapefiles by ArcGIS for key population, and household attributes. This dataset is collected from the website of the Statistics Bureau of the Ministry of Internal Affairs and Communications via e-stat. Dataset included 2010 population census data (prefectures, cities, wards, towns and villages and towns). The coordinate system of this dataset is Geodetic system: World geodetic system (JGD2000) and coordinate system: latitude and longitude. Table 3.1 shows the descriptive statistics for Chapter 4 and Chapter 5.

Table 3.1: Descriptive statistics

Variable	Mean	Std.Dev	Min	Max
Population	66763.36	97183.621	178	903,346
Net Migration	29.337	1685.814	-8279	68917
Male Net Migration	17	776.239	-1044	31,822
Male Immigration	1,660	8,195	0	337629
Male Emigration	2401	13230	6	547290
Female Net Migration	19	903.962	-896	37095
Female Immigration	1,460	7506	2	309618
Female Emigration	1,387	6297	6	258300
Working Age Population (15-64)	27,390	46094.009	0	573317
Number of Employees in all Industry	31357.87	44604.26	139	394885
Number of Employees in 1st Industry	1249.956	1452.162	4	12670
Number of Employees in 2nd Industry	7426.012	9922.661	13	96761
Number of Employees in 3rd Industry	20807.525	31070.582	81	280286
Number of Retailers	10949.84	7716.154	4	18670

For Chapter 6, 2010 to 2020 actual data of foreign resident's cohort datasets are used to estimate the pattern analysis for two cross sections (2015/2010 and 2015/2020). For foreign resident's cohort's transition, this study uses the dataset on the registered foreign population in Japanese prefectures in 2010, 2015 and 2020 by Census of Japan by the Statistics Bureau of the Ministry of Internal Affairs and Communications. According to the data availability for foreign residents for cohort structure and migration, this study will only focus on the prefecture level estimation for foreign residents and discussion will be mainly made on the 8 regions with 47 prefectures of Japan for simplicity. Figure 3.3 describes the regions and prefectures appearing in the following outcomes. On this figure, colors express the regions and numbers show the formal code of prefectures in Japan. In Census, immigrants or long-term foreign visitors staying for more than three months, foreign residents having the status of the permanent residents and those who married to Japanese are surveyed and summarized in 14 cohorts for each 5-years-cohort groups. Figure 3.4 shows the summary of cohort dynamics in whole Japan.

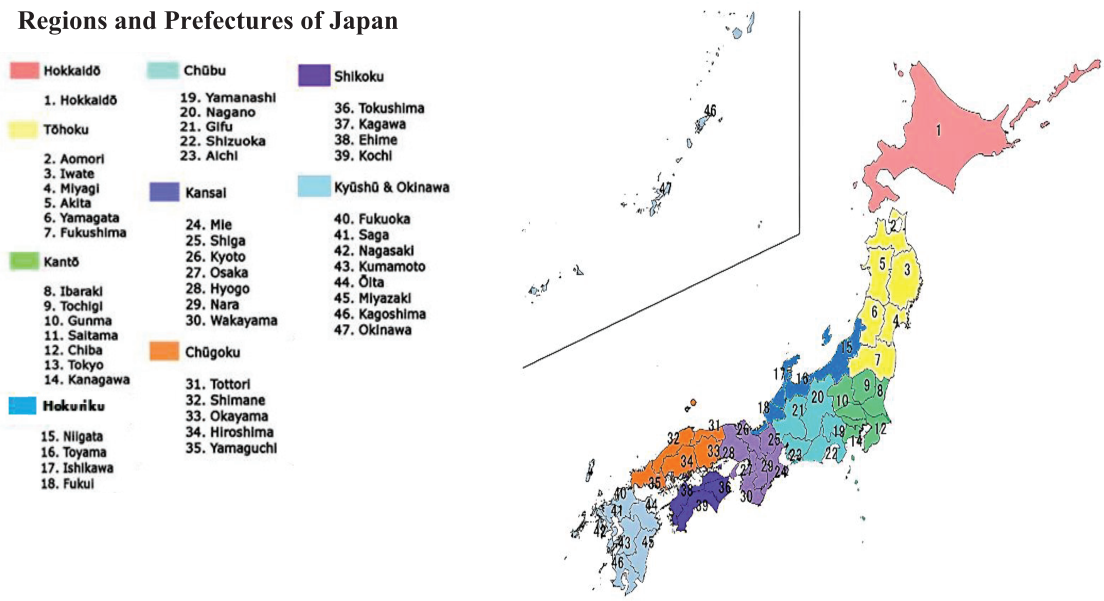


Figure 3.3 Regions and Prefectures of Japan

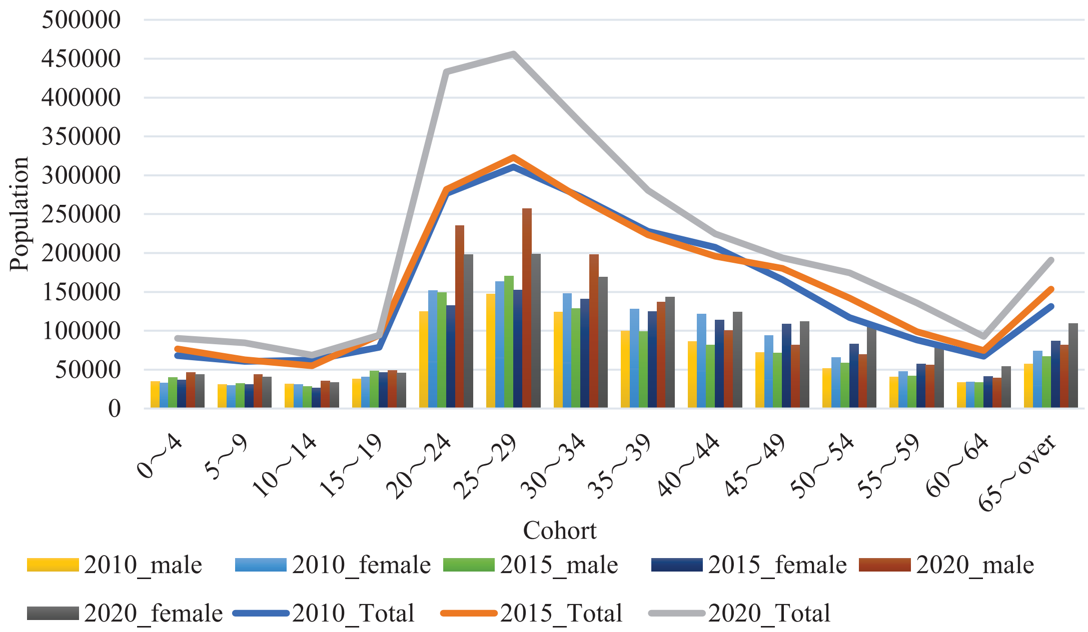


Figure 3.4 Foreign Residents' Cohorts in Japan from 2010 to 2020

For Chapter 7, actual data of foreign domestic migrants and international migrants between 2010 to 2020 is used to find out the structural break of foreign migrants' transition. In this study, the number of foreign migrants in *t* year are used to predict the number of foreign migrants in the successive year *t+1*, where *t*= 2010, 2011, …., 2020. Regarding to the foreign resident's domestic migration, prefectural-level data between 2010 and 2020 form Statistics Bureau of the Ministry of Internal Affairs and Communications is used and the dataset of international migration of foreign people coming to/ leaving from Japan between 2010 to 2020 is collected from Immigration Services Agency of Japan to estimate foreign residents' distribution. Dataset includes number of foreign migrants from between 47 prefectures with international migration from/ to each prefecture, from 2010 to 2020 for each year. Table 3.2 describes the descriptive statistics of foreign migrants for origin to destination matrix.

Table 3.2 Descriptive statistics of foreign migrants for OD table

Variables	Mean	Std.Dev	Min	Max
2010_Internal	25.468	92.27018175	0	2355
2011_Internal	24.51175	87.3548152	0	2224
2012_Internal	24.88224	89.90773643	0	2305
2013_Internal	124.828	585.0993364	0	1270
2014_Internal	146.5921	690.3182913	0	1721
2015_Internal	369.8004	780.0421826	0	4756
2016_Internal	426.6034	801.2700795	0	5735
2017_Internal	520.9959	942.7480859	0	6742
2018_Internal	750.8262	1348.085857	0	9842
2019_Internal	1058.837	1438.961825	0	10287
2020_Internal	98.00815	454.3529248	0	10609
2010_International	1765.624	2597.505189	559	13315
2011_International	6994.163	12081.26062	516	70703
2012_International	7098.77	12241.86151	500	71845
2013_International	7160.106	13527.47876	557	79769
2014_International	8322.574	15879.70812	684	94515
2015_International	9097.596	17481.16433	687	104523
2016_International	10106.26	19449.02753	750	116493
2017_International	11057.11	21482.79996	844	129903
2018_International	16949.4	25129.82321	480	97624
2019_International	17097.34	27971.21914	521	85174
2020_International	2656.745	3893.127717	263	23726

Chapter 4 Internal Migration Prediction For Economic Development In Japan By Considering The Spatial Dependencies

4.1 Introduction

In order to design the social and regional sustainability, it is essential to understand the distribution of population and its transition over the municipalities in Japan. In conventional population prediction, local or area-specific effects were discarded. However, the correlations of migration among the neighbor areas can be introduced as an area-specific characteristics into a population prediction procedure. The spatial correlation is then likely to improve the quality of local estimates of the population (Pascal et al., 2018). Among spatial statistic models, spatial autoregressive (SAR) model has an advantage which substantially takes the neighboring effect into account for the dependent variable. However, there is an issue of how to scale the neighborhood spatial dependencies in the empirical analysis. Most often, the neighborhoods are defined following to the available data unit such as census tracts or census block groups. In the existing migration studies, migration has been modeled only at the prefectural level. The migration phenomenon in smaller-scale units has not yet been studied in the existing literatures. In this chapter, spatial dependences of the regions are estimated with municipality scale.

This chapter briefly summarizes the prediction procedure for migration considering spatial dependencies among the municipalities. The procedure can examine the significance of interactions between industrial characteristics and cohort-wide migrants of each cohort. As the first step, this chapter examines whether the SAR model yields significant dependencies or not, so then the integration with the CCA model will be discussed in the following Chapter 5. The rest of the chapter is organized as follows. In section 4.2, the explanation of proposed methodology (to integrate CCA with SAR model) in order to analyze the migration structure. Section 4.3 presents the direct and indirect effect results of the SAR model for migration prediction and in section 4.4 we make some concluding remarks are presented.

4.2 Spatial Autoregressive Model For Migrants

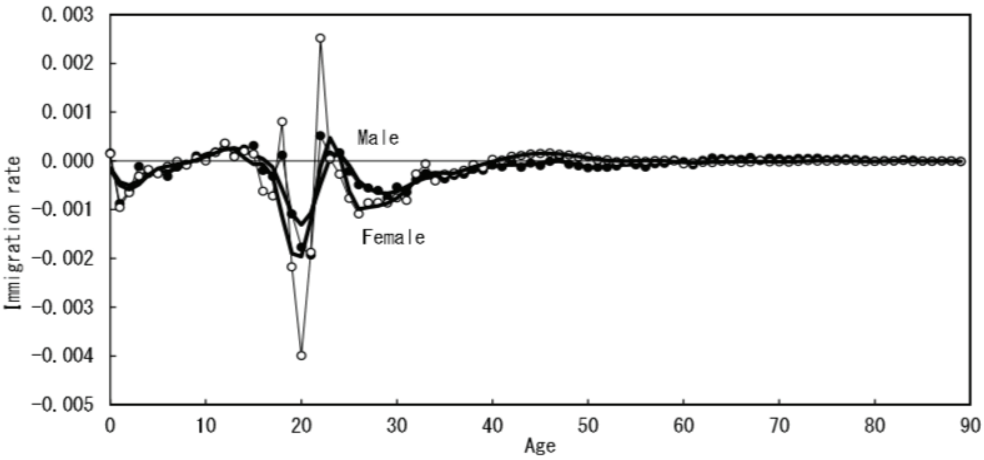


Figure 4.1 Age-specific Net Migration Rates by Sex for Japanese Population (Source: Portal Site of Official Statistics at https://www.e-stat.go.jp)

In the national prediction method by conventional CCA, the average of annual net migration rate between 1986 and 2015 is used to predict the future. 4 years observations, excluding the maximum and minimum values were smoothed out the rates to remove random fluctuations, and set the result as the net migration rate for 2016 and onward

(Figure 4.1); (Population Projections for Japan 2017 by National Institute of Population and Social Security Research Japan).

In this study, the migration inputted for CCA is calculated by spatial statistic modeling which can examine the changes of immigration and emigration for each cohort throughout the entire prediction period. The illustrative steps were shown in Section 3.3 of Figure 3.2.

The proposed prediction procedure represents the interaction between the spatial distribution of population and that of industries. Such the interaction is sometimes referred that the spatial distribution of population affects somewhat on the spatial distribution of industries, and that also it is true for vice versa. As the model to describe such the interactions, the following specification is adopted the lagged / future population is explained by the industrial characteristics at present, and the lagged / future industrial characteristics are explained by the population of each cohort, considering spatial dependency. Of course, how to link the population and industrial activity can be specified with more complex form, but it is another issue to examine the model stability or data appropriateness. Therefore for the simplicity, the basic equation of shown in Chapter 3, SAR model in eq. (3.7) is applied to the industrial employee ($\boldsymbol{IE}$) model as **SAR-1** eq. (3.12) and the immigration ($\boldsymbol{IM}$) and emigration ($\boldsymbol{EM}$) models as **SAR-2** in eq (3.13) and eq (3.14) respectively.

4.3 Discussion

4.3.1 Discussion on the Estimated Parameters

Before the estimation of SAR model, this study conducts the Moran's I test to clarify the necessity of the spatial dependency in the dependent variable which null hypothesis is no spatial dependency with given W. In Moran's I, the statistical significance of standard errors is shown as * p <0.05, ** p <0.01, and *** p <0.001, respectively. According to the significance of Moran's I test in Table 4.1, it is appropriate to apply the spatial model in this estimation. Figures 4.2a, 4.2b, 4.2c and 4.2d are the summary of adjusted R-squared of the estimated migration models for each cohort. In this estimation, the adjusted R-squared ranges between 0.786 to 0.976, so then the spatial lag autoregressive model is quite appropriate for describing the migration. The spatial correlation parameters (ρ) were positive and significant in the 65 out of 76 models. Significant ρ_s appear almost all child cohorts for both migration, the male immigration cohorts from 20 to 49 and from 60 to 90 over cohorts, all of the male emigration and female immigration cohorts, the emigration of female cohorts from 25 to 59 and from 65 to 79 (Table 4.2). According to the results, all the working-age cohort's spatial correlation parameters (ρ_s)are positive and highly significant. Therefore, the migration of working-age cohorts is indeed affected by industrial characteristics.

Table 4.1. Global Moran's I Analysis of Total Migration and Industrial Variables

Variable	Moran's Index	Expected Index	Variance	Z-score	p-value
Male Total Immigration	0.39692***	-0.00072	0.00856	45.28304	0.00000
Male Total Emigration	0.41763***	-0.00072	0.00859	48.67499	0.00000
Female Total Immigration	0.39061***	-0.00072	0.00857	45.66852	0.00000
Female Total Emigration	0.37421***	-0.00072	0.00556	43.8016	0.00000
Number of Employees in 2nd Industry	0.34752***	-0.00072	0.00726	47.94531	0.00000
Number of Retailers	0.34389***	-0.00072	0.00726	47.44475	0.00000

4.3.2 Discussion on the Industrial Characteristics

In order to observe the influence of industrial characteristics, the estimated results about the number of retailers on male and female migrant cohorts are shown in Figure 4.3(a) and Figure 4.3(b), respectively. Since the number of retailers is used to represent the geographical characteristics of urban agglomeration, the parameter of retailers in SAR model shows the cohort characteristics whether they are attracted to urban agglomeration, or not. For this variable, the models from infants and children (0-4,5-9 cohorts) were not estimated because these cohorts will not be directly influenced the retailers, rather they are obedient with their parent cohorts. The impact of retailers on 10-14 and 15-19 cohorts of both genders are also insignificant as shown in Figures 4.3(a) and 4.3(b). From Figure 4.3(a), the direct effects of male immigration between 20 to 54 cohorts are greater than the emigration however, the indirect effects are opposite. Hence, the number of retailers from the own region will affract the 20 to 54 male cohorts to cause more immigrants and the number of retailers from neighboring regions will attract the male cohorts. According to the total effects, the younger male cohort will be located closer to the from the location of retailers.

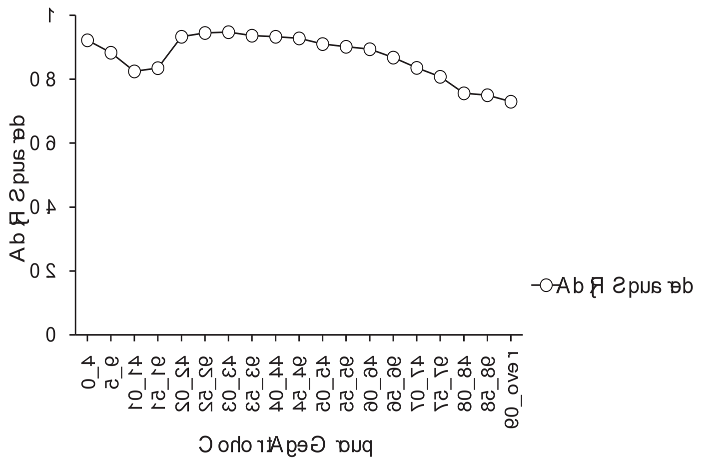


Figure 4.2 (a). Male Immigration Adj- R squared

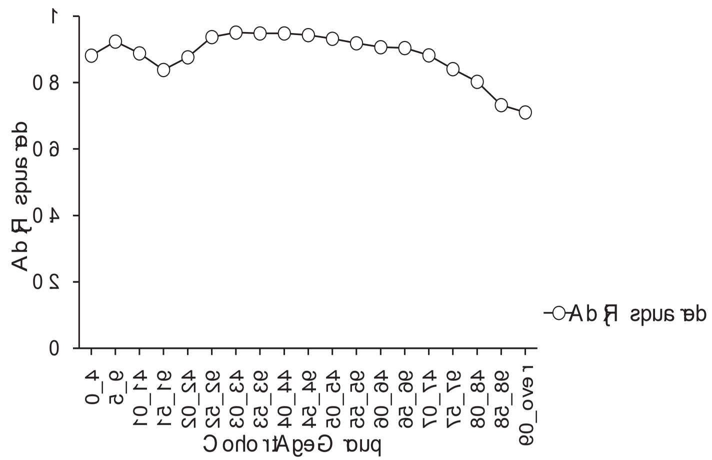


Figure 4.2(b). Male Emigration Adj R squared

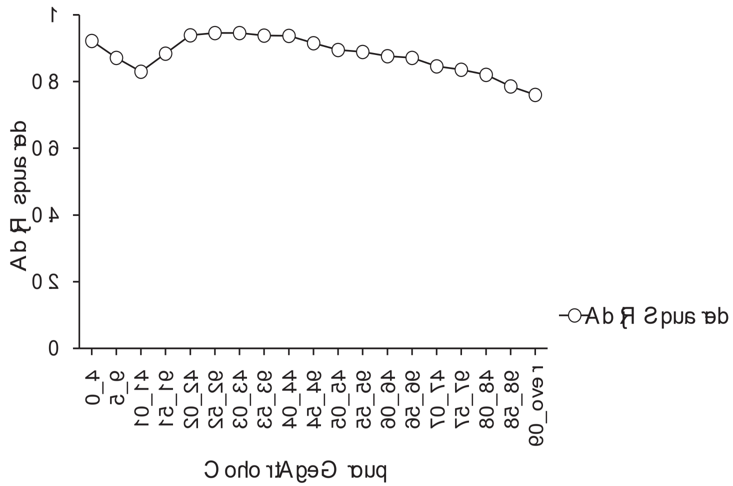


Figure 4.2(c). Female Immigration Adj R squared

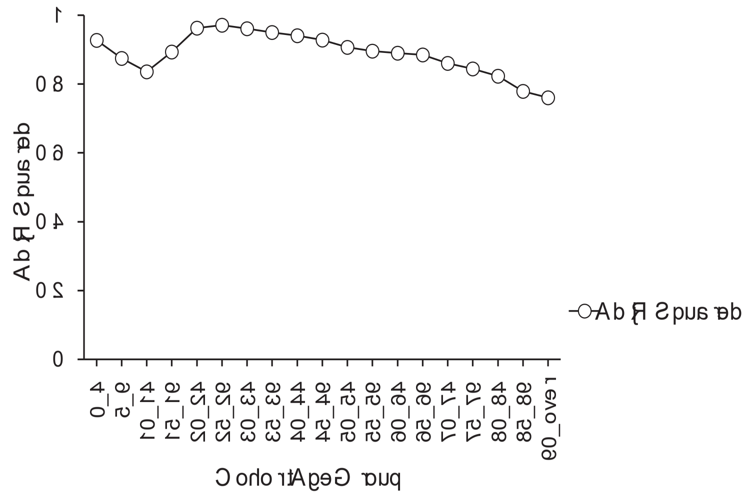


Figure 4.2(d). Female Emigration Adj R squared

Table 4.2. Results of Spatial Correlation Parameter for Both Genders with Cohorts

Cohorts	Spatial Correlation Parameter (ρ)			
	Male Immigration	Male Emigration	Female Immigration	Female Emigration
0_4	0.196***	0.238***	0.195***	0.056
5_9	0.0868*	0.113*	0.121**	0.0949*
10_14	0.0848*	0.130**	0.152**	0.0895
15_19	0.157**	0.126*	0.11*	0.0688
20_24	0.137***	0.199***	0.145***	0.0693
25_29	0.142***	0.199***	0.210***	0.185***
30_34	0.210***	0.294***	0.234***	0.196***
35_39	0.209***	0.242***	0.234***	0.127***
40_44	0.117***	0.213***	0.144***	0.0693*
45_49	0.0746*	0.135***	0.0987**	0.129***
50_54	0.0599	0.146***	0.181***	0.172***
55_59	0.0748	0.111**	0.212***	0.0979**
60_64	0.0908*	0.0913*	0.131***	0.0657
65_69	0.173***	0.198***	0.161***	0.176***
70_74	0.220***	0.259***	0.292***	0.204***
75_79	0.284***	0.334***	0.221***	0.101*
80_84	0.349***	0.304***	0.236***	0.0863
85_89	0.284***	0.345***	0.168***	0.0348
90_over	0.456***	0.514***	0.193***	0.0934
Total	0.338***	0.524***	0.415***	0.416***

Significance level parenthesis

* ρ <0.05, ** ρ <0.01, *** ρ <0.001

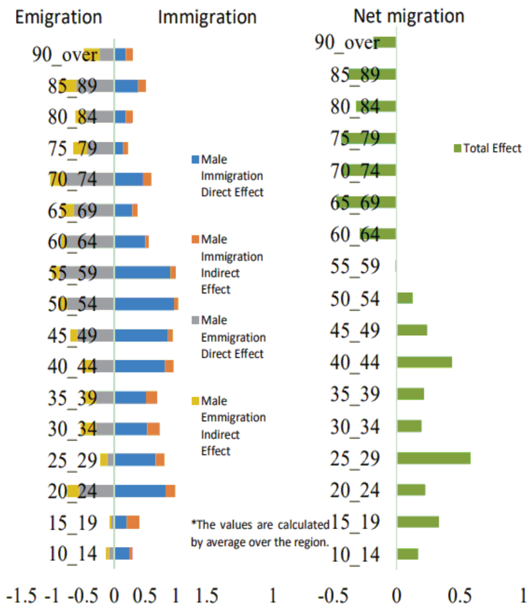


Figure 4.3 (a). Male Immigration, Emigration and Net Migration Effected by Number of Retailers

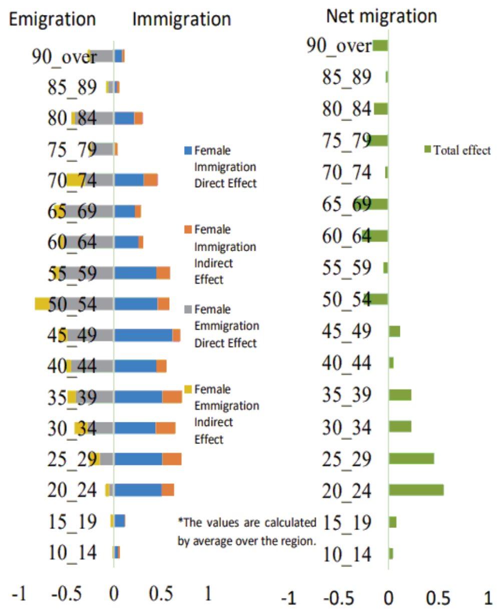


Figure 4.3 (b). Female Immigration, Emigration and Net Migration Effected by Number of Retailers

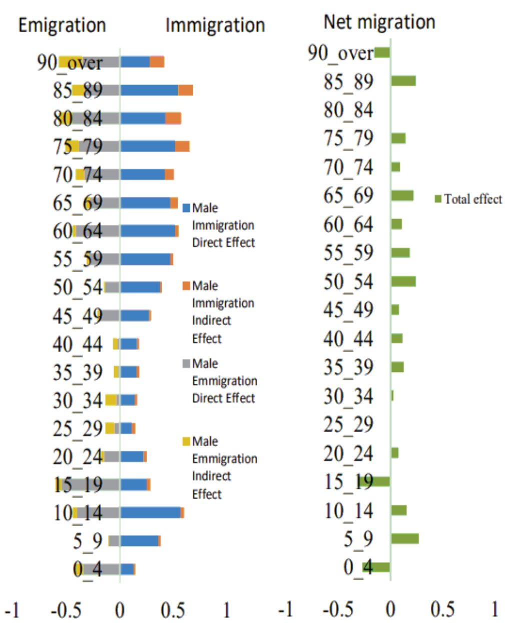


Figure 4.4 (a). Male Immigration, Emigration and Net Migration Effected by Number of Employees from 2nd Industry.

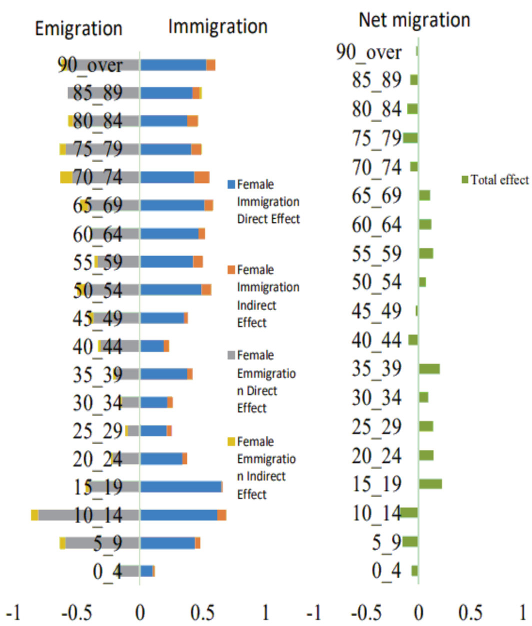


Figure 4.4 (b). Female Immigration, Emigration and Net Migration Effected by Number of Employees from 2nd Industry.

From Figure 4.3(b), both the direct and indirect effects of female immigration between 20 to 49 cohorts are greater than those effects of the emigration. This result suggests that the number of retailers in the own region and surounding regions attract the female younger cohort. The total effects, shows that the tendency of migration is weak for female cohorts. Similar with male cohorts, female younger cohorts are be much attracted to the retailers. By comparing Figures 4.3(a) and 4.3(b), the younger generations (10 to 54 male cohorts and 10 to 49 female cohorts) are much attracted by the retailers and move to the urbanized regions, while elderly cohorts (55 to 90 over male cohorts and 50 to 90 over female cohorts) are not attracted by retailers and they would remain at the local regions. The female elderly generation is much closer to the retailers' location rather than the male elderly cohorts.

Regarding the influence of the industrial characteristics on migration, it is assumed that the 1^{st}, 2^{nd}, 3^{rd}, and overall industrial employee forces can be explanatory variables in our model. However, the discussion only focused on the effects of the number of employees from the 2^{nd} industry since the 2^{nd} industries are located in limited areas such as manufacturing or industrialized zones. Figures 4.4(a) and 4.4(b) are the summaries on the effects of 2^{nd} industry employees on migrants, which have a significant impact on male and female cohorts' migration. From Figure 4.4(a), the direct effects on immigration for almost all-male cohorts (expect 0-4 and 15-19 cohorts) are greater than that on the emigration. Therefore, the employees in the 2^{nd} industry of their own region will attract the male cohorts. Indirect effects on the emigration of all-male cohorts, on the other hand, are larger than that on immigration. Therefore, in the surrounding region of manufacturing employees, male cohorts make more emigrations. From the total effects, infant cohort, 15-19 and 90 over cohorts are not attracted by the manufacturing industrial employees and these cohorts are closely distributed to the industrial zones.

From Figure 4.4 (b) in the female child cohorts (0-4,5-9,10-14), middle-aged cohort (40 to 49) and elderly cohort (70 to 90 overs), the direct effects of emigration are greater than those of immigration. In opposite, the direct effects on immigration of cohorts between 15 to 39 and 50 to 69 are greater than those of the emigration. For indirect effects, the results are similar for both migrations. Therefore, the surrounding manufacturing industrial employees influence both on emigration and on emigration of regions. According to the total effects, the younger cohort (15 to 39) and middle-aged cohort (50 to 69) are going to be attracted by manufacturing industrial employees and they are closely located close to the specific industrial zones. In Figures 4.4(a) and 4.4(b), the immigrant and emigrant of female cohorts are more fluctuated than those of male cohorts. Male cohorts including elderly cohorts are strongly attracted by manufacturing industrial employees than the female cohorts, except the younger female cohort.

In manufacturing employees, the estimated parameters are fairly larger for both migrants, while the total effects (i.e., the effects on net migrants) are not so large comparing with that of retailers. In other words, even the migrants around the industrialized employee’s location seem to be large, its net effect on the population is limited. On the other hand, the net effect of retailers which is introduced as an index of urban agglomeration would have a stable impact on migrants, resulting in the attraction of younger cohorts to the retailers, i.e., to the urbanized areas.

4.4 Conclusion

This chapter developed the prediction models for migration phenomenon considering spatial dependencies among the municipalities, examined the significance of interactions between industrial characteristics and migrants of each cohort. Interregional migrants and emigrants for each cohort are modeled with spatial dependency recursive specification, which are incorporated with population prediction by CCA adopted as the national population prediction method. The target municipalities are 1 prefecture (Fukushima Prefecture) and 1799 municipalities.

The results of spatial parameters indicated that spatial dependencies should not be ignored in the analysis of population prediction. In the estimated models, immigration and emigration are positively related on that of surrounding municipalities, respectively, especially in working-age cohorts (15 to 64). The net migration for younger cohorts would be much attracted by the retailers and those cohorts moved to the urbanized regions. Elderly cohorts, however, would not be attracted by retailers, so then they remain in the original regions. This can cause social problems for elderly cohorts in rural areas such as shopping. For the effect of industrial factors, the male and female migration was different. For males, almost all of the male cohorts (expect infant cohort, 15-19 and 90 overs cohorts) are attracted by the manufacturing and are much attracted at the industrial zones which might be located around the metropolitan areas or developed regions. For females, the younger generation and middle-aged cohorts are going to be attracted by the manufacturing. Female child cohort cohorts and elderly cohorts were not attracted by the manufacturing. In our model, male cohorts made much amount of emigrants than female cohorts.

The above results give strong evidence to consider the spatial dependencies in population prediction, which is possible to be integrated by adopting the model frame shown in Chapter 3, Section 3.3 of Figure 3.2. Therefore, the simulation analysis of the population prediction following to the proposed approach will be tried in the next chapter.

Chapter 5 Long-term Impact of Interregional Migrants on Population Prediction

5.1 Introduction

This chapter applies a novel model for future demographic structures into long-term population prediction in Japan. The proposed procedure combines CCA with a migration model that includes spatial dependencies. The SAR model gives the migration among the municipalities, which output is combined with the natural increase/decrease population calculated by CCA as to obtain the population prediction for each cohort at the end of an interval. As above set of calculation is be repeated until a target year. A comparison of the population in the target year by the proposed model with the existing CCA method is performed in order to clarify impacts upon the projected future population. With this development, the following three questions are set to be answered. The first question is how heterogeneous CWR will effect on the transitions in the population distribution of children, women, and the elderly in municipalities, compared with conventional CCA. The second question is which cohort will be more attracted to urban agglomeration in the output of the proposed CCA model. The third question is how interregional migration predicted by the proposed model is related to the level of urbanization. This question will be tested through the use of urbanized indices in terms of the industrial characteristics.

The remainder of this chapter is organized as follows. Section 5.2 briefly explained the proposed methodology that integrates CCA with the SAR model to analyze population distribution and predict future demographic structures. Section 5.3 presents a comparison of existing CCA predictions with the results of our proposed approach. This chapter also discusses the population distribution in terms of urbanization indices and population translation in terms of CWR. Concluding remarks and future challenges are presented in Section 5.4.

5.2 Proposed Model System: Integration of CCA with the SAR Model

The parameter settings in ordinary CCA by the Japanese government relies on a simple extension of past trends. Those settings are extensively explained in Chapter 3, Section 3.1. Table 5.1 briefly explain the summary of parameter setting for CCA calculation for this chapter.

This study used the 2010's population as initial input from the population census of Japan and the population estimation is made for 5 years from 2015 to 2040. Immigration and

Table 5.1 Parameter settings using Cohort Component Analysis (CCA)

Parameter	Descriptions
Initial Population ($\boldsymbol{P}(i,t)$)	(2010) 5-year age cohorts for both sexes in Japan at the municipality level.
Survival Rate $\boldsymbol{S}(i,x{\sim}x+n)$	$\frac{\mathbf{P}(i,x+n)}{\mathbf{P}(i,x)}, x = 0,5,10,\ldots,90, n = 4$, constant for t
Cohort Age-specific Child–Women Ratio ($\boldsymbol{CWR}\ i,x{\sim}x+n$)	$\frac{\mathbf{P}(i,0{\sim}4)}{\mathbf{P}(i,f,x{\sim}x+n)}, x = 15,20,\ldots,45, n = 4$, constant for t
Relative Disparities for $\boldsymbol{CWR}\ i,t\ (R_i)$	$\frac{\sum \mathbf{CWR}(i,2010,x{\sim}x+n)}{\mathbf{CWR}\ (2010)}$, constant for t
Child–Women Ratio ($\boldsymbol{CWR}_{(i,t+k)}$) or Fertility Rate ($\boldsymbol{TFR}_{(i,t+k)}$)	$\mathbf{CWR}_{(t+k)} * \mathbf{R}_{(i)}$, $\mathbf{CWR}_{(t+k)}$ is adopted from national population projection data
Sex Ratio (**SR**) for Ages 0–4	$\frac{\mathbf{P}(m,0{\sim}4)}{\mathbf{P}(f,0{\sim}4)}$, constant for t

emigration are calculated for each cohort and the workers in the focused industry. This calculation is made for whole residents including the Japanese and non-Japanese residents of municipalities. According to the data availability at the municipalities level in 2010, the local characteristics is assumed to be represented by the industrial characteristics. The data were obtained from Geographic Data (ArcGIS Data Collection 2015, Esri Japan) and e-Stat of Japan. The target area includes 1858 municipalities.

This study assumes that the number of retailers represents the geographical characteristics of urban agglomeration, in order to clarify which cohorts are attracted to urbanized areas. Regarding the influence of industrial characteristics on the population distribution, primary, secondary and tertiary employees and overall industrial employee workforces could be explanatory variables in the proposed model. However, in this study, the discussion only focused on the effects of the number of employees from secondary industries (manufacturing industry employees) because they are located in limited areas, such as manufacturing or industrialized zones; for example, the Pacific coastal belt ("Taiheiyo Belt"). The migration of the manufacturing industry's workforce is the highest among all three industries, which could be a main factor in the expansion of urban areas.

5.3 Discussion

5.3.1 Comparison between CCA Output and the Proposed Approach

This study evaluates the proposed approach against the conventional CCA population projection published in the Portal Site of the Official Statistics of Japan (E-Stat). Table 5.2

shows the differences in the population predictions between conventional CCA and the proposed approach. Both models show a decline in the total population for each cross-section. In the final predicted year of 2040, CCA predicted the total population as around 110.92 million, while the proposed approach predicted a decrease in population as around 109.73 million. The children's cohorts (0-19) and all of the working-age cohorts (age 15–64) are predicted to decrease throughout the entire prediction period (2015 to 2040), even though the elderly cohorts (65 and over) increase in both methods. The proposed approach predicted fewer children and fewer elderly populations in 2040 than those by CCA's prediction, whereas the predicted population of the working-age cohorts (25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, and 60–64) in 2040 is higher in the proposed approach than those by CCA.

Table 5.2 Population of Japan according to Cohort

Cohort	Initial Year 2010 Population (Person)	Final Predicted Year 2040 Population using CCA (Person)	Final Predicted Year 2040 Population using Proposed Approach (Person)
Total	128,057,352	110,923,739	109,728,234
0–4	5,322,799	3,536,609	3,453,977
5–9	5,593,452	4,195,635	4,112,763
10–14	5,910,750	4,205,658	4,122,782
15–19	6,160,687	4,268,129	4,267,003
20–24	6,518,181	4,367,966	4,363,330
25–29	7,352,494	6,561,470	6,586,601
30–34	8,358,745	6,245,334	6,266,845
35–39	9,748,001	7,291,696	7,325,188
40–44	8,743,156	6,542,081	6,566,990
45–49	8,038,243	5,409,622	5,421,565
50–54	7,649,769	5,118,017	5,126,621
55–59	9,042,016	6,214,705	6,235,866
60–64	10,372,889	7,848,735	7,888,604
65–over	29,246,170	39,118,082	37,990,098

The migration prediction by the proposed model (SAR) are shown in Figure 5.1 (a) and (b). The estimated spatial population distribution by the proposed model is more distinctively different among the municipalities than that by CCA. In the conventional CCA, only the urban municipalities gain immigrants, and most of rural municipalities suffers from emigration. In the proposed model, some of rural municipalities also enjoy the increase of immigration, as shown in Figure 5.1 (b). The proposed model observed that the population distribution is more skewed, which means that strong population concentrations are present in the municipalities to have an attractiveness for the workers such as industrial development. On the other hand, the emigration from rural municipalities is larger than immigration, because most of rural municipalities lack the factors to attract population. Therefore, the proposed model can appropriately describe the population movement along with the potential mechanism to drive them.

The long-term cohort-based populations in the future can be predicted by the conventional CCA, but the economic factors and urban characteristics are neglected. In recent studies, Vollset et al. (2020) developed a conventional CCA with statistical models for forecasting mortality, fertility and migration to determine the potential economic and geopolitical effects of future demographic shifts. This study pointed out that the integration of CCA with various statistical model analyses, which is highlighted in the present demographic prediction study, is useful for assessing future socioeconomic and urbanization indices. The proposed integration of CCA with a spatial statistical approach in this study enables us to observe the effect of urbanization factors and to model the relationship between these factors with population distribution.

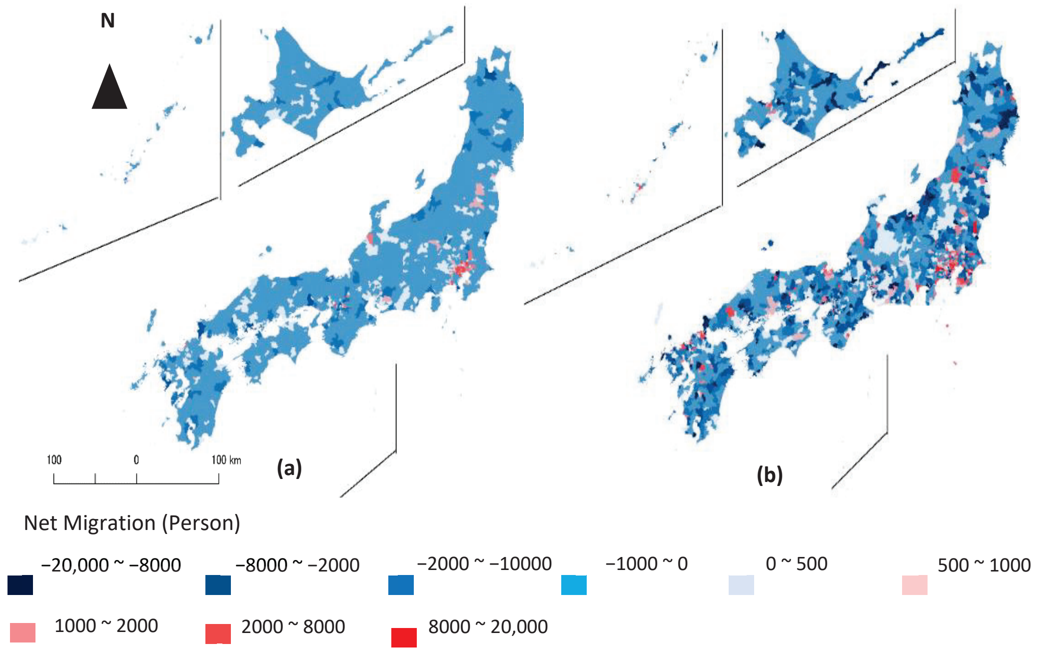


Figure 5.1 (a) Net migration for 2040 using CCA; (b) Net migration for 2040 using SAR.

5.3.2 Distribution of Urbanization Indices: Retailers and Manufacturing Employees

Figures 5.2(a), (b) and 5.3(a), (b) show the distribution of the estimated density of retailers and of manufacturing employees from 2010 to 2040, at the municipality level respectively. From the estimated distribution of retailer densities, in 2010 as the initial year in Figure 5.2(a), 130 municipalities have retailer densities that are larger than 1000 persons/km2 (red and orange colors), and these are primarily distributed in four main metropolitan areas (Tokyo, Yokohama, Osaka, and Nagoya). The 1195 municipalities with retailer densities of less than 50 persons/km2 (blue color) are distributed in all of the other areas. However, in 2040, as shown in Figure 5.2(b), only 39 municipalities have retailer densities that are larger than 1000 persons/km2 (red and orange colored), and the number of municipalities with retailer densities of less than 50 persons/km2 (blue colored) increase to 1300. Comparing the estimated retailer densities in 2010 and in 2040, 73% of municipalities lose retailer workers by 2040, including the major metropolitan areas.

Among the industrial employee predictions, only the manufacturing employee is increased. In 2010 as shown in Figure 5.3(a), the municipalities with a manufacturing employee density larger than 1000 persons/km2 (red and orange colored) amounts to 56, most of them are distributed within four main metropolitan areas; Tokyo, Yokohama, Osaka, and Nagoya. The number of municipalities with a manufacturing employee density less than 50 persons/km^2 (blue colored) is 1100, which are distributed in all other areas. The manufacturing employees are distributed in the coastal regions. As shown in Figure 5.3(b), in 2040, manufacturing employees is distributed in the municipalities with the population densities larger than 1000 persons/km2 in all 14 major urban areas: Tokyo, Yokohama, Osaka, Nagoya, Sapporo, Fukuoka, Kobe, Kawasaki, Kyoto, Saitama, Hiroshima, Sendai, Chiba, and Kitakyushu. Even in rural areas, 890 municipalities enjoy an increase in manufacturing employees by 2040.

This study also observes that the retailer density is much skewed than that of manufacturing employees in 2040. To sum up manufacturing employees are attracted to industrialized areas, located closer to metropolitan or developed regions while the retailer density decreases over time, even in urbanized areas.

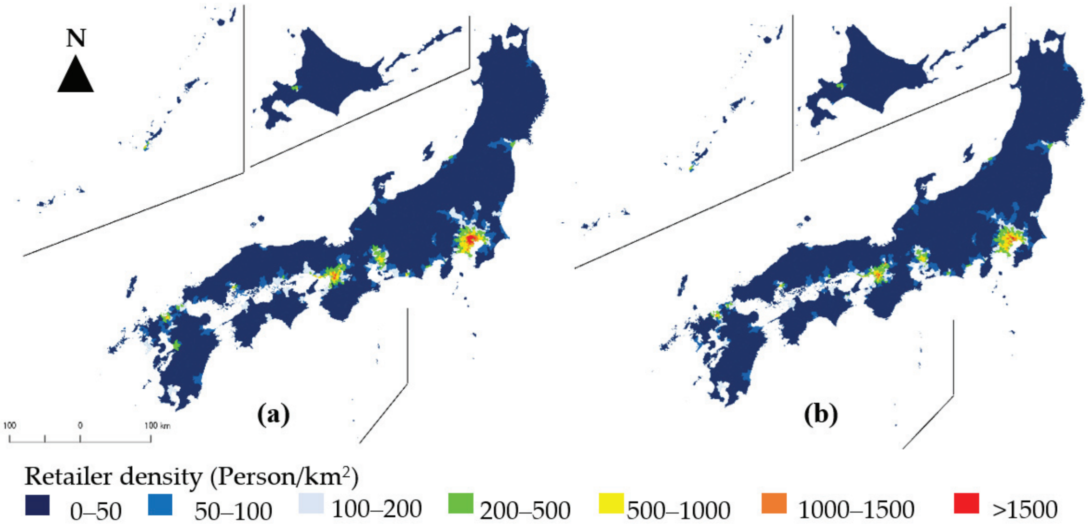


Figure 5.2 Distribution of estimated retailer density. (a) Distribution of estimated retailer density in 2010; (b) Distribution of estimated retailer density in 2040.

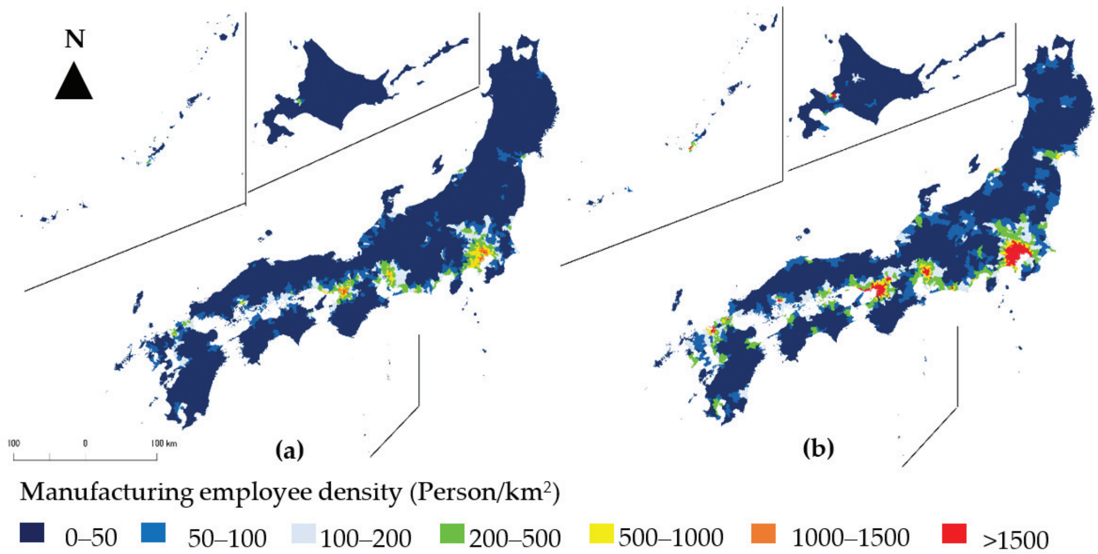


Figure 5.3 Distribution of estimated manufacturing employee density. (a) Distribution of estimated manufacturing employee density in 2010; (b) Distribution of estimated manufacturing employee density in 2040.

5.3.3 Transition of Population According to Urbanization Indices

In this section, the manufacturing industry and retail workers are used as urbanization indicators, and the correspondence between these indicators and population transitions. In order to understand the characteristics in population transition, the population are divided into three groups in the following sections: child population (0 to 14 cohorts), female childbearing population (cohorts of women aged 15 to 49) and elderly population (65 and over cohorts). The urbanization indices change according to the population of the three groups observed in a normally distributed bar graph. If the graph tilted to the left as time passed, the population moved to urban areas; if it tilted to the right as time passed, the population moved to rural areas. The differences in the distribution between 2010 and 2040 are clarified as to refer the bell curves of the normal distribution.

Figure 5.4 (a) to (c) indicate the number of retailers compared to the children, female childbearing, and elderly population transitions for 2010 and 2040, respectively. The transitions of all age groups with the number of retailers are normally distributed and skew to the left, which indicates that people move to urbanized areas with higher retailers' indices. According to Figure 5.4 (d) to (f), employees in the second industry is normally distributed in all three cohorts, in both 2010 and 2040. The gap in the distributions between 2010 and 2040 clearly shows an increase in the number of employees in secondary industries. Both graphs in 2010 and 2040 are skewed to the left, and the population distribution of employees in the secondary industry goes to the right between 2010 and 2040. Such a transition indicates that a massive population moves from rural to urbanized areas. These graphs demonstrate that the future population distribution in Japan will be concentrated in urbanized areas,

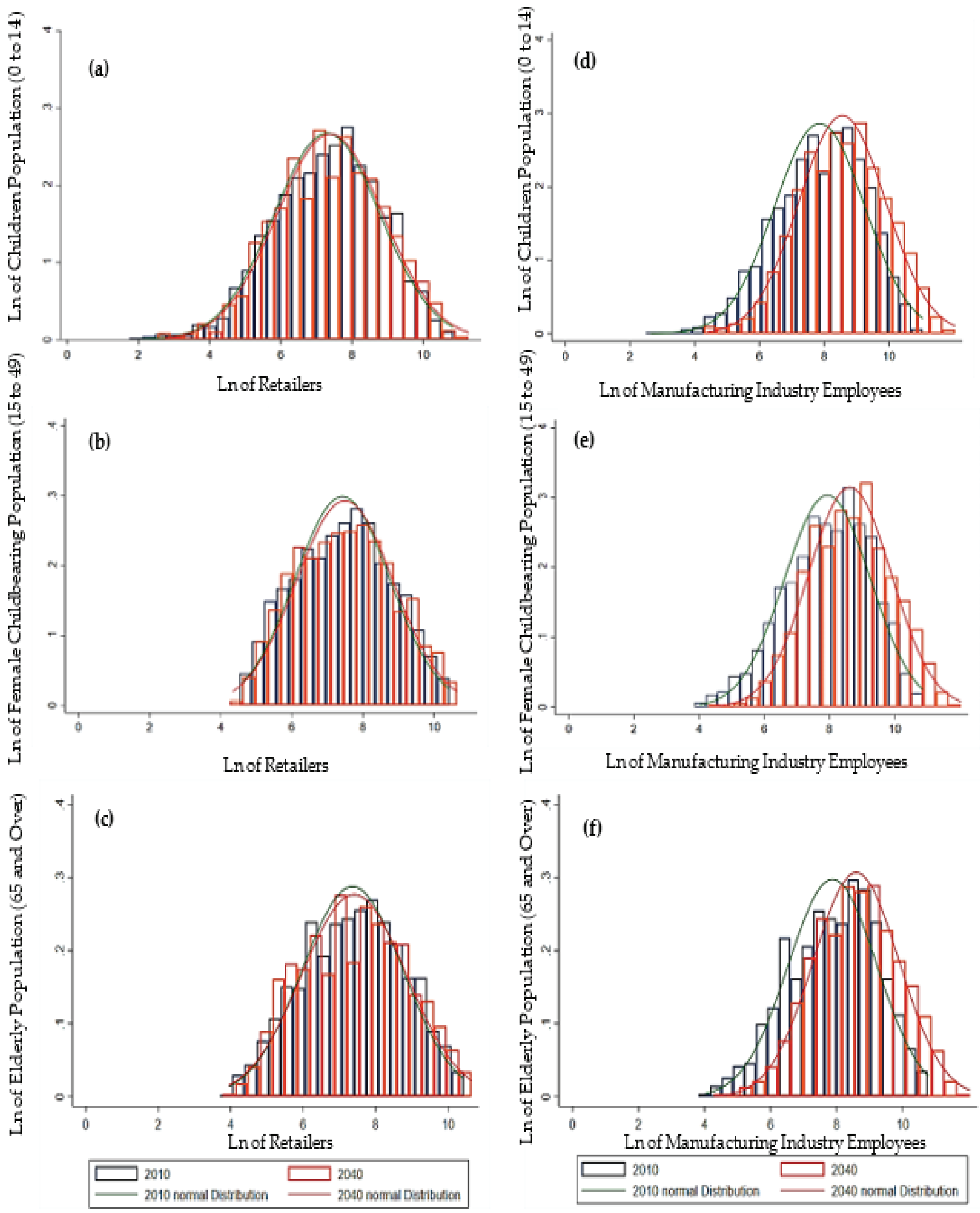


Figure 5.4 Distribution of population according to urbanization indices (2010 to 2040)

(a) Retailers with children population (0 to 14); (b) Retailers with female childbearing population (15 to 49); (c) Retailers with elderly population (65 and over); (d) Manufacturing industry employees with children population (0 to 14); (e) Manufacturing industry employees with female childbearing population (15 to 49); (f) Manufacturing industry employees with elderly population (65 and over).

whereas rural areas will suffer from depopulation coupled with a lack of labor force.

5.3.4 Population Distribution in Terms of Child–Women Ratio (CWR)

In order to find factors behind the population distribution in future, it is essential to compare the spatial distribution of CWR with the population distribution across all regions, which is significant in terms of the long-term demographic dynamics. Note that the distribution of relative CWR over the region is fixed in this calculation, but that its averages of CWR in each cross-section changes. According to Figure 5.5, the average of CWR in 2015 is 1.38. The average is expected to gradually decrease until 2025 at 1.33, whereupon it increases slightly from 2030 to 2040 at 1.35. CWR has slightly increased for women in 30s while 40s have clearly increased in recent years. Figure 5.6(a) and (b) show the distributions of CWR across all municipalities in 2010 and 2040, respectively, to confirm the relationship between the newborn cohorts and the population distribution. These figures give the spatial distribution of CWR. Some municipalities in Okinawa and Hyogo enjoy a higher CWR of over 1.90 and 129 municipalities are consistently above the national average of 1.35. Almost all urban municipalities, especially Tokyo, Hokkaido, and Kyoto, will have around the bottom of CWR in 2040.

The relationship between CWR and the three population groups—children, a female childbearing and the elderly—demonstrates how the reproduction of population goes along the transition. Figure 5.7 (a) to (c) show the relationship between municipalities' CWRs and the three groups of populations in 2010 and 2040, respectively. These graphs show that the relationships have changed. According to figure 5.7 (a), the peak of CWR with the child cohort changes from around 1 in 2010, to around 0.8 in 2040. The approximated normal curve in 2040 shifted slightly to the left from that in 2010. Figure 5.7 (b) illustrates that all female childbearing groups move from municipalities with higher CWR to those with lower CWR from 2010 to 2040. Figure 5.7 (c) shows that the spatial distribution of the elderly group is going to the municipalities with higher CWRs in 2010, and that it is not significantly different in 2040. According to Figure 5.7 (a) to (c) the municipalities with CWRs between 0.8 to 0.9 becomes the highest populations for all age groups, and the overall population shifts to municipalities with lower CWRs.

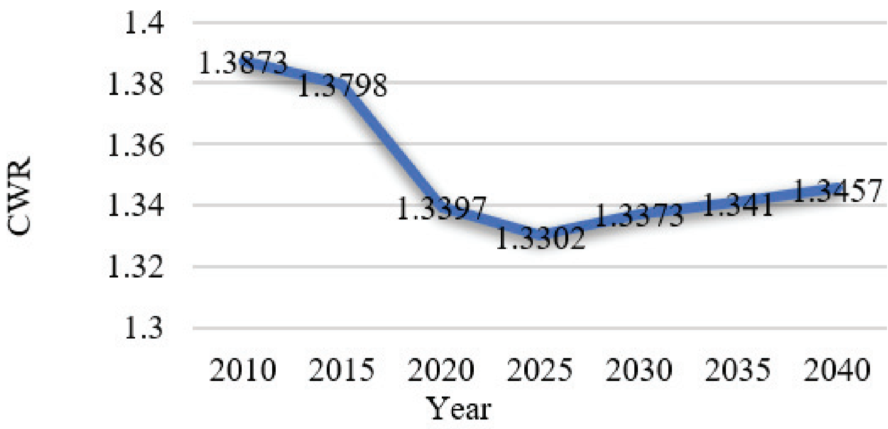


Figure 5.5 Medium CWR assumption (Source: https://www.e-stat.go.jp, accessed on 1 March 2021).

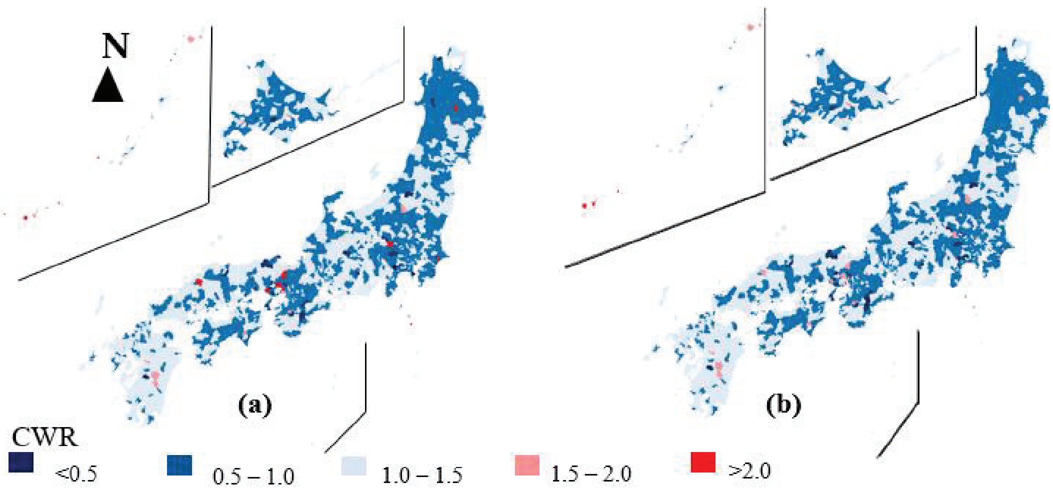


Figure 5.6 (a) CWRs of municipalities in 2010; (b) CWR of municipalities in 2040.

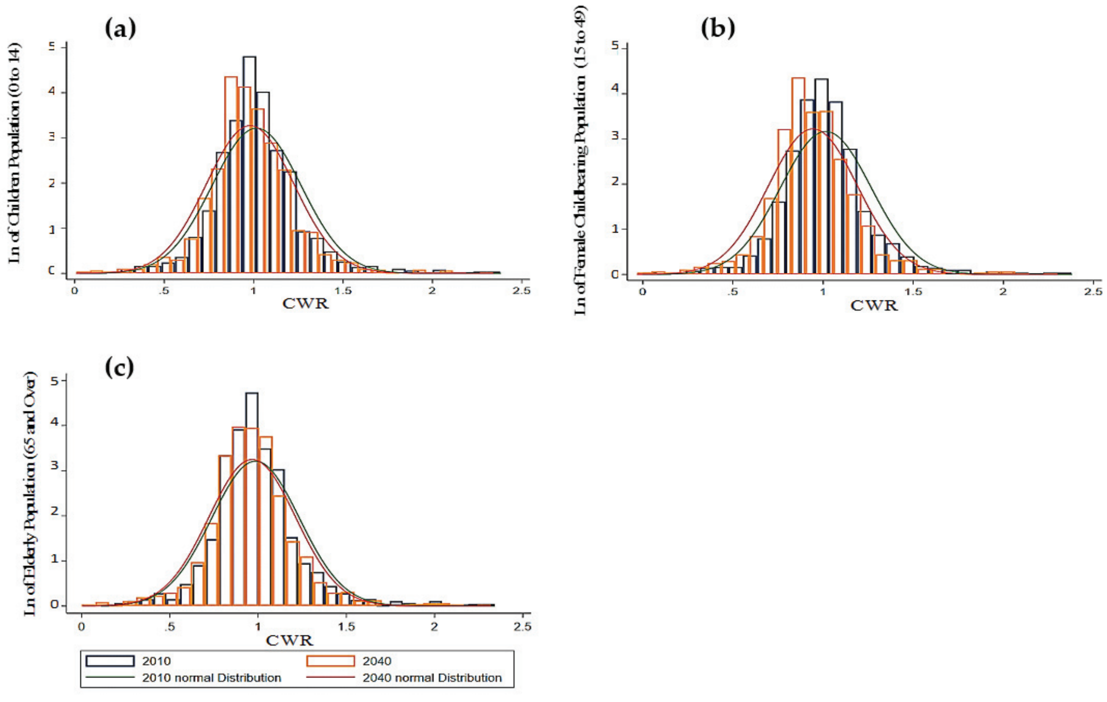


Figure 5.7 Distribution of population by CWR (2010 to 2040).

(a) CWR with children population (0 to 14); (b) CWR with female childbearing population (15 to 49); (c) CWR with elderly population (65 and over).

5.4 Conclusions

Population decreases with urban agglomeration in Japan have triggered policy concerns on economic and demographic sustainability. In order to preserve social sustainability, it is essential to understand the agglomeration and depopulation phenomena occurring in Japanese municipalities in the long-term perspective. In this study, an integrated CCA with a spatial statistical approach as to estimate the domestic migration was proposed. In the proposed approach, immigrants and emigrants for each cohort are modeled with spatial dependencies. Predictions in population distribution for each cohort were performed by recursive estimations until 2040.

The conventional CCA only provides information on the future population. However, the proposed approach in this chapter enables to provide the relationship between a population and the urban indices. Since the proposed model include the bidirectional causation between the cohorts and urban indices, the change in cohorts and the change in urban indices in the period t cause both of change in the period $t+1$. Therefore, the workforce agglomeration at the municipality level is also changed. In this study, the population movements in terms of CWR to observe shifts in the distribution of children, women and elderly populations between municipalities in the future are also clarified.

The three research questions can be answered as follows. For the first question, the proposed model predicts a slightly smaller total population in 2040 than the population estimated by the conventional CCA. Specifically, the model predicted that the fewer children and elderlies than those by CCA. The number of newborns was decreased nationwide because the childbearing female cohorts migrated into the municipalities with smaller CWR.

If this trend continues, Japan's population will be rather severely decreased than the expected level by CCA. Regarding the second question, the proposed approach predicts higher populations among the middle-aged cohorts than the population by the conventional CCA. One reason for this outcome is a contribution of foreign migrants from oversea, because the inclusion of international migrants is referenced in the dataset. Even though the foreign migrants are not explicitly modeled, the models were separately estimated for immigrants and emigrants, which suggested the difference between immigrants and emigrants is no way to be filled with interaction of overseas. Foreign migrants are also attracted to urbanized areas with more retailers and manufacturing employees. The future population are highly concentrated in urbanized areas because domestic migrants have moved from rural areas to urban areas, and the migration from overseas is also concentrated in urban areas.

Accepting foreign migrants is an effective way to resolve Japan's workforce needs. However, the national government should design the policies to care for both Japanese residents and foreign migrants. The proposed model observes the influence of the inflow and outflow of foreign migrants on total population predictions, and the findings underscore the need to set up policies to support social services for foreign immigrants in the long term. For example, language support and medical care to compensate for the loss of jobs by a recession, and to manage problems related to the foreign employees who are permitted to invite family members to stay with them in Japan. The proposed approach can assist in build some policies for attracting foreign migrants and for improving the future of Japan's demographic distribution, in order to counter the future population aging and declining fertility.

The answer to the third question is that the number of retailers and manufacturing industry employees affect the population distribution. The estimated results show that the impact of retailers is small, but the impact of manufacturing industry employees is significant. Manufacturing locations are highly skewed toward urbanized areas, and the manufacturing industries will be a driving factor in attracting people, especially middle-aged cohorts (15 to 49) from rural areas to urban areas. According to these findings, the government should prepare for the rapid population movement to such the regions, for example, to make appropriate investments into their infrastructures. It is essential for Japanese urban areas to find effective and efficient ways to utilize limited resources to realize a sustainable society. Otherwise, Japanese urban areas could face severe congestion, insufficient infrastructure, health, job and environmental problems, etc., whereas some areas such as metropolitan Tokyo already struggle to overcome the above aspects of urban agglomeration.

With the proposed approach, the distribution of migrants and the locations of working opportunities are correlated with the population estimation. In this study, all the estimated models showed positive correlations between cohort migration and the urbanization indices. The advantage of the proposed model is in its capacity to consider such the relationships in terms of migration and working opportunities. The proposed approach can be used to analyze the significance of local services, natural resources, and local attractiveness. If such the factors to attract populations to local areas against the urban agglomeration is found, much strategic regional plan can be built for revitalizing community region and society.

Chapter 6 Cohort-based Analysis of Foreign Resident’s Growth in Japan

6.1 Introduction

Chapter 5 clarified that foreign resident’s migration has a positive contribution on the future demographic structures of Japan according to the population prediction by the proposed approach. This chapter focuses on foreign residents’ cohort to clarify their transition by nonnegative matrix factorization model (NMF). According to the data availability of foreign resident’s cohorts, the dataset in prefecture level is used and the discussion will be mainly made on the 8 regions for 47 prefectures in Japan. Even though, the area scales are not the same with Chapter 4 and 5, it is worth discussing since there is no study with foreign resident cohorts transition in Japan according to the best knowledge of author about the demographic geography.

This chapter clarifies the transition of foreign residents’ cohorts by using NMF which gives some of patterns and geographical weights of the patterns. In term of Covid-19, even the data covers its beginning, the demographic patterns extracted by our analysis would be strongly affected by the transition between 2015 and 2019 rather than that between 2019 to 2020. Therefore, the policy for the new life after Covid-19 cannot be directly discussed from the patterns in 2015 to 2020. The extracted patterns would be interpreted the transition of before Covid-19. The rest of the chapter is organized as follows. After introducing the background context, section 6.2 describes the methodology flows and data setting. Section 6.3 shows the experimental results. Finally, the findings and concluding remarks are presented in Section 6.4.

6.2 Methodology and Data Setting

The explanation of NMF is stated in Section 3.4. In this study, the ratios of foreign residents' cohorts between two periods (2015/2010 and 2020/2015) of both genders in 47 prefectures are represented as $n \times m$ matrix $\boldsymbol{X}$, where m is the number of 47 prefectures and n is 26 as 13 cohorts for both genders.

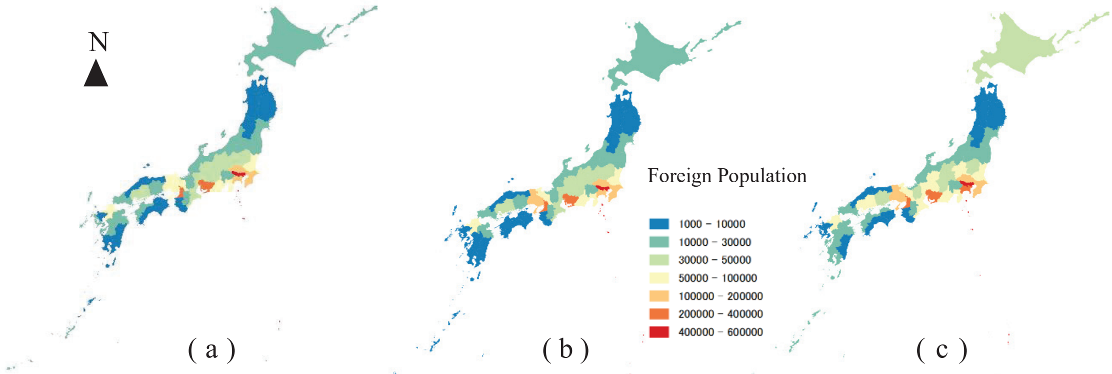


Figure 6.1 Foreign Population in Japanese Prefectures (a) 2010 (b) 2015 (c) 2020

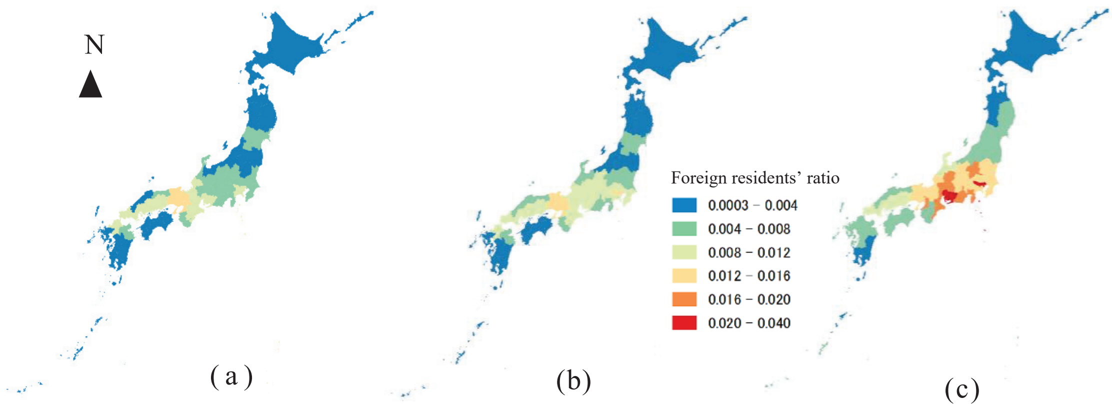


Figure 6.2 Share of Foreign Residents in Domestic Population (a) 2010 (b) 2015 (c)2020

Figure 6.1 (a), (b) and (c) show the population of foreign residents in each prefecture in 2010, 2015 and 2020, respectively. These figures show that the distribution between urban and local regions is clearly different. For example, Akita has around 5,000 foreign residents while Tokyo has over 500,000. The foreign population in Japan is still concentrated in the urban areas between 2010 and 2015 while the trend changes in 2020, as that some rural regions to attract the foreign population. According to Figure 6.2 (a), (b) and (c), the share of foreign residents to domestic population is continuously increase at the prefectures in urban areas and in some local areas of Western Japan such as Shikoku and Kyushu regions. Based on Figure 6.1 and 6.2, the geography of foreign population is indeed transforming and hence, in this study, the trend changes of foreign population distribution are worth discussing.

This study focuses on the demographic trend change in local regions regardless to the population size. In order to evenly deal with the prefectures regardless of their population size, the foreign cohort's data in 5-year cohorts is aggregated into the ratio of cohorts between two cross-sections for both genders as shown in eq. (6.1).

$$\boldsymbol{x}_{\boldsymbol{m},\boldsymbol{f}}^{\mathbf{2015}} = \frac{\boldsymbol{N}_{\boldsymbol{m},\boldsymbol{f}(\mathbf{2015})}}{\boldsymbol{N}_{\boldsymbol{m},\boldsymbol{f}(\mathbf{2010})}} \quad , \qquad \boldsymbol{x}_{\boldsymbol{m},\boldsymbol{f}}^{\mathbf{2020}} = \frac{\boldsymbol{N}_{\boldsymbol{m},\boldsymbol{f}(\mathbf{2020})}}{\boldsymbol{N}_{\boldsymbol{m},\boldsymbol{f}(\mathbf{2015})}} \tag{6.1}$$

where $\boldsymbol{x}_{\boldsymbol{m},\boldsymbol{f}}$ is the ratio of the cohorts for both genders and *N* is the number of foreign residents in each cohort for 47 prefectures.

If the ratio is calculated for the same age-group observed in the different cross-section, the ratio does not indicate the growth rate of the same cohort. Therefore, a cohort shifting is applied to keep the consistency of a cohort among the different cross-sections. For example, a cohort in 2010 (ex., 15-19) is recorded as the cohort in 2015 with 5-years-upward shifting (ex.,20-24) because of the observation interval. It is worth notifying if a cohort in 2010 simply remains to 2015 in a region, the cohort growth with shifting will be 1. Hence, the ratio with cohort shifting can detect the net migration during the interval. Note that, the shifting cannot apply to the newborn cohort (0-4) so then it is excluded for the analysis. Also, the ratio of cohorts shifting between two cross sections, will be referred this term as cohort transition, is always positive. This is the reason why the dataset made by eq. (6.1) is analyzed by NMF. Table 6.1 shows the aggregated dataset of the growth rate calculated by eq. (6.1). The prefecture numbers in Table 6.1 are referred in Figure 3.3 of Section 3.6. The color scales show the deviation from the average growth rate of the prefectures for each cohort. Blue color represents the decreasing deviation and red color represents the increasing deviation from the average growth rate. According to Table 6.1, some prefectures attract or lose the foreign cohorts. For example in 2010 to 2015, Akita and Tokushima seriously lose the female children's cohorts and this trend changes in 2015 to 2020. In Oita, the growth rate of both male and female younger age cohorts is higher than the average in 2015 and this trend continues to 2020.

Table 6.1. Cohort Transitions of Foreign Residents in Prefectures

Prefecture Number	2010 to 2015								2015 to 2020							
	Male				Female				Male				Female			
	C	Y	M	E	C	Y	M	E	C	Y	M	E	C	Y	M	E
1	0.88	0.81	1.01	1.42	0.87	0.74	0.94	1.45	0.91	0.77	1.25	1.60	0.91	1.09	1.31	1.45
2	0.88	0.78	0.90	1.47	0.96	0.75	0.86	1.45	0.88	1.00	1.17	1.59	0.60	0.99	1.34	1.43
3	1.17	0.73	0.91	1.46	0.50	0.62	0.96	1.39	0.74	0.90	1.22	1.47	0.62	0.87	1.53	1.43
4	0.75	0.84	1.00	1.48	0.65	0.83	0.92	1.59	0.85	0.91	1.29	1.60	0.89	0.86	1.37	1.42
5	0.67	1.02	0.85	1.31	0.10	1.04	0.84	1.47	0.72	1.04	1.11	1.63	0.88	0.75	1.51	1.44
6	0.71	0.90	1.07	1.33	0.61	0.99	0.82	1.43	0.75	0.99	1.30	1.67	0.82	0.68	1.41	1.43
7	0.74	0.92	1.00	1.31	1.04	0.78	0.89	1.47	0.76	0.91	1.20	1.82	0.75	0.73	1.42	1.60
8	0.76	0.88	1.01	1.35	0.75	0.87	0.93	1.5	0.97	0.76	1.42	1.95	0.92	0.72	1.41	1.91
9	0.84	0.79	1.00	1.44	0.84	0.89	0.90	1.45	0.93	0.80	1.33	1.91	0.91	0.73	1.37	1.92
10	0.83	0.85	0.97	1.36	0.98	0.76	0.92	1.43	0.94	0.82	1.31	1.81	0.94	0.74	1.39	1.97
11	0.92	0.74	1.08	1.38	0.92	0.71	0.99	1.5	0.97	0.75	1.36	2.00	0.96	0.70	1.40	1.76
12	0.94	0.69	1.04	1.40	0.83	0.73	0.95	1.54	0.99	0.73	1.37	1.93	0.95	0.68	1.39	1.75
13	0.86	0.77	1.13	1.38	0.87	0.75	1.08	1.39	0.97	0.73	1.36	1.73	0.93	0.76	1.37	1.57
14	0.85	0.75	1.04	1.38	0.89	0.71	1.00	1.39	0.96	0.72	1.31	1.83	0.93	0.69	1.33	1.65
15	1.18	0.62	1.02	1.41	0.95	0.70	0.89	1.54	0.93	0.81	1.31	1.63	0.86	0.71	1.49	1.45
16	1.26	0.68	0.92	1.47	0.62	0.68	0.90	1.3	0.99	0.77	1.39	1.74	0.95	0.78	1.48	1.61
17	1.04	0.75	0.97	1.29	0.67	0.77	0.87	1.3	0.93	0.93	1.34	1.59	0.95	0.94	1.35	1.47
18	0.79	0.83	0.88	1.28	0.66	0.74	0.89	1.29	0.91	0.76	1.25	1.47	0.81	0.82	1.32	1.42
19	0.94	1.28	1.03	1.46	0.79	1.05	0.95	1.52	0.95	0.83	1.32	1.80	0.86	0.76	1.35	1.90
20	0.60	0.95	0.95	1.29	0.73	0.93	0.92	1.37	0.98	0.81	1.26	1.88	0.91	0.74	1.35	1.84
21	0.77	0.81	0.90	1.32	0.78	0.88	0.88	1.25	0.95	0.83	1.29	1.75	0.89	0.77	1.45	1.53
22	0.93	0.78	0.97	1.31	0.90	0.75	0.93	1.36	0.91	0.79	1.32	1.92	0.91	0.71	1.39	1.93
23	0.80	0.78	0.97	1.30	0.77	0.80	0.94	1.27	0.96	0.75	1.28	1.60	0.95	0.74	1.33	1.45
24	0.74	0.87	0.97	1.31	0.79	0.83	0.88	1.32	0.96	0.75	1.32	1.85	0.93	0.82	1.33	1.65
25	0.69	0.91	0.94	1.30	0.79	0.81	0.90	1.31	0.95	0.81	1.23	1.69	0.94	0.75	1.28	1.47
26	0.78	0.85	0.95	1.32	0.74	0.88	0.92	1.26	0.78	0.81	1.08	1.42	0.77	0.87	1.09	1.32
27	0.75	0.82	0.92	1.34	0.74	0.79	0.90	1.29	0.83	0.80	1.08	1.48	0.81	0.79	1.09	1.36

28	0.75	0.87	0.92	1.35	0.77	0.81	0.90	1.3	0.83	0.82	1.06	1.51	0.83	0.83	1.09	1.37
29	0.69	0.90	0.93	1.31	0.58	0.82	0.93	1.29	0.85	0.79	1.13	1.54	0.91	0.82	1.15	1.43
30	1.41	0.57	0.97	1.35	0.74	0.74	0.90	1.32	0.76	0.85	1.10	1.46	0.70	0.70	1.19	1.39
31	1.36	0.74	0.96	1.33	1.11	0.67	1.02	1.32	1.21	0.81	1.20	1.42	0.86	0.81	1.39	1.33
32	0.61	0.86	0.97	1.34	0.85	1.31	0.89	1.34	0.94	0.67	1.31	1.49	0.70	0.74	1.59	1.34
33	0.85	0.77	0.96	1.34	0.79	0.77	0.93	1.3	0.91	1.01	1.20	1.47	0.89	0.87	1.32	1.34
34	0.87	0.81	0.94	1.34	0.81	0.83	0.90	1.28	0.97	0.84	1.24	1.48	0.90	0.83	1.26	1.41
35	0.58	0.94	0.88	1.39	0.75	0.90	0.88	1.29	0.76	1.00	1.03	1.41	0.80	1.05	1.08	1.33
36	0.50	0.79	1.04	1.47	0.11	1.05	1.02	1.56	1.13	0.75	1.47	1.68	1.00	0.79	1.76	1.64
37	1.11	0.92	1.01	1.33	0.67	0.84	1.02	1.39	0.84	0.89	1.36	1.90	0.92	1.00	1.42	1.62
38	1.06	0.80	1.03	1.36	1.30	0.93	0.92	1.36	0.99	0.77	1.42	1.63	0.87	0.89	1.48	1.39
39	0.80	1.24	0.94	1.28	0.52	1.08	0.95	1.38	0.56	1.22	1.25	1.64	0.70	0.88	1.42	1.54
40	0.89	0.74	0.98	1.41	0.80	0.81	0.95	1.32	0.89	1.02	1.20	1.46	0.85	0.94	1.24	1.33
41	0.82	0.70	0.98	1.35	1.00	0.89	0.97	1.25	0.90	1.12	1.21	1.58	0.86	1.00	1.41	1.40
42	0.72	0.84	1.00	1.56	1.01	1.16	1.04	1.25	1.07	1.04	1.19	1.86	0.83	1.04	1.35	1.65
43	0.58	0.94	1.05	1.37	0.77	0.84	0.98	1.43	1.02	0.87	1.28	2.07	0.88	0.79	1.49	1.82
44	0.68	1.48	1.01	1.42	0.84	1.57	0.90	1.35	0.80	1.30	1.26	1.52	0.72	1.45	1.33	1.35
45	0.93	1.01	1.11	1.22	0.96	0.70	1.12	1.36	0.83	1.12	1.27	1.80	0.83	0.88	1.42	1.55
46	0.80	0.81	1.21	1.36	1.33	0.55	1.08	1.51	0.85	0.83	1.23	1.95	0.81	1.04	1.55	1.98
47	1.18	0.56	1.17	1.29	1.14	0.67	1.25	1.79	1.05	0.79	1.17	1.95	0.91	0.73	1.28	1.99

* C= Children Cohort Transition, Y= Younger Aged Cohort Transition, M=Middle Aged Cohort Transition, E=Elderly Cohort Transition

6.3 Discussion

6.3.1 Growth of Newly Born Cohort

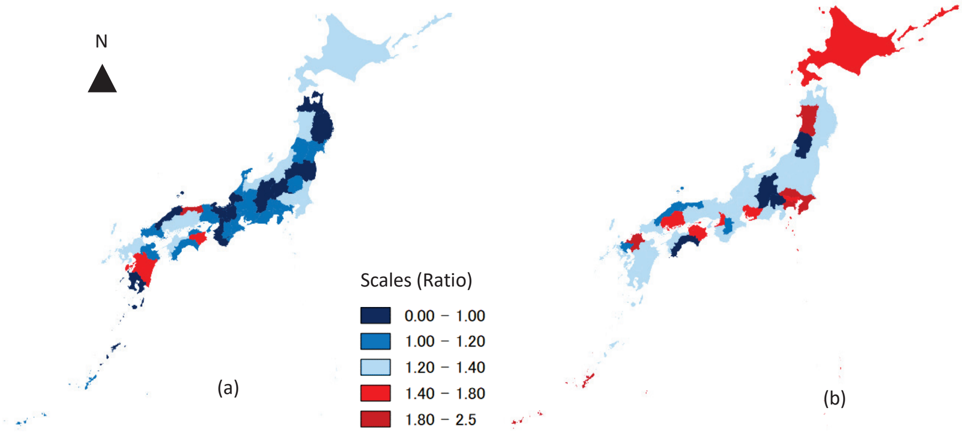
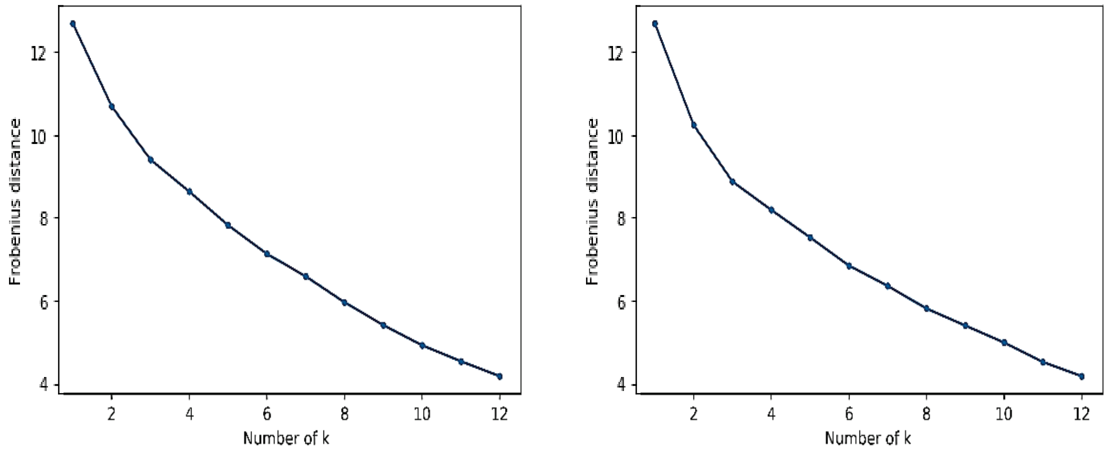


Figure 6.3. Foreign Residents Newly Born Cohort (0-4) Ratio (a) 2015/2010 (b) 2020/2015

Since the new-born cohort cannot be included in the dataset with the cohort shifting, the growths of new-born cohort are discussed without the cohort shifting. Figure 6.3 (a) and (b) show that from 2010 to 2015 and that from 2015 to 2020, respectively. According to Figure 6.3 (a), Tottori, Tokushima, Kagawa, Kumamoto and Miyazaki enjoyed the drastic increase of new-born cohort, and all the urban areas also gained the new-born cohort in 2015. Some of local prefectures such as Aomori, Gunma and Shimane prefectures were decreased in new-born cohort from 2010 to 2015. From 2015 to 2020, almost all the prefectures gained the new-born cohort but only Yamagata, Nagano, Yamanashi and Kochi suffered from the decrease. It is remarkable that the geographical distribution of the growths from 2015 to 2020 is completely different from those from 2010 to 2015.

6.3.2 Pattern Extraction by NMF and its Spatial Distribution



(a) (b)

Figure 6.4. Numbers of k by Frobenius Distance Graph (a) 2015/2010 (b) 2020/2015

In NMF estimation, previous study (Brunet et al., 2004) suggested that the number of patterns; *k* should be chosen to observe the plot between NMF model fit (Frobenius distance between the data and NMF model) against *k*. The "elbow" of the graph is *k* such as an inflection point in the graph regarding *k* and the NMF model fit. The NMF model in this study is repeatedly estimated for several *ks* from 1 to 12. From Figure 6.4 (a) and (b), the Frobenius distance is constantly decreased from *k*=3, hence the "elbow" point can be determined as *k*=3. However, for interpretability, *k* in this study is determined by also referring to the similarity in both genders of corresponding cohorts. According to the observation, the patterns with *k*=3 are too complex and abstract. Since the contribution of each cohort in both genders were different, it was difficult to interpret in terms of trend-oriented discussion. Considering the purpose of the analysis in this study, the "elbow" criteria should be discarded and the criteria about the similarity between the corresponding male and female cohorts should be referred. By checking all the patterns starting from k=4 to 12 in both models and selects the patterns with k=8 which almost satisfy the similarity criteria with some exceptions. Therefore, the patterns in k=8 are adopted for both cross-sections and then aggregated based on the four different age groups (children, younger age, middle age and elderly).

Figures 6.5 and 6.6 show the plot of the pattern matrix H of male and female cohort growth with k=8. In Figure 6.5, pattern 1 to pattern 8 represent the characteristics of cohort transition from 2010 to 2015. Pattern 1 shows the characteristics of 20-24 male and female cohorts, pattern 2 shows the 15-19 female cohorts characteristics, pattern 3 shows the average cohorts characteristics and pattern 4 represents the 25-29 female cohort characteristics. Pattern 5 shows the 55-59 male and female cohorts, pattern 6 is about the 10-14 female cohort characteristics, pattern 7 shows the 45-49 female cohort and pattern 8 represents 50 and over female cohorts' characteristics. From Figure 6.5, the patterns are common between male and female in 1, 3, 5 and 8, while the pattern 2, 4 ,6 and 7 are that the female cohorts' characteristics appear stronger than male cohorts. In Figure 6.6, pattern 1 to 8 represent the characteristics of cohort transition in 2015 to 2020. Pattern 1 shows the average cohort characteristics, pattern 2 shows the 5-9 male, female cohort characteristics, pattern 3 represents the stronger appearance of working age male cohorts between 25 to 54 except 45-49 cohort and 60-64 female cohort characteristics and pattern 4 shows the elderly cohort characteristics. Pattern 5 shows the 25-29 male and female cohort characteristics, pattern 6 shows the 55 and over male, female cohorts characteristics, pattern 7 represents 25 to 34 male cohorts' characteristics along with the appearance of 45-49 female cohort characteristic and pattern 8 shows a type of parent-child household highlighting the 5-9 and 35-54 for both male and female cohorts' characteristics. According to Figure 6.6, the common patterns in male and female cohorts are observed in 1,2, 4, 6, and 8. The patterns in 3 and 7 show the stronger contribution of male working age cohorts than female, except pattern 5. Figures 6.7 and 6.8 show the shares of each pattern obtained from the weight matrix W. On the couple of figures, the dominant patterns are differently distributed among the regions defined in Figure 3.3 of Section 3.6.

Table 6.2 is a recap of all the outputs of above analysis. The 3rd and 4th columns are the population growth rate of foreign residents in total and in new-born cohort, respectively. The 5th column shows the change of foreign population share between the period from 2010 to 2015 and that from 2015 to 2020. In these three columns, the prefectures are marked for top and bottom 10 in each column. From the 3rd to 5th columns, there are common tendency among the three attributes that Hokkaido, Tohoku, Kyushu and Okinawa have lower growth rates in total population. Hokuriku, Kansai, Chugoku and Shikoku have middle to lower growth rate while Kanto and Tokai located at the central Japan have the higher growth rate from 2010 to 2020. The 6th and the 7th columns are the summary of patterns obtained by NMF analysis. In order to clarify the bias of each pattern from the viewpoint of regions, the pattern's shares in each prefecture are calculated, and then the shares of each pattern are ranked to mark the prefectures with higher shares. In Figure 6.7 and the 6th column of Table 6.2, the 5 representative patterns that have characteristics in children (2; female and 6; female), young (1 and 4; female) and middle, elder cohort(s) (8; female) are focused on. In terms of children cohorts of pattern 2 (15-19 female) / 6 (10-14 female), the differences in the spatial distribution are seen among the urbanized (the prefectures with regional capital) areas and the others. About pattern 1 (20-24 cohorts), Akita, Yamagata, Tochigi, Wakayama and Shimane have higher share. In terms of pattern 4 (25-29; female), Akita, Yamanashi and Nagasaki have the higher share. For pattern 8 (50 over; female), Aomori, Iwate, Akita, Toyama and Wakayama have the higher share, which are mainly distributed in the Eastern Japan and are occupied with local prefectures. General trend of pattern distributions from 2010 to 2015 is that all the local capitals do not have distinct growth of foreign cohort but some of local prefectures face the increase of foreign cohorts.

In Figure 6.8 and the 7th column of Table 6.2, the 5 representative patterns that have characteristics in children (2), young (5) and elder cohorts (4) and composite patterns 3 (20-44; male, 50-54; male and 60-64; female) and 8 (5-9 and 35-54) are focused on. In terms of the young cohort of pattern 2 (5-9), Chiba, Tottori, Kumamoto, Miyazaki, and Okinawa have higher share. Note that the growth of young cohort was not seen for 2010 to 2015. In terms of the children cohort of pattern 2 (5-9), Chiba, Tottori, Kumamoto, Miyazaki and Okinawa have higher shares. Note that the growth in lower cohort was not seen for 2010 to 2015. In terms of pattern 5 (25-29), Aomori, Yamaguchi, Fukuoka, Nagasaki and Oita have the higher shares. About pattern 4 (65 over), Tochigi, Gunma, Shizuoka Kagawa and Okinawa have the higher share. Patterns 3 and 8 have multiple peaks in cohort contributions. Since the cohort in 5-9 cannot determine the residential location by themselves, the increase of them and the middle age (24-49) cohort may indicate an increase in parent-child households. In terms of pattern 3, Miyagi, Akita, Yamagata, Ibaragi and Niigata have higher share, which are located in Eastern Japan. About pattern 8, Fukui, Shimane, Hiroshima Tokushima, and Ehime located in Western Japan have higher shares.

6.4 Conclusion

Due to the policy change about the foreign labor force acceptance to Japan, the trend of foreign migration from 2010 to 2020 was structurally changed. Table 6.3 describes the total numbers of foreign residents and the major immigration policies implemented between 2010 to 2020 referring the report of Major Policies Related to Immigration Control Administration. According to Table 6.3, the total number of foreign residents were significantly increased after the introduction of new residency management system in 2012. Comparing the trend from 2010 to 2015 with that from 2015 to 2020, the number of foreign migrants were still concentrated in Kanto and Chubu region. This was the results of the acceptance of foreign residents in the entrepreneurs, housekeeping services starting from 2015 in national strategic special zones such as Tokyo Area National Strategic Special Zone, Aichi Prefecture National Strategic Special Zone. However, the transition of foreign migrants for each cohort were significantly different especially between Tohoku and Kyusyu. From 2015 to 2020, the increase of workforce cohorts was mainly observed at Tohoku, Shimane in Chugoku and some prefectures in Shikoku and in Kyusyu. According to the reports of the regional governments, agriculture, forestry, and fisheries are the primary industries in Tohoku region, transport equipment and shipbuilding are the primary industries in the Chugoku, and semiconductor, automobile, forestry, and fisheries are the primary industries in the Kyushu. Therefore, the cohort transition in these regions would be brought by the implementation of policies that allow for the accepting of the foreign construction workers and shipbuilding starting from 2015 and the accepting of foreigners conducting agricultural works in 2017. Note that the increase of workforce cohorts was continued in those regions, but the increase of young cohorts (below 20) was accompanied with them from 2015 to 2020. The foreign migrants with infants or children are surely increased at the above regions. Such the parents for younger households would have a linguistic problem due to rather short living period in Japan. Not only for childcare for example, but also linguistic support (translation and multi-linguistic documentation) is necessary in the above regions. Note that in Kyusyu, the increase of young cohort was continuously occurred, which also requires the schooling support in that region. In terms of elder cohorts, their period to live in Japan would be longer than the working cohorts, so then the linguistic problem would be minor. However, the transition of elder cohort from 2015 to 2020 was high in Tohoku, where the foreign residents in Tohoku are still minor. This might be a result of the retirement of foreign residents which cannot be observed in actual dataset. Therefore, the community acceptance and the creation of social bond between foreign residents and Japanese locals will be the matter in such the region. Through the above analysis, addition to the known problems about the supporting policies to the foreign residents in the regions where relatively large number of foreign people lives such as Kanto or Chubu, the problems in the regions such as Tohoku and Kyusyu where the foreign residents are still minor has been clarified. The local government in the above regions should much care for then in order to keep the stable acceptance not only as for foreign workforce, but for long term residents in Japan.

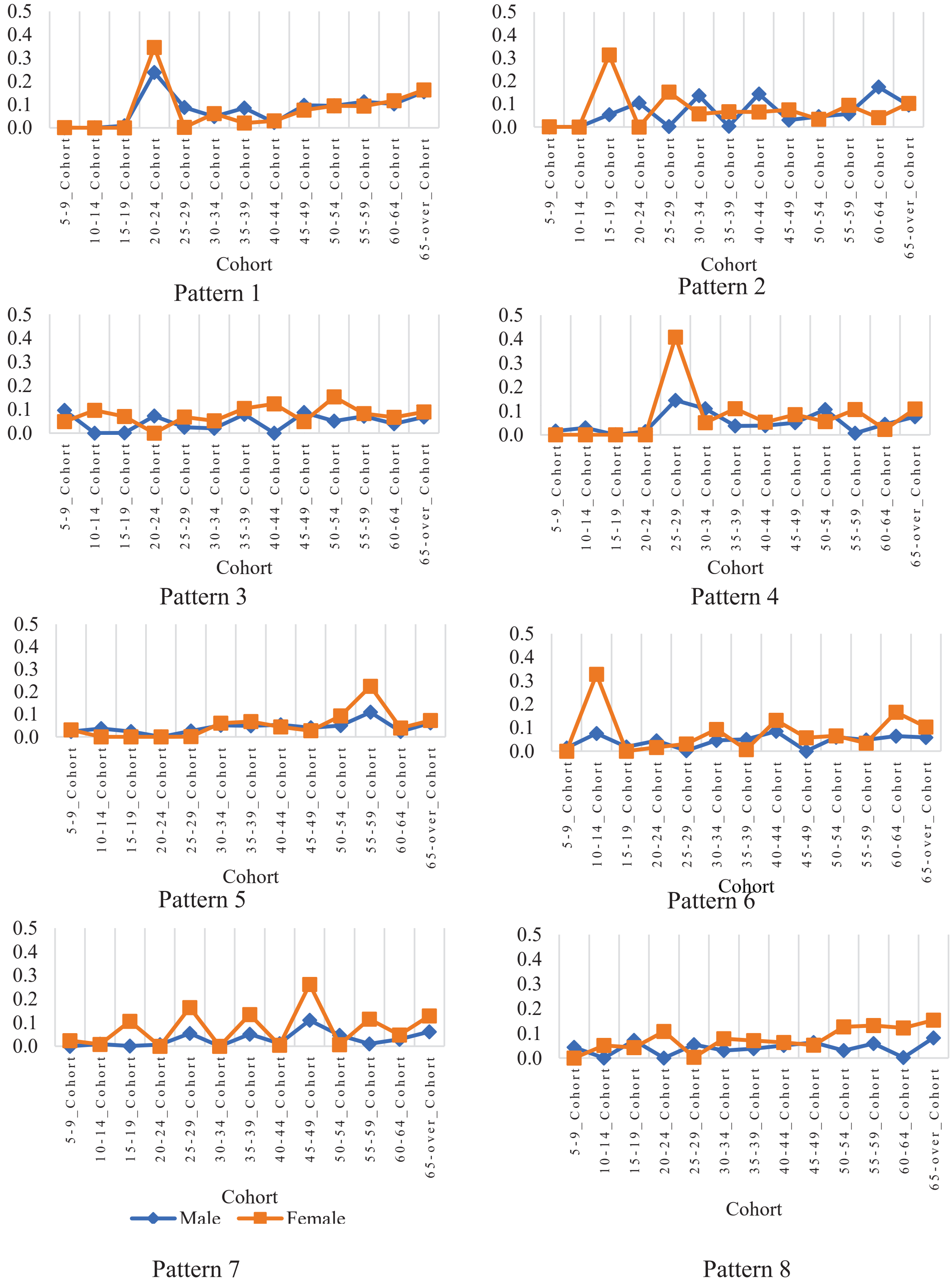


Figure 6.5. Coefficient Matrix H for Foreign Residents Cohorts Transition in 2010 to 2015

Figure 6.6. Coefficient Matrix H for Foreign Residents Cohorts Transition in 2015 to 2020

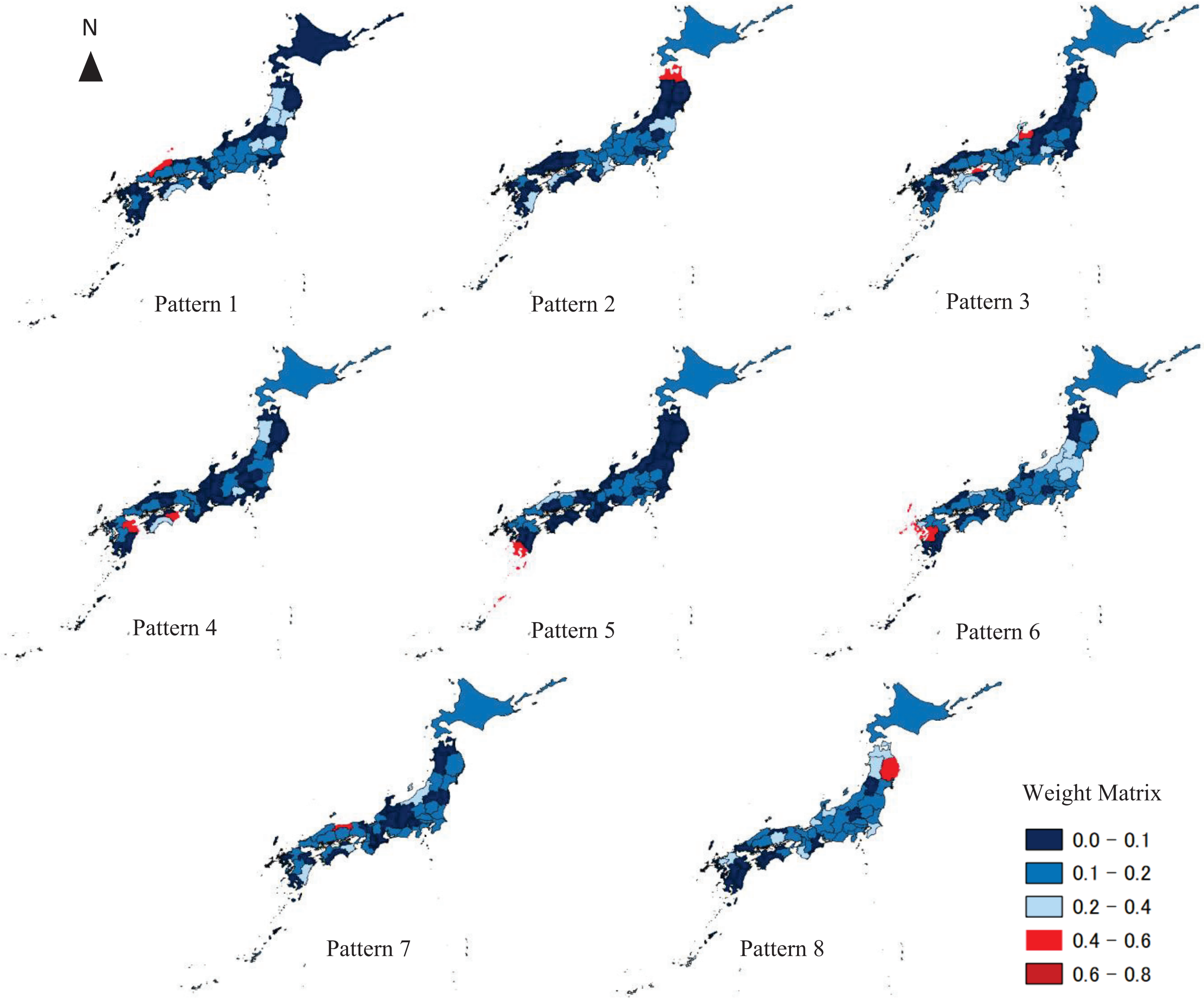


Figure 6.7. Weight Matrix W for Foreign Residents Cohorts Transition in 2010 to 2015

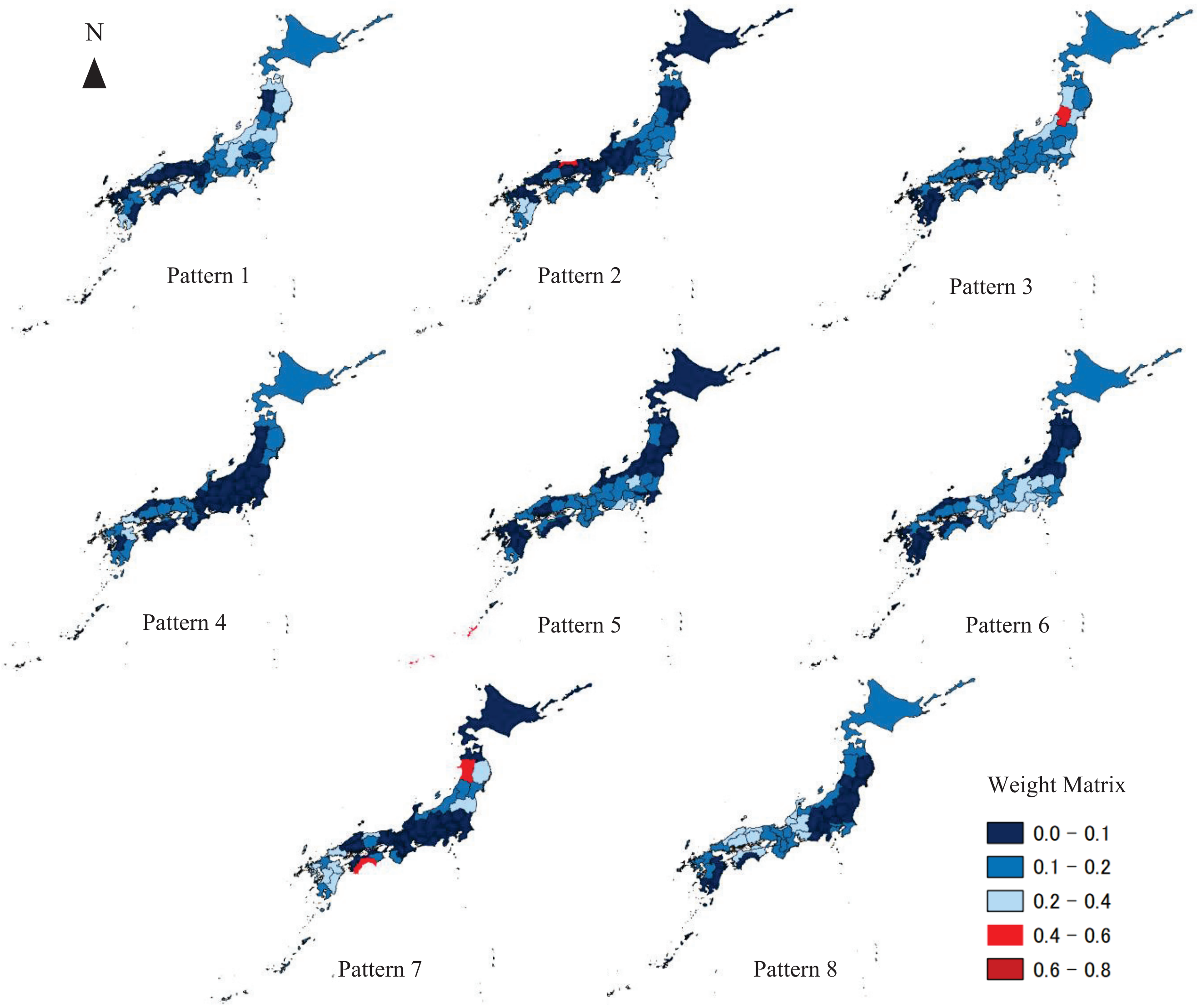


Figure 6.8 Weight Matrix W for Foreign Residents Cohorts Transition in 2015 to 2020

Table 6.2. Summary of Foreign Residents Transition Characteristics

(Rank symbols: Top 10 =▲, Middle 27= ▬, Lowest 10=▼)

Region	Prefecture	Foreign Population Growth Rate	Newly Born Cohort Transition	Change in Foreign Residents Share	Patterns by NMF from 2010 to 2015	Patterns by NMF from 2015 to 2020
Hokkaido	1. **Hokkaido**	▼	▬	▼		
Tohoku	2. Aomori	▼	▬	▼	[2]15-19 cohort (f) [8]50-over cohorts (f)	[5]24-29 cohorts (m, f)
	3. Iwate	▼	▼	▬	[8]50-over cohorts (f)	[1]Average
	4. **Miyagi**	▬	▬	▬		[3]25 to 49 cohorts (m) [3]60-64 cohort (f)
	5. Akita	▬	▼	▼	[1]20-24 cohort (m, f) [4]25-29 cohort (f) [8]50-over cohorts (f)	[7]25 to 34 cohorts (m) [3]25 to 49 cohorts (m) [7]45-59 cohorts (f) [3]60-64 cohort (f)
	6. Yamagata	▬	▬	▼	[1]20-24 cohort (m, f)	[3]25 to 49 cohorts (m) [3]60-64 cohort (f)
	7. Fukushima	▼	▬	▼	[6]10-14 cohort (f) [2]15-19 cohort (f)	
Kanto	8. Ibaraki	▲	▬	▲		[3]25 to 49 cohorts (m) [3]60-64 cohort (f)
	9. Tochigi	▬	▼	▲	[1]20-24 cohort (m, f)	[4]60-over cohorts (m, f)
	10. Gunma	▲	▲	▲		[4]60-over cohorts (m, f)
	11. Saitama	▲	▲	▬		
	12. Chiba	▲	▲	▬		[2]5-9 cohort (m, f)
	13. **Tokyo**	▲	▲	▲		
	14. Kanagawa	▲	▲	▬		[6]55-over cohorts (m ,f)
Hokuriku	15. **Niigata**	▬	▬	▬	[6]10-14 cohort (f) [7]45-49 cohort (f)	[3]25 to 49 cohorts (m) [3]60-64 cohort (f)
	16. Toyama	▼	▬	▬	[3]Average, Elderly [8]50-over cohorts (f)	
	17. Ishikawa	▬	▬	▬	[3]Average, Elderly	
	18. Fukui	▬	▬	▬		[8]5-9 cohort(m, f) [8]35 to 54 cohorts (m, f)
Chubu	19. Yamanashi	▬	▼	▲	[4]25-29 cohort (f)	[6]55-over cohorts (m ,f)
	20. Nagano	▬	▬	▲		
	21. Gifu	▲	▬	▲		
	22. **Shizuoka**	▲	▲	▲		[4]60-over cohorts (m, f)
	23. Aichi	▲	▲	▲		[6]55-over cohorts (m ,f)
Kansai	24. Mie	▲	▬	▲	[2]15-19 cohort (f)	
	25. Shiga	▬	▬	▬		[6]55-over cohorts (m ,f)
	26. Kyoto	▬	▬	▬		

	27. **Osaka**	—	▲	—		[6]55-over cohorts (m ,f)
	28. Hyogo	—	▲	—		
	29. Nara	—	—	—		
	30. Wakayama	▼	—	—	[3]Average, Elderly [8]50-over cohorts (f)	
Chugoku	31. Tottori	—	▼	▼	[7]45-49 cohort (f) [5]55- 59 cohort (m, f)	[2]5-9 cohort (m, f) [7]25 to 34 cohorts (m) [7]45-59 cohorts (f)
	32. Shimane	—	▼	▼	[1]20-24 cohort (m, f) [5]55- 59 cohort (m, f)	[1]Average [8]5-9 cohort(m, f) [8]35 to 54 cohorts (m, f)
	33. Okayama	—	—	—		
	34. **Hiroshima**	—	—	—		[8]5-9 cohort(m, f) [8]35 to 54 cohorts (m, f)
	35. Yamaguchi	—	—	—		[5]24-29 cohorts (m, f)
Shikoku	36. Tokushima	—	—	▼	[4]25-29 cohort (f) [7]45-49 cohort (f)	[1]Average [8]5-9 cohort(m, f) [8]35 to 54 cohorts (m, f)
	37. Kagawa	—	—	—	[3]Average, Elderly	[1]Average [4]60-over cohorts (m, f)
	38. Ehime	▼	—	—	[2]15-19 cohort (f) [7]45-49 cohort (f)	[8]5-9 cohort(m, f) [8]35 to 54 cohorts (m, f)
	39. Kochi	—	—	—	[1]20-24 cohort (m, f) [3]Average, Elderly	[7]25 to 34 cohorts (m) [7]45-59 cohorts (f)
Kyushu	40. **Fukuoka**	—	▲	—		[5]24-29 cohorts (m, f)
	41. Saga	—	—	▼	[5]55- 59 cohort (m, f) [6]10-14 cohort (f)	[7]25 to 34 cohorts (m) [7]45-59 cohorts (f)
	42. Nagasaki	▼	▼	▼	[4]25-29 cohort (f) [6]10-14 cohort (f)	[5]24-29 cohorts (m, f)
	43. Kumamoto	—	▼	—	[6]10-14 cohort (f)	[2]5-9 cohort (m, f)
	44. Oita	▼	▼	▼	[4]25-29 cohort (f)	[5]24-29 cohorts (m, f)
	45. Miyazaki	—	—	—	[2]15-19 cohort (f) [7]45-49 cohort (f)	[2]5-9 cohort (m, f) [7]25 to 34 cohorts (m) [7]45-59 cohorts (f)
	46. Kagoshima	—	▼	—	[5]55- 59 cohort (m, f)	[1]Average
Okinawa	47. Okinawa	▼	—	—	[5]55- 59 cohort (m, f)	[2]5-9 cohort (m, f) [4]60-over cohorts (m, f)

1~8= Pattern 1 to 8, m= male, f= female

Table 6.3. Number of Foreign Residents and Immigration Policies Implementation between 2010 to 2020

Year	Number of Foreign Residents	Immigration Policies
2010	2,036,161	Creation of "Technical Intern Training Program (TITP)"
2011	2,080,519	
2012	2,031,870	Introduction of New Residency Management System (point-based system)
2013	2,065,276	
2014	2,121,952	Japan Revitalization Strategy (Highly skilled professionals)
2015	2,232,981	• Projects for Facilitation of Acceptance of Foreign Entrepreneurs and Housekeeping Services in National Strategic Special Zones • Projects for Acceptance of Foreign Construction Workers and Shipbuilding
2016	2,383,714	
2017	2,561,767	• Implementation of Technical Intern Training Act • Project to Accept Foreigners Conducting Agricultural Works in National Strategic Special Zones
2018	2,731,829	
2019	2,933,137	Establishment of " Specified Skilled Worker " System
2020	2,887,116	Boarder Control for Covid-19 Pandemic

Chapter 7 Foreign Residents Distribution in term of Internal and International Migration

7.1 Introduction

The finding in Chapter 5 was that the foreign migrants have contribution in the future demographic structures of Japan. This is also approved by the finding in Chapter 6, which observes the significant transition of foreign residents' cohorts from 2010 to 2020. Chapter 6 only focused to analyze the transition of foreign residents cohort characteristics with time series and did not focus on the migration transition. Therefore, this chapter purposes to clarify the structural break on foreign residents' migration in Japan.

In this chapter, a multiple linear regression models specifically designed for the detection of structural breaks are estimated for the foreign residents in Japan with 47 prefectures and with an oversea interaction. The oversea interaction and domestic prefectures include both migration about inflow (immigration) and outflow (emigration). The period of dataset is from 2010 to 2020, which covers the big social events to possibly cause the structural breaks in migration such as the Great East Japan Earthquake in 2011, the change in immigration policy in 2014 and Covid 19 pandemic. The rest of the chapter is organized as follows. Section 7.2 describes the flow of methodology and data setting. Section 7.3 shows and discusses the experimental results and findings. The concluding remarks are presented in Section 7.4.

7.2 Methodology and Data

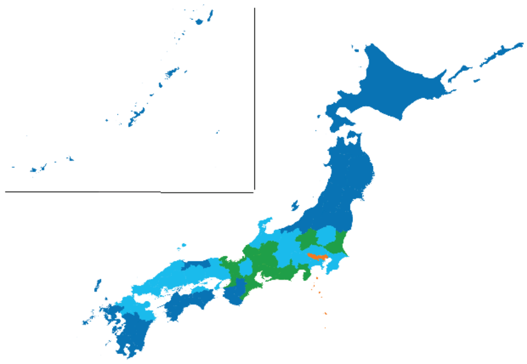
The analytical framework of this chapter was explained in Section 3.5.

7.3 Discussion

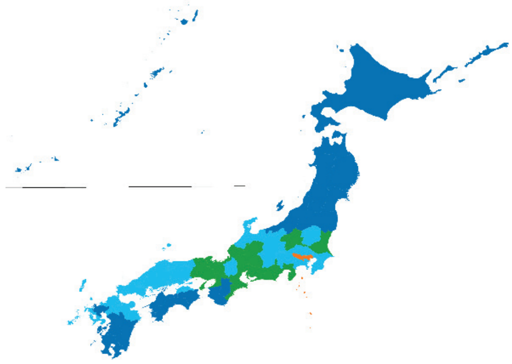
7.3.1 Foreign Internal and International Migration from 2011 to 2020

In order to find the spatial distribution of foreign resident's domestic migration and their international migrants (i.e., oversea migration), the ratio of immigration divided by emigration is calculated and shown in Figure 7.1 and Figure 7.2. Note that, as discussed in Chapter 6, the amount of foreign migrants and that of inflow/ outflow between urban and local regions were clearly different. Therefore, in this chapter, the amount of migrants among the prefectures are standardized by an adequate scale. Figure 7.1 shows that the foreign resident's domestic migration in overall prefectures is significantly increasing which trend is held on from 2011 to 2019. From 2013 to 2014, the foreign residents' domestic migration to the prefectures in Kanto, Chubu, Kansai and Chugoku started to change with over immigration. From 2015 to 2017, the foreign resident's domestic migration of the prefectures with mega cities in central Japan (Kanto and Kansai) attracted immigrants and the prefectures with rural areas suffered from lower immigration with higher emigration. However, from 2018 to 2019, the structure drastically changes. Not only the prefectures with mega cities, but also the prefectures with rural areas enjoyed the excess immigration. In 2020, all the domestic migration structure of whole prefectures changed again with excess emigration such that the highest immigration/emigration ratio ranges between 1 to 1.5.

Figure 7.2 shows that foreign international migration is quite stable with significant net increase from 2011 to 2019 for whole Japan, comparing with the foreign resident's domestic migration. From 2011 to 2012, the foreign international migration is stable but only Tokyo experienced the increasing emigration in this period. From 2013, the international migration structure has started to change into significant increase of immigration. In 2016 and in 2017, the migration trend is stable again and hit the highest immigration/emigration ratio between 2 to 2.6, so that the acceptance of foreign population and the net increase of foreign population is also at peak. In 2018 and in 2019, the immigration structure has changed again. For example, Iwate experienced the lowest immigration among all the prefectures below 1. Similar to the domestic migration, the international migration in 2020 is decreased for both immigration and emigration due to the strict boarder control by Covid-19. Since Covid-19 significantly impact on society, almost all the prefectures in central Japan and Kyushu regions face the net decrease in international migration.



(2011)



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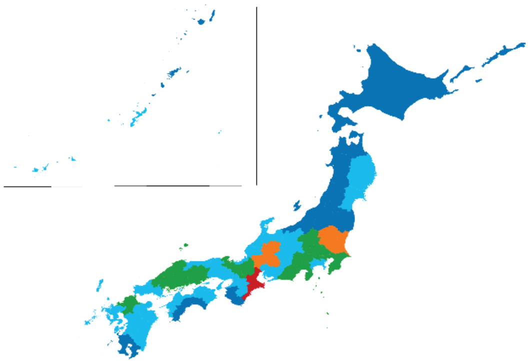

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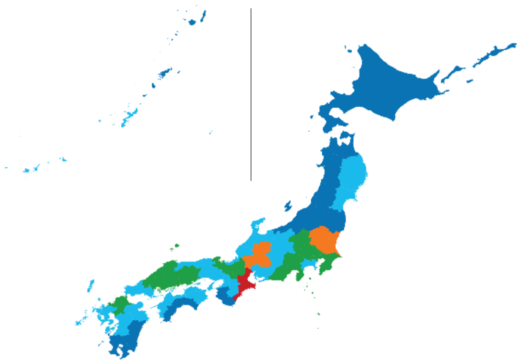

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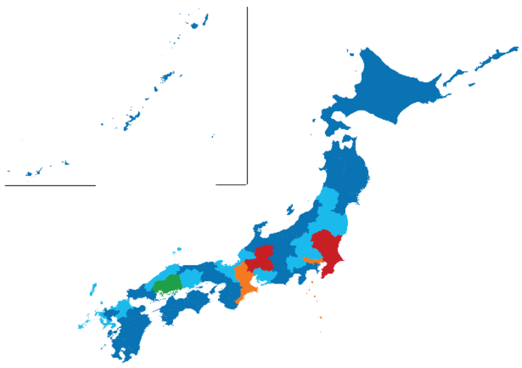

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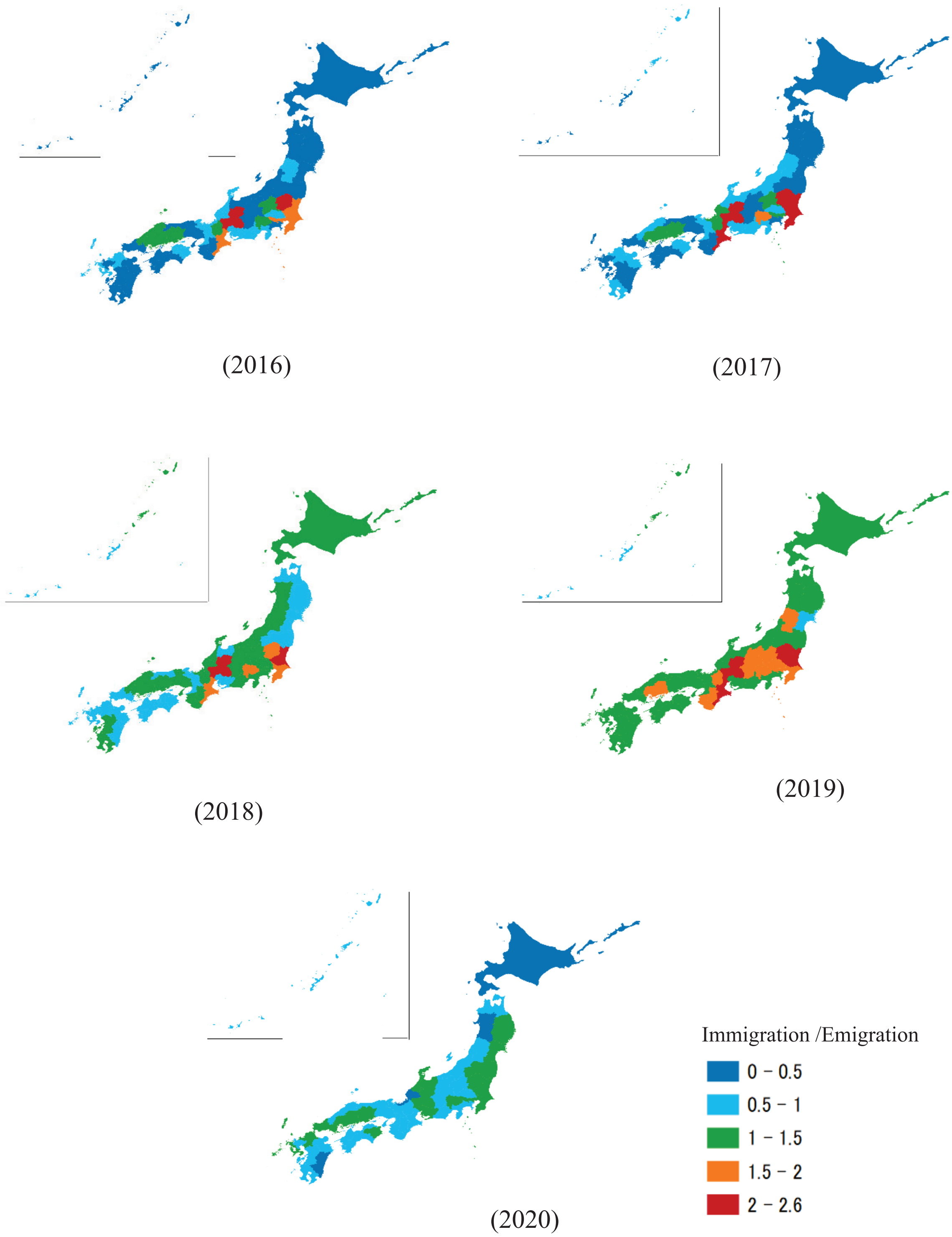
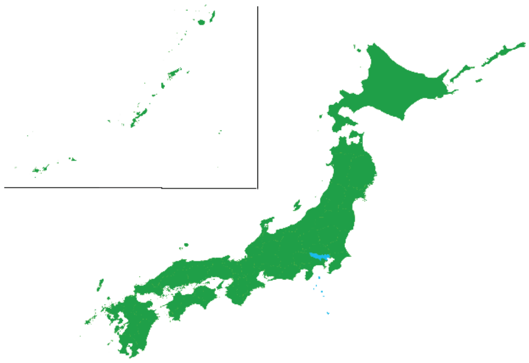


Figure 7.1 Immigration to Emigration Ratio of Foreign Residents Domestic Migration



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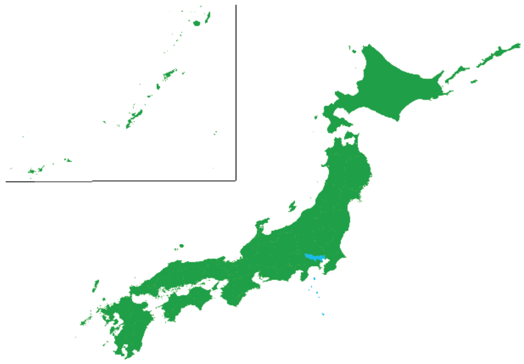

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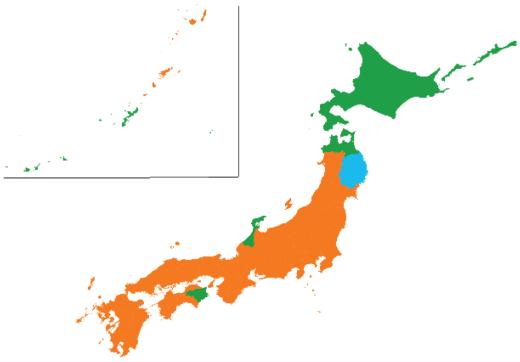

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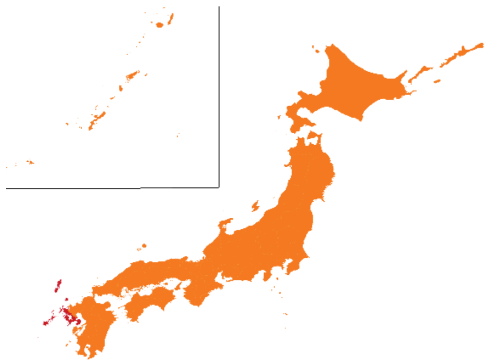

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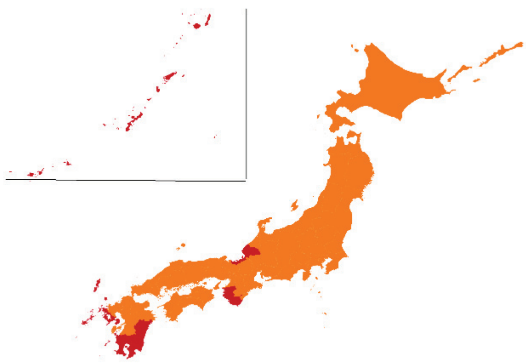

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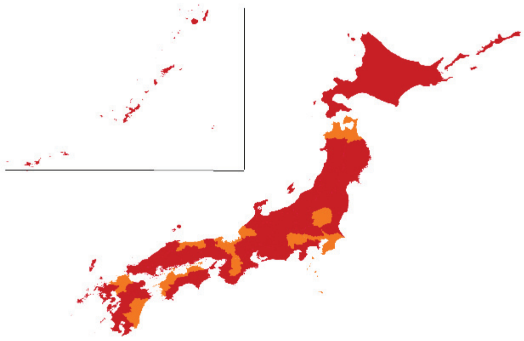

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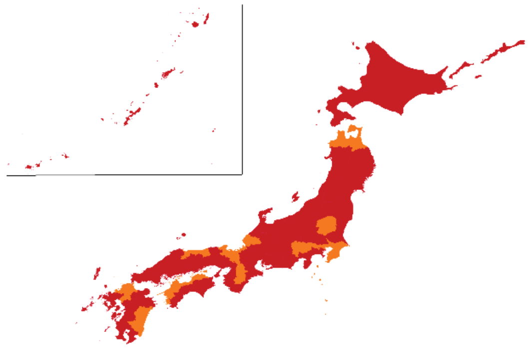

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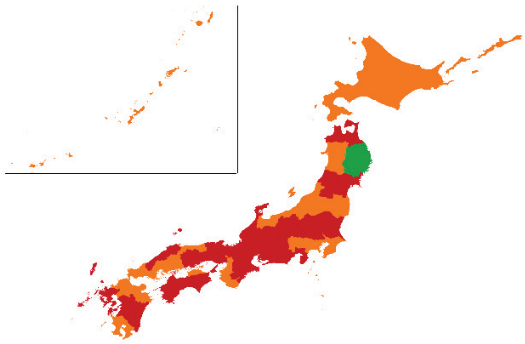

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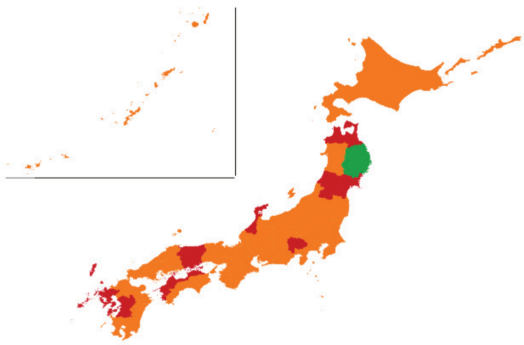
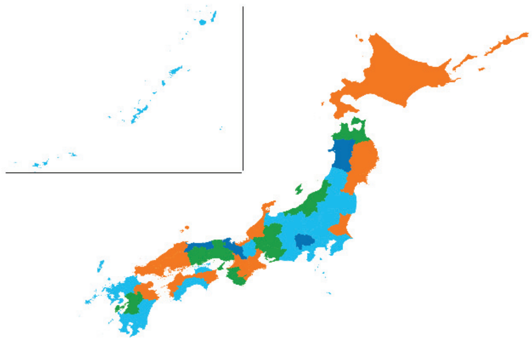
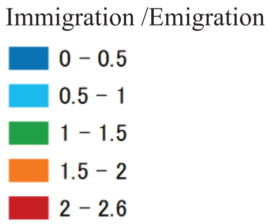


(2019)





(2020)

Figure 7.2 Immigration to Emigration Ratio of Foreign International Long-term Migrants

7.3.2 Structural Break Observation of Foreign Internal and International Migration by Multiple Linear Regression with OD Matrix Structure

To find the structural break in foreign residents' migration, this chapter analyzes the inflow/outflow of foreign migrants by OD matrix and estimates multiple linear regression models between the successive two years. Figure 7.3 shows the summary of R-squared indexes for foreign migration from the proposed regression models. In this estimation, R-squared indices ranges between 0.930 to 0.994. Therefore, the migration OD in *t+1* is well explained by the immigration/emigration distribution in *t*. According to the R-squared indexes, the model for 2011 with 2010 dataset has the lowest fit and the model for 2015 with 2014 dataset has a highest fit. The R squared indices of the estimated models show enough high. Therefore, the following analysis about the structural breaks is reliable because higher fit models were estimated.

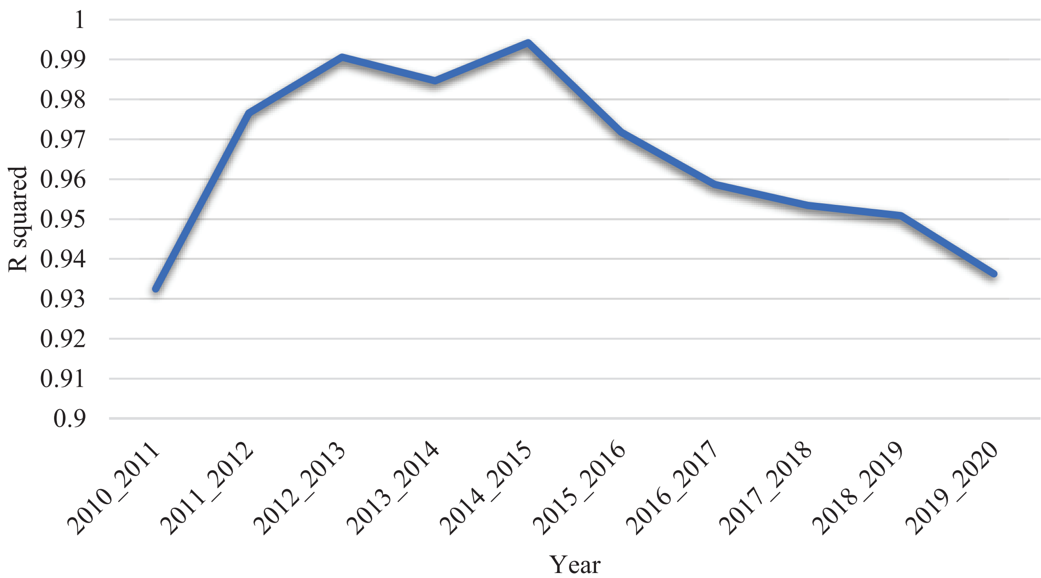


Figure 7.3 R squared of Foreign Migration from Regression Models

Table 7.1 Global Moran's I test

Variables	Parameter Global Moran's I	Global Moran's I for Inflow Residual $({\varepsilon_i}^{t+1})$	Global Moran's I for Outflow Residual $({\varepsilon_j}^{t+1})$
2011	0.7748***	0.3823	0.6123
2012	0.7740***	0.3908	0.6128
2013	0.7551***	0.6469**	0.5069
2014	0.7546***	0.6121	0.6236
2015	0.7788***	0.7282***	0.6264
2016	0.7609***	0.6159	0.6289
2017	0.7762***	0.4253	0.6040
2018	0.7826***	0.6795**	0.6242
2019	0.7952***	0.5276	0.6288
2020	0.7711***	0.6495**	0.6589**

Significance level parenthesis

* ρ <0.05, ** ρ <0.01, *** ρ <0.001

Table 7.1 describes the global Moran's I tests for the estimated parameters and the residual estimations to find a structural break. The results of parameters Moran's I test are to measure the spatial distribution of foreign residents in 47 prefectures with oversea OD matrix. The Moran's I test for inflow and outflow residuals are to confirm the heterogeneity of foreign residents' immigration and emigration in each cross-section between 2010 and 2020. The Moran's I test for the residuals determines whether the errors are independent with the surroundings, in other words, the residuals do not depend on the value of residuals at neighboring locations (i.e., no spatial autocorrelation in the residuals). If there is no spatial correlation in the residuals, the estimated model works well, and the trend continues from *t-1* to *t* without a structural break. If there is a significant global Moran's I in the set of residuals in the cross-section as *t*, there is a structural break and the trend change in that estimated period at *t*. The statistical significance of Moran's I is shown as * p <0.05, ** p <0.01, and *** p <0.001. In all cases of parameter estimation are rejected the null hypothesis of no spatial heterogeneity in the estimates of immigration/ emigration with the p-values less than 0.001. As there are residuals on inflow and outflow calculated from multiple linear regression analysis, the estimation of global Moran's I in the residuals can also give for both flows. For inflow's Moran's I, there is no significant results from 2010 to 2012 which means the trend of foreign immigration in 2010 is held up to 2012. The first structural break occurs in 2013 suggests that the new trend began in 2013. The second structural break occurs in 2015, according to the highly significant result in inflow's global Moran's I. This break shows there is an immigration trend between 2013 to 2014 and the new trend begins in 2015. The third structural break occurs in 2018, according to the inflow's global Moran's I. Therefore, the immigration trend from 2015 to 2017 can be seen and the new trend begins in 2018. There is a fourth structural break in 2020 according to the significant Moran's I. The immigration trend from 2018 ends and new trend starts in 2020. On the other hand, the outflow's global Moran's I from 2010 to 2019 show no spatial correlation which means the trend of foreign emigration in 2010 is continued until 2019. The first structural break for emigration occurs in 2020 because there was a significant in outflow residuals in Moran's I. The structural break in 2020 is affected by the national border control and the restriction of passenger trip across the prefectures under the Covid-19 pandemic. According to table 7.1, there are the evidence of structural break in migration. As a result, 4 structural breaks in immigration due to the significant of inflow's Moran's I and only one structural break in emigration are found.

7.3.3 Transition of Foreign Residents Distribution

The trends shown in Figure 7.1 and Figure 7.2 are comparable with the structural breaks found by the global Moran's I. The first term is from 2010 to 2012. To see the trend in this term on the couple of figures, the domestic migration of foreign people is concentrated among Kanto, Chubu, Kansai and Chugoku. These regions are known as the industry of manufactures. Therefore, these foreign migrants would be the workers in those industries. In terms of international migrants, the trend is almost homogenous over all the prefectures and the excess immigration is mild. The second term is from 2013 to 2014. The domestic migration is still concentrated in Kanto, Chubu, Kansai and Chugoku. The higher foreign immigrants in local prefectures are seen in Ibaraki, Tochigi, Gifu, and Mie. In this term Kyushu also experiences slightly higher immigration than the first term. The international migrant's trend in this term is still homogenous over the prefectures with some exceptions in 2013. All the above areas and regions are known as the location of factories of 2^{nd} industries had come to there. So, then the workers for the industries. The third term is from 2015 to 2017. Even though, the foreign domestic migration is still concentrated in Kanto, Chubu, Kansai and Chugoku, the excess immigration is observed in both urban and local prefectures. In this term, the trend of foreign domestic migration has changed even after the structural break of immigrants. The international immigrants in this term were the highest. Even the structural break is not observed, the trend between 2015 to 2017 is slightly different from the first and second trends. The forth term is from 2018 to 2019. In this term, the foreign domestic migration trend changes as shown in the figures. Almost all the prefectures experience the excess domestic immigration and local prefectures enjoy accepting the foreign domestic migrants. International immigration in this term slightly decreases from the third term and Iwata prefecture experience the lowest foreign international immigration. The fifth term is 2020 which is the start of Covid-19. In the fifth term, both domestic and international foreign migration was quite different from the previous term. The domestic migration trend in all the prefectures differs and depends on a declaration of a state of emergency within prefectures. The border control for overseas is uniformly applied to shut out the migrations.

Table 7.2. Number of Foreign Residents Migration and Immigration Policies Implementation between 2010 to 2020

Term	Year	Foreign Domestic Migrants	Foreign Inter-national Immigrants	Foreign Inter-national Emigrants	Foreign Residents	Immigration Policies
I	2010	161,392	243,696	191,652	2,036,161	Creation of "Technical Intern Training Program (TITP)"
I	2011	147,727	286,867	239,002	2,080,519	
I	2012	154,831	309,926	284,754	2,031,870	Introduction of New Residency Management System (point-based system)
II	2013	164,010	316,742	279,267	2,065,276	
II	2014	145,535	336,525	275,636	2,121,952	Japan Revitalization Strategy (Highly skilled professionals)
III	2015	168,042	391,160	275,542	2,232,981	• Projects for Facilitation of Acceptance of Foreign Entrepreneurs and Housekeeping Services in National Strategic Special Zones • Projects for Acceptance of Foreign Construction Workers and Shipbuilding
III	2016	185,015	427,585	271,342	2,383,714	
III	2017	217,754	474,996	290,728	2,561,767	• Implementation of Technical Intern Training Act • Project to Accept Foreigners Conducting Agricultural Works in National Strategic Special Zones
IV	2018	242,108	519,683	342,275	2,731,829	
IV	2019	271,081	591,961	382,099	2,933,137	Establishment of " Specified Skilled Worker " System
V	2020	216,500	114,661	157,261	2,887,116	Boarder Control for Covid-19 Pandemic

7.4 Conclusion

This chapter clarified the structural break on the foreign resident's migration between 2010 and 2020 with 47 prefectures and oversea category in Japan by a structured regression analysis. The proposed models fit well for all the predicted periods, so then the residual test about spatial dependency can be used to find the structural breaks. The foreign resident's domestic migration in Japan is significantly changed in the observed period. Concerning to the immigration of foreign people, the structural break of the immigrants occurs four times between 2010 and 2020. Concerning to the structural break of emigrants in the same period, only a break is observed in 2020. This finding suggests that the immigration is unstable, while the emigration is stable except in 2020.

This chapter approves that the trend of foreign migration from 2010 to 2020 is structurally changed. The list of the implemented policies for the foreign labor force acceptance in Japan were shown in Table 7.2. Acceptance of foreign international migrants is significantly increasing after the implementation of foreign immigration policies. The structural breaks are occurred in 2013, 2015, 2018 and in 2020. The first structural break in 2013 would be the effect of the introduction of new residency management in 2012. The second structural break in 2015 is supported to be the effect of Japan Revitalization Strategy approved in June 2014. Even though there is no structural break between 2015 to 2017, the study observes both domestic and international migration have changed even after the break. This transition is considered as the effect of the projects for facilitation of acceptance of foreign entrepreneurs, housekeeping services in national strategic special zones, acceptance of foreign construction and shipbuilding workers in 2015. The third break in 2018 would be the effect of technical intern training act in November 2017 and the acceptance of foreigners conducting agricultural works in national strategic special zones. The last structural break in 2020 is surely the effect of the declaration of a state of emergency for Covid 19 and border control policy by the government to almost prohibit the movements of foreign residents among the prefectures and oversea.

Japan is now aiming for a massive immigration of foreign workforce to overcome the labor shortage especially in agriculture, food-processing, and construction; it is necessary to urgently prepare a social integration policy in the local government for foreigners. On the other hand, the novel national immigration policy “Specified Skilled Worker System” applied in 2019 would bring more foreign migrants. The results in this chapter show that except the emergency outbreak, novel immigration policies in Japan would especially effect on immigrants. According to the observation from 2010 to 2015, the foreign migrants are mainly concentrated among the urban and industrialized areas such as Kanto and Chubu where relatively large number of foreign people lives with the sufferance facilities and supporting policies. However, after the policy implementation of technical intern training act especially on the construction and shipbuilding, and also the acceptance of foreigners conducting agricultural works in national strategic special zones in 2017, foreign migrants are started to concentrate not only on urban regions but also on the local regions in Tohoku, Chugoku and Kyusyu where the foreign residents are rather minor up to 2017. This finding highlights how the policy instated in 2017 caused the trend of foreign migration in Japan to shift from urban to local regions. Expecting the massive acceptance of foreign immigrants from “Specified Skilled Worker System” which was implemented in 2019, Japanese local regions will experience an increase in foreign labor force, reflecting the situation experienced after the policy's implementation in 2017. As the foreign community is significantly increasing in local regions where acceptance of foreign residents is recently started, the local government need to implement the supportive policies for foreign residents, such as healthcare services, education for the younger generation and linguistic supports. Without such an integration policy, the new immigration policy for foreign migrants will result in social problems in social divisions and make the society unsustainable in local regions.

Chapter 8 Conclusion and Recommendations

8.1 Conclusion

Over the past decades, Japan experienced a depopulation with rapid aging society, and the economically active groups (working-age cohorts) face the tension to support not only the younger cohorts in their education, social activities and elderly cohorts in their health care, nursing, etc. The shortage of labor force as a consequence of low fertility can directly impact on the economic growth of Japan. Population losses have triggered social concerns about the economic and demographic sustainability. In order to clarify the goals of national or local policies, it is essential to understand the population distribution over the regions in long term. In regional planning, population prediction is one of attentive methods that give fundamental information for decision-making about maintaining the infrastructures, subsidizing to public projects.

In order to consider the spatial dependency, this study examines the effectiveness of interregional migration model based on the industrial indices by applying the spatial autoregressive (SAR) model in Chapter 4. The proposed models tested the significance of spatial dependency of migration and in employment opportunities and daily life convenience among Japanese municipalities. In Chapter 5, the proposed methodology composed of conventional CCA with statistical models SAR for migration were estimated and applied to predict the future Japanese population until 2040. The results of the proposed approach show that the spatial dependencies related to the job opportunities and daily life convenience factors should be considered in the population prediction. According to the findings in Chapter 5, the foreign residents' cohort transition was analyzed by NMF in Chapter 6. In order to look into the trend of migration of foreign residents with the national policy implementation, the structural breaks of the foreign migration trend between the successive years were analyzed by a constrained multiple linear regression in Chapter 7.

First, this study explored the significant spatial dependencies among the Japanese municipalities. The estimated models in immigration and emigration were positively correlated with those of the surrounding municipalities respectively, especially in working-age cohorts (15 to 64). Male working-age cohorts make much movement than female working-age cohorts, and their concentration occured in urban or metropolitan areas as labor force drawn areas related to the manufacturing industry. Elderly cohorts remained in the local areas which would arise the problems related to the social services for supporting the elder generations.

Second, this study also examined the future population distribution and the share of the cohorts in Japanese municipalities. According to the proposed prediction approach, the younger age cohorts fall from 16.84 million to 8.8 million in 2040. The working-age cohorts (15-64) drop to 55.76 million in 2040, which is approximately ten percentage lower than that in 2010. The elderly population (65 and over) is over 37 million in 2040 when the baby-boom generation (born from 1947 to 1949) and second baby-boom cohorts (born from 1971 to 1974) enter into elderly cohorts. The share of elderly out of the entire population is 37% in 2040, corresponding to one by 2.7 people will be elderly in our prediction.

The proposed model predicted that the number of newborns decreases nationwide, since female childbearing cohorts are moving to the areas with smaller CWR. The proposed approach predicts higher population among the middle-aged cohorts than that by the conventional CCA. This outcome would be brought by foreign migrants in the dataset. The future population is highly concentrated in urbanized areas because domestic migrants have moved from rural areas to urban areas, and the migration from overseas is also concentrated in urban areas. This study also finds out that manufacturing industries would be a driving factor in attracting people, especially middle-aged cohorts (15 to 49) from rural areas to urban areas.

As a result of the proposed approach, depopulation occurred in nationwide even in metropolitan areas. Also, nearly all rural disadvantage areas (islands and intramountainous regions) suffer from serious population shrinkage. Most of the local municipalities in Hokkaido, Shikoku and Kyushu reach the population of less than 10,000 aspect the prefecture capitals in 2040. The rate of population decrease is high in the almost all the local municipalities with a small population and it is low in the urban municipalities such as Tokyo, Aichi and Osaka with a large population. Although some areas will increase population, the population decrease is severe in almost all rural areas. Therefore, the population gap between rural areas and urban areas is enlarged. In Hokkaido, Yamaguchi and Nagasaki will face serious population declining for over 50% of the total population in 2040. As a rare case in Fukuoka and Okinawa, the rate of population increase is positive from 2010 to 2040.

The estimated results of this study give strong evidence to consider the spatial dependencies, because of significant impact on population prediction. Therefore, the simulation analysis of the population following to the proposed approach were tried. Since the spatial distribution of industries is skewed or agglomerated, this study results in more severe demographic disparities in Japan, comparing with the conventional population prediction by CCA.

Third, in order to analyze the transition of the foreign residents' characteristics, this study also applies NMF to the cohort structure dataset on the registered foreign population of Japanese prefectures in 2010, 2015 and 2020 in census of Japan by the Statistics Bureau of MIAC. According to the dataset, the number of foreign migrants were concentrated in the central Japan from 2010 to 2020 where the industrial workforce accumulates. However, the transition of foreign migrants for each cohort estimated by NMF were significantly different in Tohoku and Kyusyu where the foreign residents are still minor. The increase of workforce cohorts was continued from 2010 to 2020 and the increase of children and younger cohorts (below 20) was also accompanied with them from 2015 to 2020 in those regions. From this observation, these regions are accepting the next generation and foreign workforce to compensate the depopulation and labor shortage and the younger generations as the children of those foreign residents who already lives there. Also, the growth rate of elder cohort was high from 2015 to 2020 in Tohoku, probably as a result of the retirement of foreign residents which could not be observed in raw dataset.

Lastly, the study observes the structural break of foreign domestic and international migration between 2010 and 2020. Findings show that the foreign resident's immigration in Japan is significantly changed as the structural break had observed four times between 2010 and 2020 but only a break was observed for emigration in 2020. This finding suggests that the immigration is unstable, while the emigration is stable except in 2020. Similar with the foreign residents' cohort transition, the result of migration transition also shows that the foreign migrants also concentrate in the regions of central Japan; Kanto, Chubu, Kansai, and Chugoku known as the industry of manufactures. The findings also approve that the trend of foreign migration from 2010 to 2020 was structurally changed due to the policy implementation of the foreign labor force acceptance to Japan. As a special case, both immigration and emigration break were observed in 2020 which is the year of Covid-19, a declaration of a state of emergency within prefectures and border control for oversea movements had been made. Therefore, the results show the amount of immigration/emigration was the lowest among the period. The declaration of a state of emergency for Covid-19 and border control policy by the government. In 2020 and 2021, the movements of foreign residents among the prefectures and oversea were almost prohibited.

According to the findings of this study, Japanese government should prepare policy implementations based on the 2030 United Nation Agenda, Sustainable Development Goal 11, which is to "make cities and human settlements inclusive, safe, resilient and sustainable", as rapid urban population growth can outstrip the capacity of infrastructure. It is essential for Japanese urban areas to find effective and efficient ways to utilize limited resources in order to build a sustainable society. Otherwise, Japanese urban areas could face severe congestion, insufficient infrastructure, health, job and environmental problems, etc., whereas some areas such as metropolitan Tokyo already struggles to overcome the problems caused by over agglomeration. As social and economic divisions between rural areas and urban areas is increased, the government need to consider the implications for social sustainability such as potential public accessibility, medical services, educational services and so on, which will be important determinants for distribution of population. The aging problems will be more severe in the future as this study also pointed out the exceed of elderly population in 2040, the government also needs to provide a wide variety of social services for elderly population such as the senior transportation services, medical services, welfare centers to prolong independence and to maintain social network of elderly people.

The predicted population in 2040 showed that, Japanese municipalities will lose 73% of the workers in retailer due to the decrease of the labor force and the effect of migration to cause the people's move to the urbanized areas with higher retailer's accumulation. In order to deal with this issue, government must implement the laws and regulations on business establishment in Japan. Also, government should make active investment in AI and IoT to substitute the human labor in retailer such as AI-powered customer engagement platform, AI solutions to personalize online shopping and online services, for example. Additionally, the implementation of policy for the acceptance of foreign nationals needs to be revised to accept more foreign entrepreneurs in the manufacturing sectors of automotive, electronics. In order to attract the young foreign investors, it is also necessary to implement the Startup and New Business promotion in Japanese local regions.

From the population prediction by the proposed model, Hokkaido, Shikoku and Kyushu will experience the significant depopulation by 2040. According to the study's findings regarding to the transition of foreign residents and migrants, Tohoku, Shikoku, and Kyushu started to accept the foreign residents in 2017. Hence, the foreign residents will mitigate to Shikoku and Kyushu, where will suffer from sever depopulation. However, the foreign residents' increase in Hokkaido are not observed in both pattern analysis and structural break test of this study. Therefore, Hokkaido government must consider implementing a policy for foreign residents, just like Shikoku and Kyushu.

Accepting the foreign migrants is one of the appropriate solutions as it is more quickly and more effective to the revitalization of Japan's economy and society. However, there are further problems in accepting the foreign migrants as the government should satisfies the Japanese people in terms of minimizing the kind of immigration-related problems (Culture and Social). The policy to bring benefits both Japanese and foreign employees should be designed. For example, the problem related to foreign employees who are permitted to invite family members should be cared to keep their stay in Japan. The findings of this study related with foreign residents highlights to apply the policies about the linguistic help for foreign migrants, schooling support for next generation and the community acceptance. The creation of social bond for foreign elderly is effective to keep the stable acceptance to the foreign residents in the regions where they are still minority. Since the regions highlighted in this study include many depopulated areas and the capacity of those local government for the policy building would not be enough, they should be supported well by the national government.

According to the Voluntary National Review of Japan (VNR 2021), the SDGs Promotion Headquarters of national government introduced the "SDG Future Cities" to select the municipalities which have presented impressive initiatives to accomplish the SDGs. In FY2021, a total of 124 cities have been chosen as "SDGs Future Cities," 10 projects have been chosen as "Municipal SDGs Model Projects" among them and are funded by the national government. As a result, an action to promote the resolution of regional issues, such as declining fertility, aging communities, and declining populations, through the principles of the SDGs has been gaining momentum throughout the country. The national government set to select a total of 210 cities as the "SDGs Future Cities" by the end of FY2024 to creating SDGs model cases for local development in Japan.

To promote the local businesses in local areas, the national government introduced “SDGs for Regional Revitalization Finance” which assist the local businesses and retail sectors by collaborating with the regional financial institutions and other stakeholders to address regional problems and boost regional economies. The number of local governments which are working on this policy was 58 as of December 2020 and the national government is aiming to over 100 in FY2024.

In addition, as a rapid depopulation and an aging society with fewer children, the national government is already aware to build a transportation system that accurately responds to the significant economic and social changes. In order for municipalities responsible for the local needs to enhance the public transportation services, the "Act for Partial Revision of the Act on the Revitalization and Renovation of Regional Public Transport for the Purpose of Promoting Initiatives that Contribute to the Provision of Sustainable Transportation Services" which is the master plan for the regional transportation was implemented in November 2020 by the national government to provide continuous transportation services, such as by establishing a system to promote efforts to maximize the use of local transportation resources. The system is expected to be beneficial for both municipalities and transport companies and is expected to increase convenience, sustainability and improve service by reviewing routes, schedules, and fares from a user-based perspective.

As Japan is expecting to increase foreign labor force with the introduction of "Specified Skilled Worker System", the government need to implement the supportive policies for foreign nationals. In order to address a society where "no one is left behind" by SDGs, the national government has implemented the Public Employment Security Office (PESO) which offers employment assistance services to foreign nationals such as career counseling and providing information about job postings. There are 544 PESO offices spread across Japan's major municipalities, and information employment opportunities can also be obtained from the Hello Work website, where users can get the employment support with appropriate institutions.

The above policies implemented by the national government (VNR 2021) support the suggested policy recommendations based on the current trends which are out of scope from the output of the direct findings of this study. Therefore, with the comprehensive understanding of the demographic phenomena in local prefectures and municipalities for both domestic and foreign residents based on the philosophy of the proposed modellings, this study can give the possible vision to accelerate the government's concrete efforts regarding with the regional sustainable development.

8.2 Limitation Of The Study And Recommendation

In the proposed approach, there are several limitations and future studies. The explanatory variables in the SAR models should be checked with caring (1). The lag of immigrant and emigrant models is also the target of research (2). This study only focuses on the continuity weight matrix to estimate the effect of surrounding neighbor regions, which cannot observe the effect of the regions where do not share a common border. Therefore, the specification of the spatial weight matrix requires more tests. For example, distance-based weight matrix such as the inter-regional travel time by high-speed railway or airline (3). The spatial unit of this study is limited to the availability of boundaries data. If the mesh data for example, $5km^2$/ $100km^2$ scales or more fine spatial units are available in the future, the use of the appropriate size of the dataset for the proposed approach should be carefully chosen (4). The validation of model structure can be confirmed by the actual population. For this purpose, the proposed model can be applied to the past data, then the outputs could be tested by the present data (5). There is also a greater demand for projections not only of population structures but also the household types and living arrangements for socioeconomic planning, regional development and infrastructure investments. Understanding the changes in housing, the life stages of each individual or household are important factors in forecasting future population and household types (6). The discussion based on the phenomenon of migration, such as identity issues, legal issues should therefore be taken into more consideration in future work (7). This study mainly based on Japanese content because the area's focus is on Japan. However, in order to apply the proposed approach to other depopulated countries, more generalization is needed for future tests (8).

For the studies related with the foreign resident’s demography, this study is limited in the following ways. This study focused on prefecture data due to its availability. In the future research, it is suggested to use the municipal data as the basic government (1). The number of patterns we selected for this study was limited on 8 patterns for simplicity. More numbers of patterns should be identified when the analysis conducted at the municipal level (2). If the transition of foreign residents’ cohorts’ characteristics is linked to the industrial characteristics of each region, it can make in-depth policy making (3). Similar with the foreign-resident-cohort-transition, foreign domestic and international migration transition can also be observed with pattern analysis by NMF (4). The study's findings indicate that in future, there will be a significant increase in the number of foreign residents in Japan. Japan's climate and topography makes the foreign residents particularly vulnerable to natural disasters such as countless earthquakes, typhoons. Therefore, the study to focus on the impact of natural disasters on the foreign residents is required in future (5).

8.3 Future Tasks based on the Taoyaka Onsite Team Project (OTP)

As one of the students from Taoyaka program, I had many opportunities to experience the problems and issues faced by the rural areas of Japan. These experiences gave the motivation to carry out this study and visions to make the policy recommendations for Japanese local regions. Also, as a future task, this study can also be applied to predict the migration of Myanmar where the action research for student migration was already conducted as the Taoyaka Onsite Team Project. According to the findings based on the questionnaire survey from the Onsite Team Project, over half of the respondence students want to migrate to the other regions of study area to continue their higher education. This result indicates that there is an intention to make student migration within the Myanmar. As part of future studies, the findings from Onsite Team Project can be linked to one of the study's main motivations, which is about the issue of job opportunities as a potential factor influencing the domestic migration.

Appendix: Empowerment as a Factor of Student Migration: Action Research in Myanmar (Individual Report for Taoyaka Team Project)

A1. Introduction

A1.1 Team members

The team consists of two members.

(i) SZYMON ANDRZEJ URBANOWICZ (Cultural creation course)

(ii) SEBAL OO (Social implementation course)

A1.2 Objectives

In our team project, we would like to spread within teachers the influence of school events on student empowerment according to history of events and festivals, to develop globally universal empowering facilitation indicators in education along with localized ones to further improve empowerment of both students and teachers, to explore the elements affecting students' decision on migration and see how student empowerment affects on migration. This study will give suggestions and ideas for how to implement the school events according to the student empowerment and implementation aimed at providing rural inhabitants with similar access to education opportunities that urban residents which can be considered in future development plan.

A1.3 Research Questions

In my team project, I would like to emphasize with these research questions:

(i) How much students want to migrate to the other townships of study area to continue their higher education?

(ii) Which factors influence on their migration decisions and what influences their choice of migration destination?

(iii) How will the influence factors make the student distribution and how to provide the social facilities to students related with their education?

A1.4 Preparation

Our team members are from different background with different research interests, we considered the project to be supportive for our individual research. Based on the individual research interest and background experiences, we tried to get a common interest which will benefit to all the members. Therefore, we decided to research about the student empowerment based on education background and demographic aspects. We selected to do our project in Myanmar which has under developing education systems. The project is planned to focus on high school students and university students.

A1.5 Background of Study area

A1.5.1 Migration

The level of internal migration in Myanmar is similar to that of neighboring countries such as Thailand, Laos. For internal migration within the five-year period before the 2014 Census, 7 per cent reported moving. A large proportion of movement within Myanmar revolved around Yangon, either as movement into Yangon or movement among Districts within Yangon. Yangon, the cultural and commercial capital of Myanmar, has seen a marked increase in migration from other parts of the country in recent years, and the boom in new construction of high-end residential and commercial buildings is very visible. Among recent migrants to Yangon, the primary origin of the move was Ayeyawady. Within Yangon, the major streams of recent migrants were from West and South Yangon to North and East Yangon.

The results of 2014 Census do suggest that for more permanent migration the flows are predominately urban-to-urban. More permanent migration from rural areas was directed towards other rural areas. The results suggest that policies aimed at providing rural inhabitants with similar access to education opportunities that urban residents enjoy would provide rural residents with the opportunity to improve their lives through migration. Also, it is important that information about opportunities in other areas is shared with both rural and urban residents.

A1.5.2 Education

Most children in Myanmar attend government-run schools, beginning formal classes each June once they have reached five years of age. Children currently spend five years at primary school, four in lower secondary and two in upper secondary. However, access to education for the children in Myanmar is very difficult for several reasons: such as Poverty, Conflict & Internal Displacement, Low-Quality Education, a lack of school facilities and trained teachers. With poverty being a crucial factor affecting access to basic education, more efforts are needed to enable students living in remote and rural areas to enroll in primary and middle schools such as develop knowledge, skills and competencies that are relevant to students lives, implement a quality assessment system to improve learning outcomes, support, develop and apply interactive classroom teaching and learning, to benefit all students.

A1.6 Previous Study area, Project Conducted Area and Issues for Second Time School Visit

Firstly, the project was planning to conduct at the Dalla Township, which is located on the southern bank of Yangon river across from downtown Yangon and neighbored with Ayeyawady division, Myanmar. However, after discussion with local authorities, we figured out the previous study area is difficult to observe the Sport Festivals and school events as most of the sport events were already conducted in Dalla

Township in that time, did not get the permission to conduct the survey in Dalla Township as we planned to conduct the observation during year-end holiday, and it is difficult to implement the sport festivals in Dalla Township in next school visit time.

Therefore, we moved to our study area into two places. For the research related with the empowerment according to history of events and festivals (Szymon research part), we made the observation and conducted the survey in Amarapura which is a former capital and now a township of Mandalay city which is located at the central Myanmar (Burma). It lies on the left bank of the Irrawaddy River and 11km north from Mandalay Township. Amarapura today is part of Mandalay, as a result of urban sprawl. And for the project related with the student migration (my research part), we distributed the questionnaires to the Shwe Say Ti High School at East Dagon Township, Yangon Division. East Dagon Township is located in the easternmost part of Yangon Division and East Dagon is still largely undeveloped and lacks basic municipal services. The township has 19 primary schools, four middle schools and only two high schools. I chose this area, as the situation of East Dagon is similar with the previous study area. The students in the survey conducted area are also facing poverty, low-quality education, lack of school facilities and trained teachers just like the previous expected study area. We made the meeting with High School Students and explaining about the information which included in questionnaire survey and collected the questionnaire survey from the students.

Previously, the first-time school visit is planned to be the observation of current situation for school sport events, festivals, and collection for pilot survey of student migration however, because of the Covid-19 pandemic and Myanmar Political crisis, we cannot conduct our second time survey and continue our project. Therefore, our team members and our mentor decided to use the pilot survey as the final data, and we made the analysis based on that data. Although the data availabilities are quite small, we tried to make the project to be finished as much as we can.

A2. Survey

The survey questionnaires related with the factors effecting on the student migration consists of two sections- first section is about the personal information and second is about the factors effecting on the student migration discussion. There are totally 9 questionnaires in the first section leading to the socio-economic situation of the respondents and second section including total 20 questions which consist of current location, previous location, planning to change the location after finished the high school, reason for moving (Higher education or job opportunities), planning to go back to the previous location after higher education, importance factors for location choice and desired location in the future. After that, we translated the questionnaires into local languages Burmese. The total respondents are 320 and the targeted grades are Grade-10 and Grade 11 students.

A3. Analysis Flow

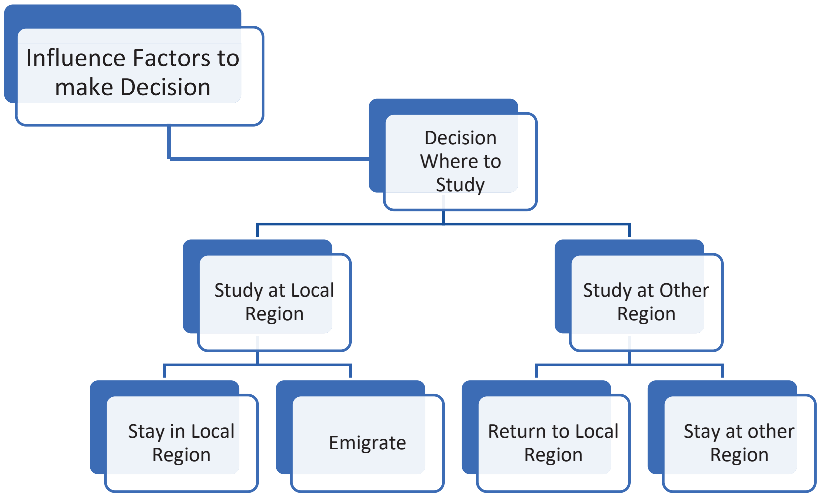


Figure A2 Analysis chart of Student-migration Decisions

According to the flow chart, the study will be finding out the higher education as a factor for migration decision choice.

A4. Discussion

A4.1 Summary Statistics for General Information

	Male	Female	Total
Grade 10	62	74	136
Grade 11	72	112	184
Respondents	134	186	320

	Max	Min	Average
Family Members	17	3	3.625

	Agriculture	Trading	Construction	Industrial	Services	Others
Father Occupation	192	22	26	14	16	50
Mother Occupation	162	70	0	28	8	52

Among the total 320 respondents, 136 respondents are Grade 10 students and remaining 184 respondents are Grade 11 Students. 134 respondents are male students and 186 are female students. The maximum household members are 17 and minimum 3 members. The highest amount of parent occupation is agriculture and services sector are the least occupation for parents. From these statistics, it is clearly observed that respondent students are belong to the middle-class households as most of the students' parents' occupation is agriculture.

A4.2 Summary Statistics for Factors Influencing for Student Migration

Chart A1: Number of Students Who want to Continue the Higher Education

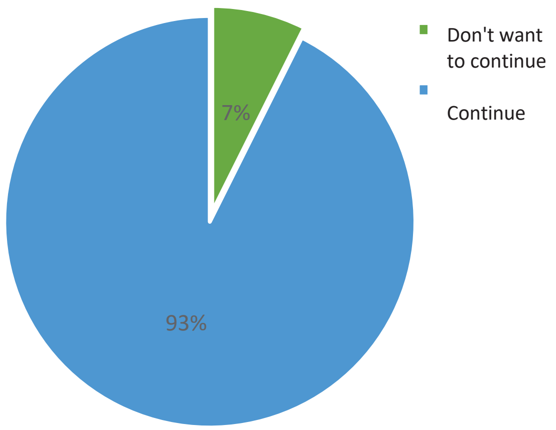
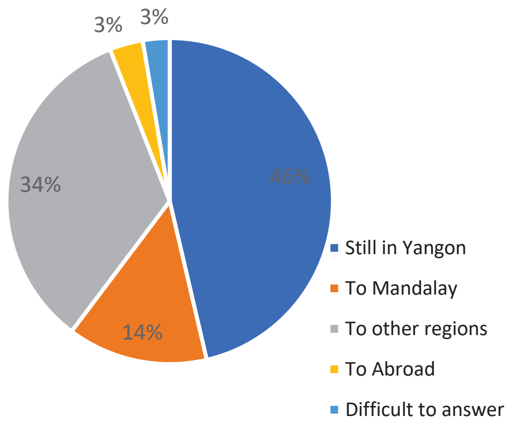


Chart A2: Desire Location for Higher Education



According to the collected data, 7% of the students don't want to continue the higher education and remaining 93% want to continue the higher education. Considering the objectives of the study, it can be divided the directions of migration into interregional migration (other regions of country), return migration (native region) and external migration (to other countries). As a result of the statistics, 46% of students will still want to live in study area (Yangon) and remaining 51% want to move to the other places. 14% want to move to the Mandalay (the capital of middle region of Myanmar) and 34% want to move to the other region, which include the return back to the previous location (return migration) before moving to Yangon for High School Examination. 3% of the respondents want to move to aboard as an international migration phenomenon 3% of respondents are difficult to answer this question.

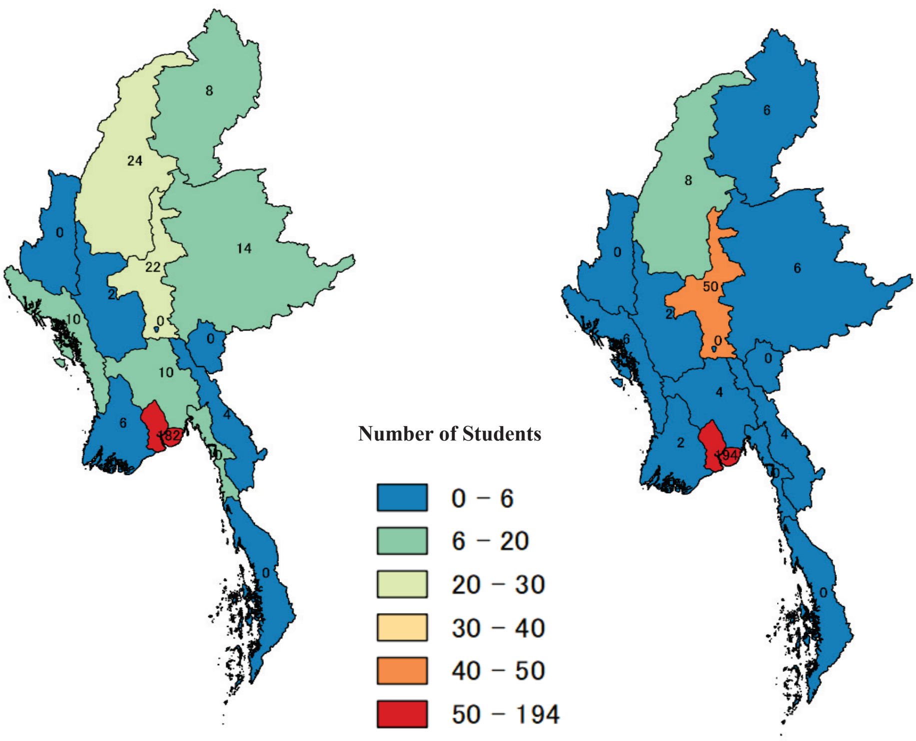


Figure A2 Location of Students Before moving to Yangon for High School Examination and After High School Examination

Before planning to take the High School Examination, respondence students were living not only in Yangon but also in Bago and Ayeyawaddy divisions which are the neighbor regions of Yangon division, northern region such as Mon state and Kayin State, middle region such as Sagaing and Bagan, east region such as Shan State, Rakain State as west region and Kachin as southern region.

After High School Examination, the 194 respondents want to continue living in Yangon and remaining want to move to other places. 140 respondents whose previous location was Yangon still want to live in Yangon and 28 respondents want to move from Yangon to the other region. 10 respondents want to move to the aboard for their higher education. Some want to move back to the previous location from Yangon and some want to move to the capital which is near to their previous location such as students whose lived-in middle region want to move to the Mandalay for their higher education. According to the Figure 2, it is clearly observed that Yangon, still be the highest number of students whose want to continue for Higher education and the middle region capital Mandalay is the second largest. Remaining region will suffer the emigration and loss of students for these regions.

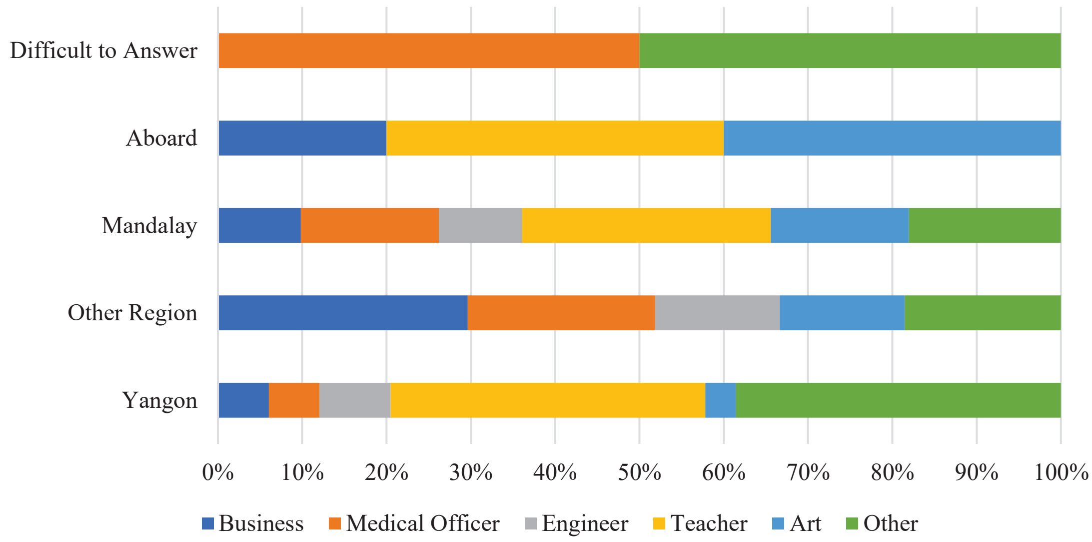
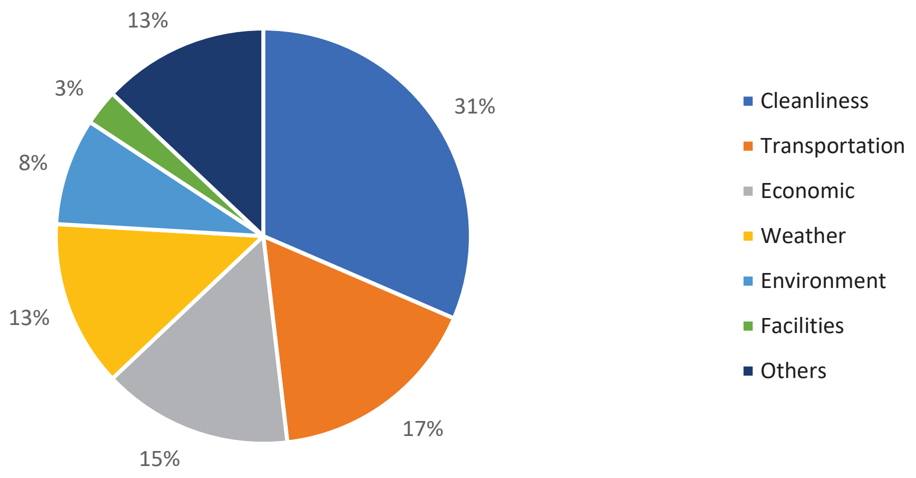


Figure A3: Direction of Migration depending on Educational Institutions

According to the Figure A3, 40% of students whose want to live in Yangon want to study educational programs, 8% of student want to study engineering, business, and medical study for 6% each, 4% of students want to study art and other remaining are for other studies such as language, law, etc.

Chart A3: Influence Factors for selecting the Desired Location



Among students who want to move to other region, 30% want to study the business, 22% want to study medical, 15% want to study engineering, 15% want to study art and 19% for other studies. For students who want to move to Mandalay, 20% want to study business and engineering (10% for each), 16% want to study medical, 30% want to study educational programs, 16 % want to study art and 18% for other studies. 20% of business, 40% for educational and 40% of art students want to move to aboard.

In here, we can observe that for educational programs, students choose only Yangon and Mandalay as a desired location. It is because, higher educational institutes are only located in main capitals cities of upper and lower Myanmar.

From Chart A3, we can observe the other influence factor for location choice apart from the higher education factor. The questions concerning respondents' motivation have revealed a set of reasons for potential migrants' intentions to move. In general, there is a wide range of views on this issue. The most popular factor that the respondents want is the cleanliness for choosing the location. Accessibility is the second choice and economic aspect as the third choice. This allows us to consider the students will move to the other location according to these special reasons.

A5. Conclusion

The study can state all three research questions. Over half of the respondence students want to migrate to the other regions of study area to continue their higher education. Educational institutions factor is the biggest influence factor on student migration decisions and most of the respondence students want to move to the capitals area as capitals have more sufficient accessibility and infrastructure for higher education and local regions are lack of these facilities. Therefore, students will distribute highly to the capitals (Yangon and Mandalay) for locational choice for higher education. From the outcomes, the better accessibility to the educational institutions from the local regions to capitals, economic development for the local regions are the must implications for providing rural inhabitants to education opportunities which should consider in future development plan.

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