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Subnational Population Projections for the Republic of Korea, 2013~2033

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Contents

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Introduction

- Korea consists 17 provinces and 226 sub-provinces. Once every five years, Statistics Korea conducts national and provincial population projections.
- As the local autonomy has been settled, the needs of sub-provincial population projections have increased.
- There was a tendency to overestimate future population growth that were produced by some local governments. Their predictions of the future population size in their area are more optimistic than their actual population growth. This overestimating tendency may result in not only cost overruns but also inefficient regional budget allocation.

Introduction (cont.)

- This paper describes the methods used for sub-provincial population projections and the framework of a web based sub-population projection program developed by Statistics Korea.
- To find the best method for sub-provincial population projection in Korea, we examines three methodologies (Hamilton-Perry's survival ratio, ratio method, and cohort component method) in terms of Goodness of Fitness (GOF) between observed sub-provincial data and projected data.
- To apply cohort component method for sub-provincial projections, we have to develop new methodologies for each population component to overcome the shortage of historical data.

Introduction (cont.)

- This study describes how the cohort component method is applied to the sub-provincial population projections despite of the large deviation in population size and the rapid population change at the sub-province level.
- Finally, this paper describes KOSTAT-SPP, which is the web-based computer sub-provincial population projection program developed by Statistics Korea based on cohort component method.

Overview of Sub-Regional Population Projection Methods

- Hamilton-Perry's survival ratio

  can be applied whenever population by age is available for more than two periods. But it has drawbacks upon regional application especially for those regions with a large yearly divergence associated with internal migration component.

- The method of proportions

  Since this method also does not consider the components of population change, it is limited in producing reliable long-term population projections.

Overview of Sub-Regional Population Projection Methods

- Cohort component method

  difficult for applying to small area population projections because of the requirement of the detailed population component data which is usually unavailable and unstable in many small areas.

- To apply cohort component method for sub-provincial projections despite of the insufficient data, we have to develop new methodologies for each component.

Population Size and Change of Sub-Provinces in Korea

- The difficulty of making reliable sub-provincial projections in Korea attributes to two reasons: large regional variation in population size and rapid population change caused by internal migration.

<Table 1> Regional Variation in Population Size for Sub-Provinces, 2005~2010

Population size (thousands)	2005 (A)		2010 (B)		Difference (C=B-A)	
	numbers	proportion	numbers	proportion	Numbers	proportion
less than 30	16	7.0	20	8.7	4	1.7
30 - 50	34	14.8	35	15.2	1	0.4
50 - 100	47	20.4	44	19.1	-3	-1.3
100 - 200	41	17.8	37	16.1	-4	-1.7
200 - 300	31	13.5	31	13.5	0	0.0
over 300	61	26.5	63	27.4	2	0.9

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Population Size and Change of Sub-Provinces in Korea

- The difficulty of making reliable sub-provincial projections in Korea attributes to two reasons: regional variation in population size and high geographic mobility.

<Table 2> Population Changes of Sub-Provinces, 2005-2010

Population change(2005~2010) in Korea at sub-provincial level					
	Numbers	Proportion		Accumulated numbers	Accumulated proportion
Less than 3%	60	26.1	Total	230	100.0
3%-5%	47	20.4	Over 3%	170	73.9
5%-10%	72	31.3	Over 5%	123	53.5
10%-20%	37	16.1	Over 10%	51	22.2
20%-30%	9	3.9	Over 20%	14	6.1
Over 30%	5	2.2	Over 30%	5	2.2

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Method: Fertility Projection

- Trend: the gaps of fertility between a province and each sub-province are consistent over time even though fertility rates have decreased for most sub-provinces.
- We project age-specific fertility rates (ASFR) using linear regression models based on the recent relationship between a province and its sub-provinces (Brass, 1979).

Linear regression model for estimating fertility

The model for fertility projections of sub-province is as follows.

$$f_{x,i} = \alpha_i + \beta_i * f_{x,k}$$

α : intercept of regression model between the k province and the i sub-province

β : slope of regression model between the k province and the i sub-province

$f_{x,i}$: ASFR of the i sub-province

$f_{x,k}$: ASFR of the k province

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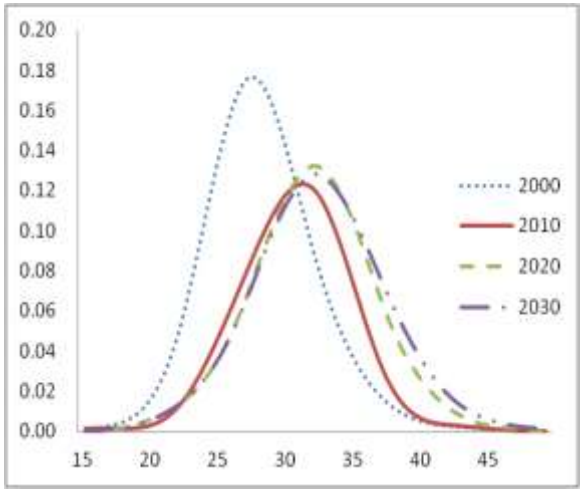
Results of fertility projection

<Table 3> Mean Absolute Percent Errors of Total Fertility Rates for Sub-Provinces, 2000~2012

Province	Average	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16
MAPE(%)	4.8	2.8	4.2	3.9	4.4	4.6	3.8	3.3	3.5	4.5	4.8	4.1	7.9	6.5	6.9	5.7	3.6

< Figure 1> Forecasted Age Specific Fertility Rates of Sub-Provinces, 2015~2030

P1



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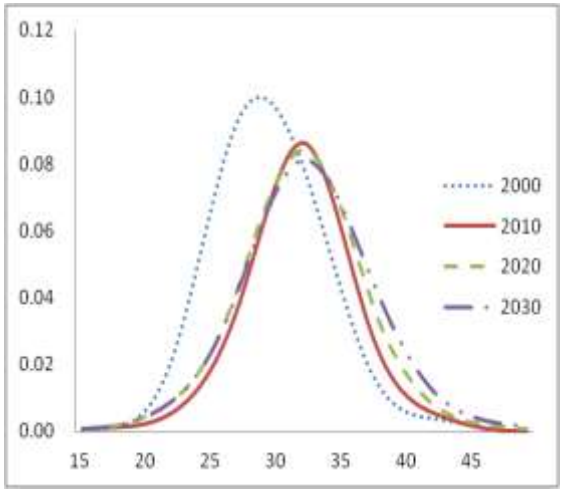

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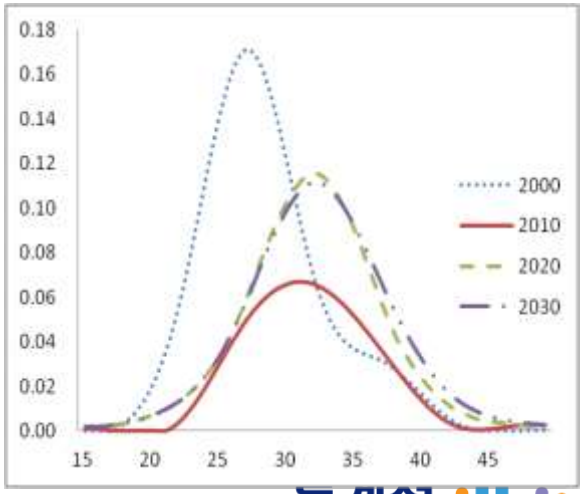

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Method: Mortality Projection

- Trend: mortality rates for each sub-province in Korea have decreased over time, but the gaps in mortality among sub-provinces have narrowed.
- We apply the Li-Lee model for mortality projections. This model is known to be useful for coherent group mortality forecasting by considering a region's common factors as well as each sub-region's specific residual factors of age specific mortality change (Li and Lee, 2005; Kim, 2011).

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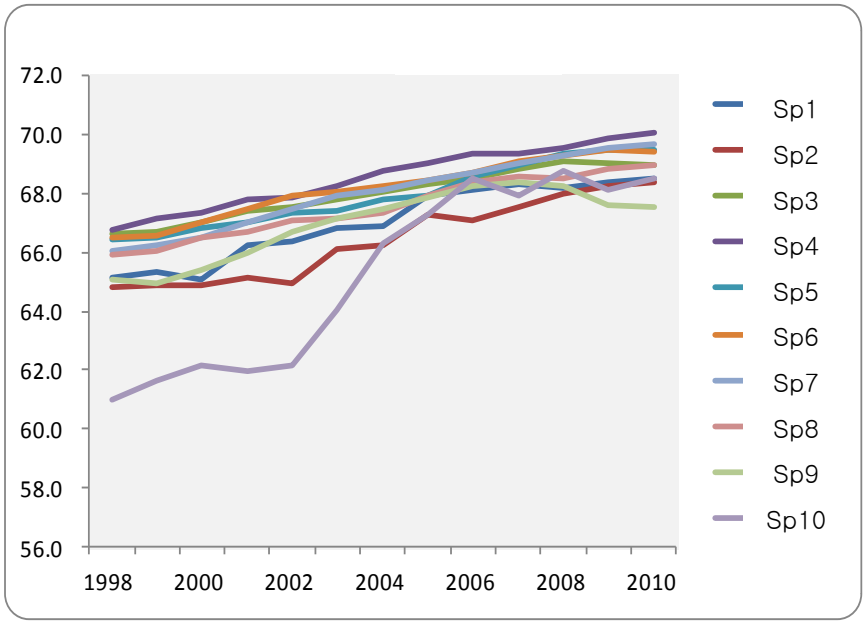
Sub-Provincial Mortality

- Trends: Increase in life expectancies for all sub-provinces
- Difference: Decrease in the gap of life expectancies among sub-provinces and between sexes

< Figure 2> Sub-Provincial Life Expectancies, 1998-2010

P1



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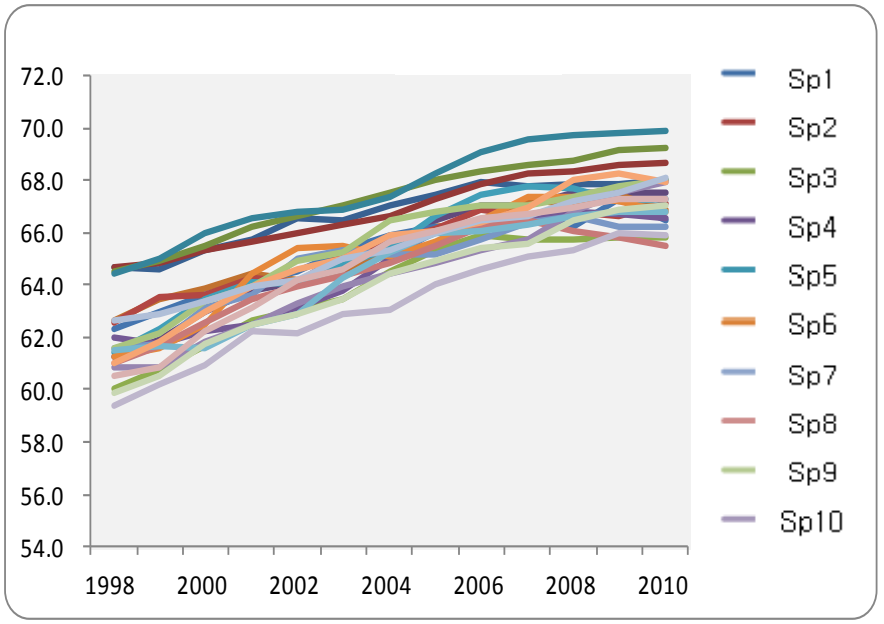

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Li-Lee model for estimating mortality

The model for mortality projections of sub-province is as follows.

$$\ln(m_{x,t,i}) = a_{x,i} + B_x * K_t + b_{x,i} * k_{t,i} + \varepsilon_{x,t,i}$$

$m_{x,t,i}$: death rates for sub-province i, year t, age x

$a_{x,i}$: age pattern of mortality for sub-province i, age x

B_x, K_t : common factors for a province (age pattern of mortality change and time varying index of the level of mortality)

$b_{x,i}, k_{t,i}$: specific factors for each sub-province (age pattern of mortality change and time varying index of the level of mortality)

$\varepsilon_{x,t,i}$: errors for sub-province i, year t, age x

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Method: Mortality Projection

- To project death rates of sub-provinces for the period of 2013 -2033, we had to perform several advanced processes including interpolation, adjusting, and old age death rates extension (Lee et al., 2013).

	1) Interpolation[1)]	1) Adjusting	3) Old age death rates extension(80+ →100+)[2)]	4) Forecasting
Data	The number of deaths for provinces and sub-provinces for the period of 2000~2012 (5 year age, age 0-79) Mid-year population	Death rates of sub-provinces for the period of 2000~2012 (single age, age 0-79)	Death rates by sub-province for the period of 2000~2012 (age 65~75)	Death rates by sub-province for the period of 2013~2033 (single age, age 0-100+)
Models	Spline interpolation	Brass-Logit Model	2 Parameters Logistic	Li-Lee model

1) Three year's moving average, extending death rates from five year age interval to one year age interval
2) In the old age death rate, the death rate of the oldest age group reflects an aggregate of the death rates of any age group overflowed above the limit. To overcome this limit and to get more accurate mortality forecasting including old age death rates, we extended the age boundary of the old age death rates from age 80 to age 100.

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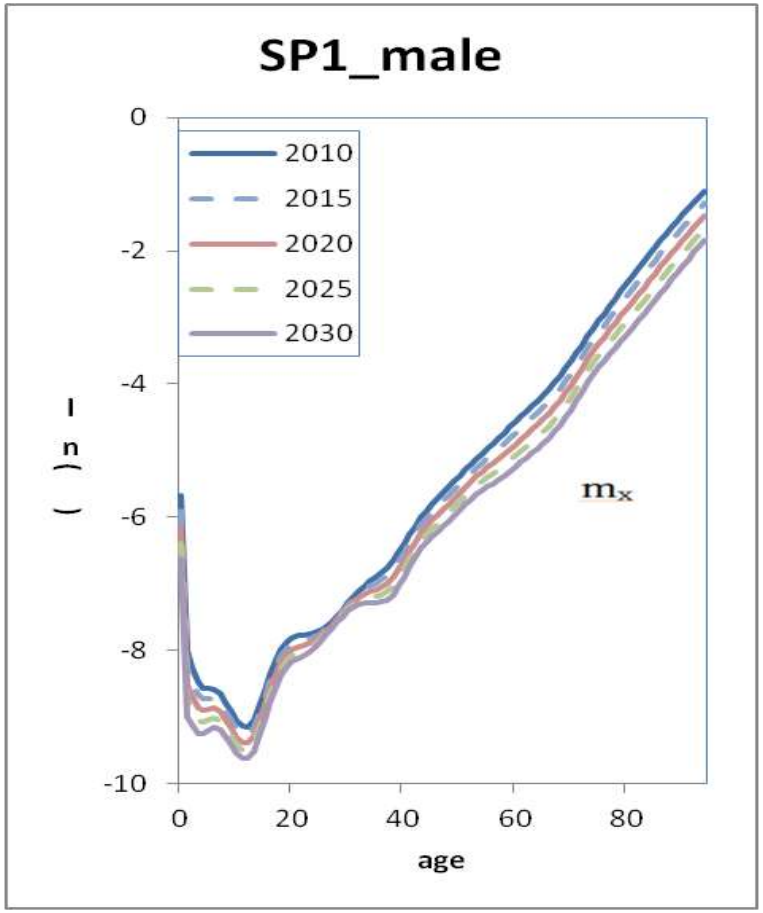
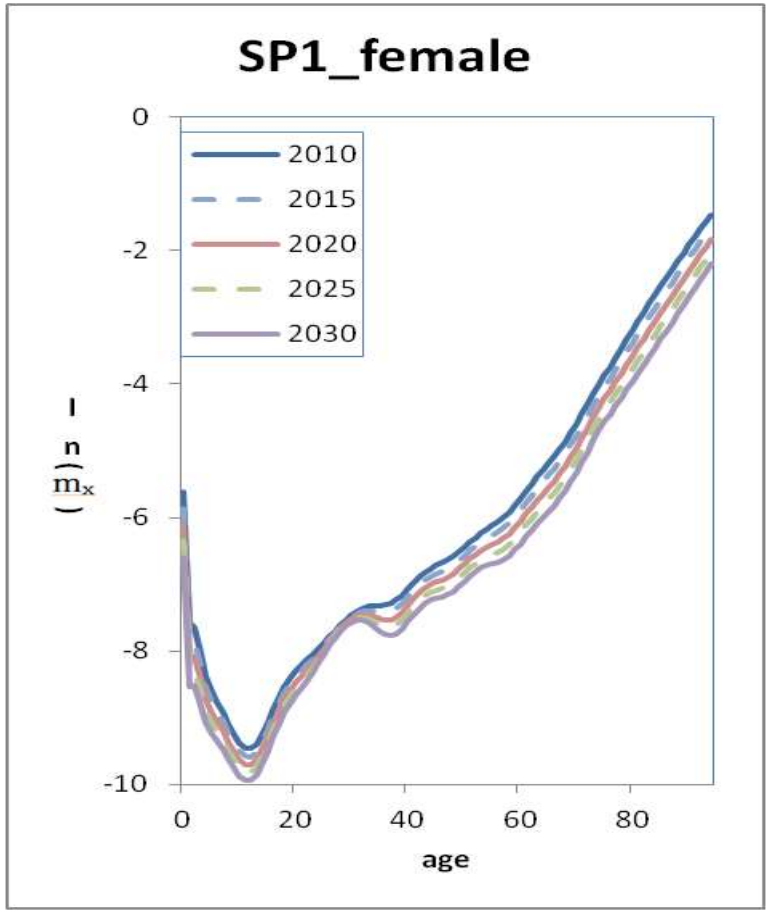
<Figure 3> Sub-Provincial Log-Death Rates, 2010~2030





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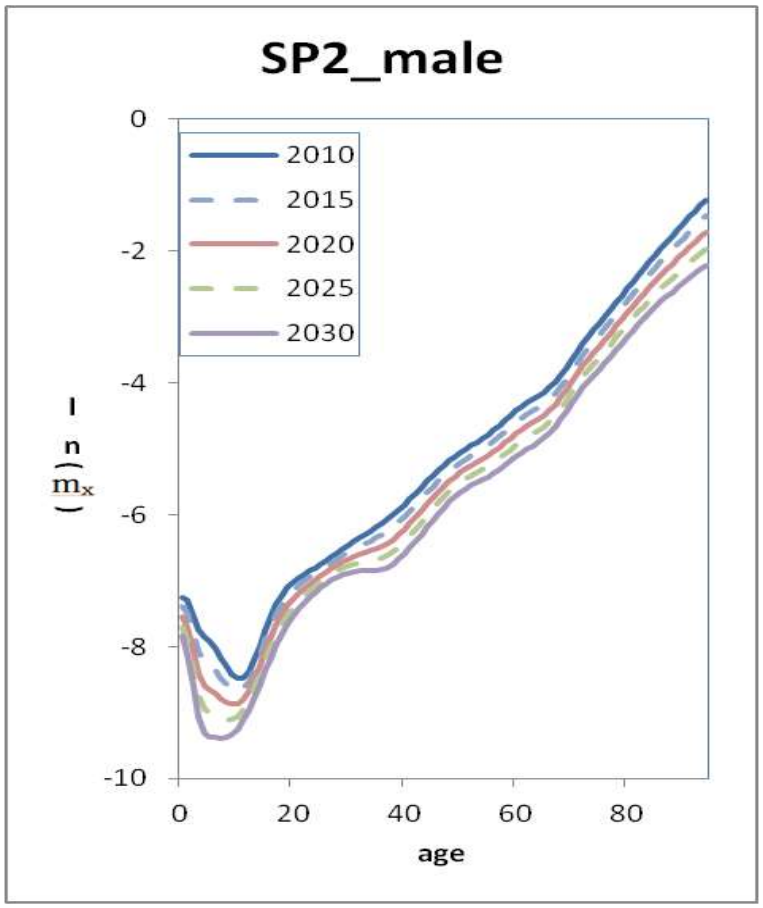
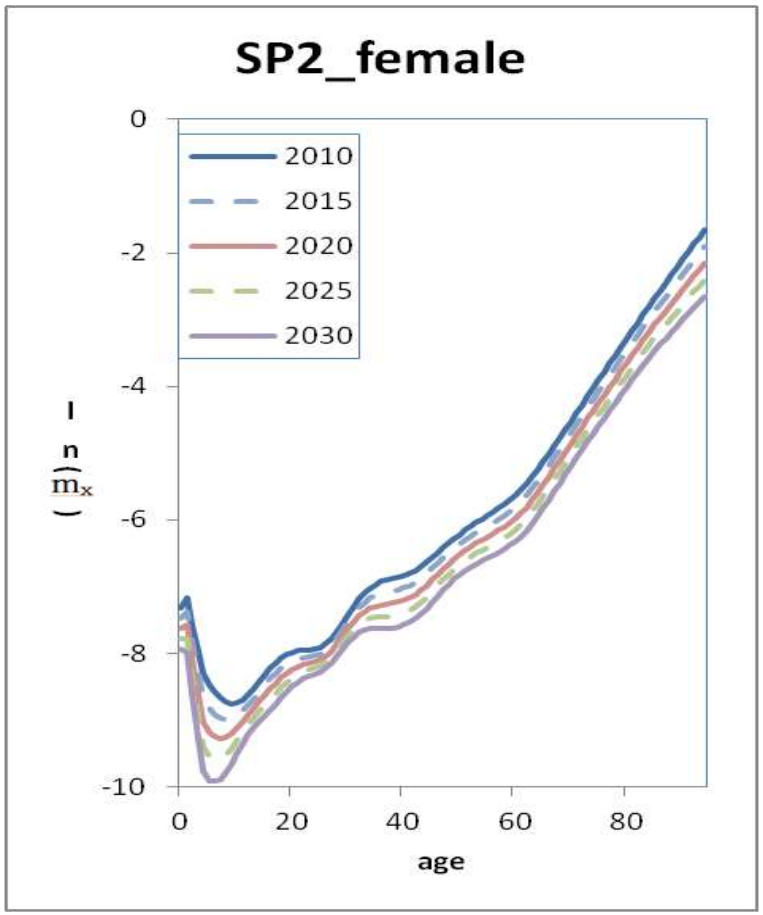
<Figure 3> Sub-Provincial Log-Death Rates, 2010~2030





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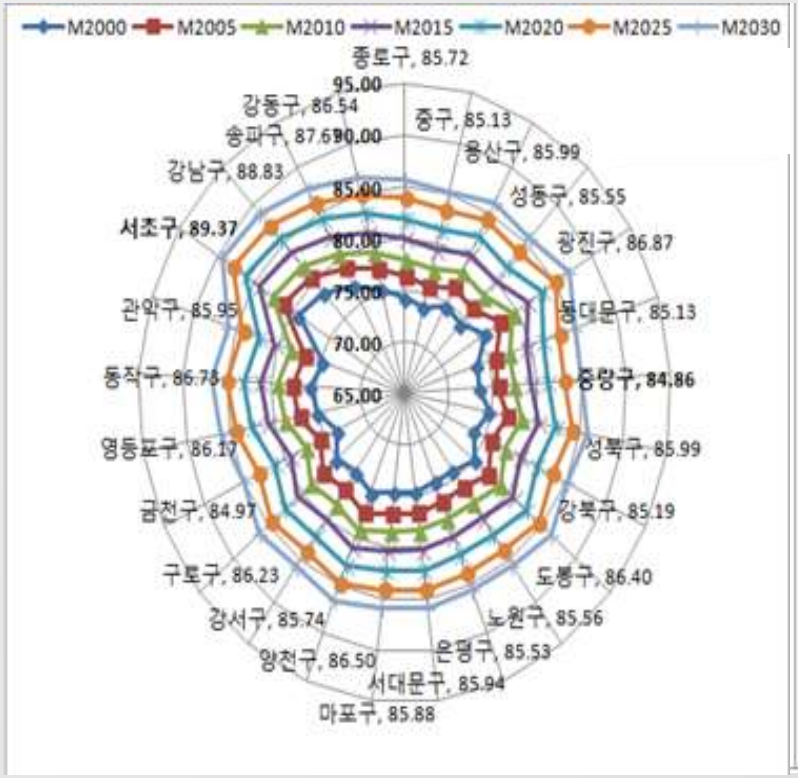
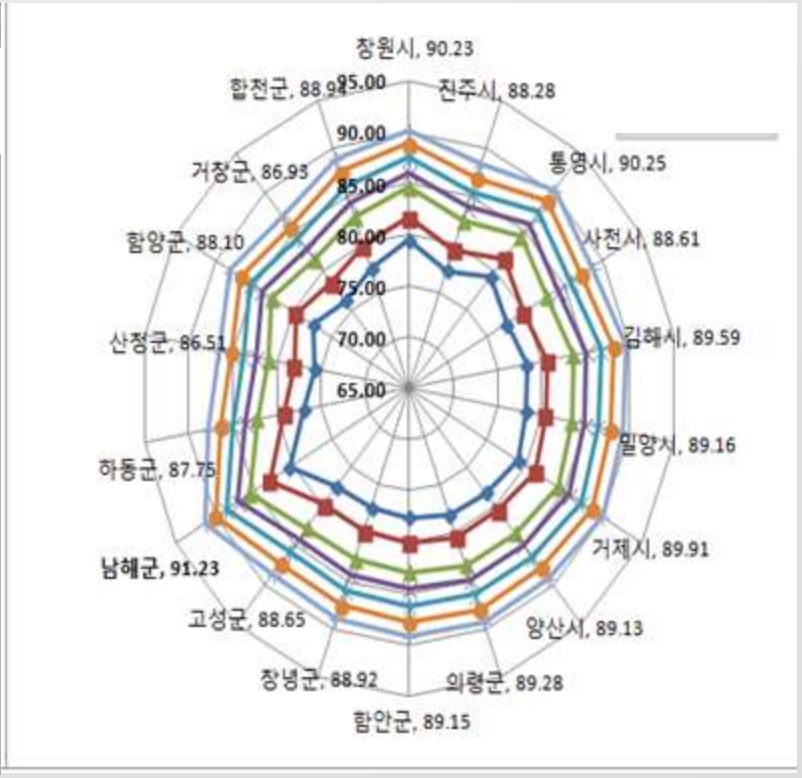
< Figure 4> Sub-provincial life expectancies, 2000~2030

<P1, Male>



<P2, Female>



< Table 4> Mean Absolute Percent Errors of life expectancies between province and sub-provinces, 2000~2030

	Males				Females			
year	2000	2010	2020	2030	2000	2010	2020	2030
P1	1.38	1.17	1.50	3.25	0.81	0.68	1.32	2.67
P2	1.21	1.12	1.00	1.69	0.94	1.06	0.89	1.84
P3	1.54	1.46	1.19	1.89	1.02	0.96	1.84	2.80
P4	1.13	0.96	1.00	0.83	1.57	1.37	1.62	1.40
P5	0.80	0.65	0.76	1.24	1.26	0.53	1.36	2.14
P6	1.74	1.64	2.02	4.28	0.54	0.46	2.40	4.40
P7	0.85	0.74	0.64	0.67	0.72	0.59	0.36	0.47
P8	1.90	1.59	1.30	1.96	1.11	1.09	0.86	1.49
P9	1.56	1.52	1.52	1.14	1.06	0.98	1.05	1.23
P10	1.62	1.01	1.07	1.08	0.90	1.32	0.88	1.08
P11	1.53	1.35	1.03	2.12	0.86	1.22	0.98	2.20
P12	1.39	1.45	1.04	1.80	0.94	0.89	1.44	2.36
P13	1.68	1.09	0.79	1.86	1.01	0.90	0.93	1.61
P14	1.40	1.19	0.98	1.13	1.08	1.15	1.13	1.36
P15	2.05	1.72	1.19	1.30	1.45	1.28	1.03	1.83
P16	5.58	3.66	2.46	3.03	3.25	2.93	3.56	3.71

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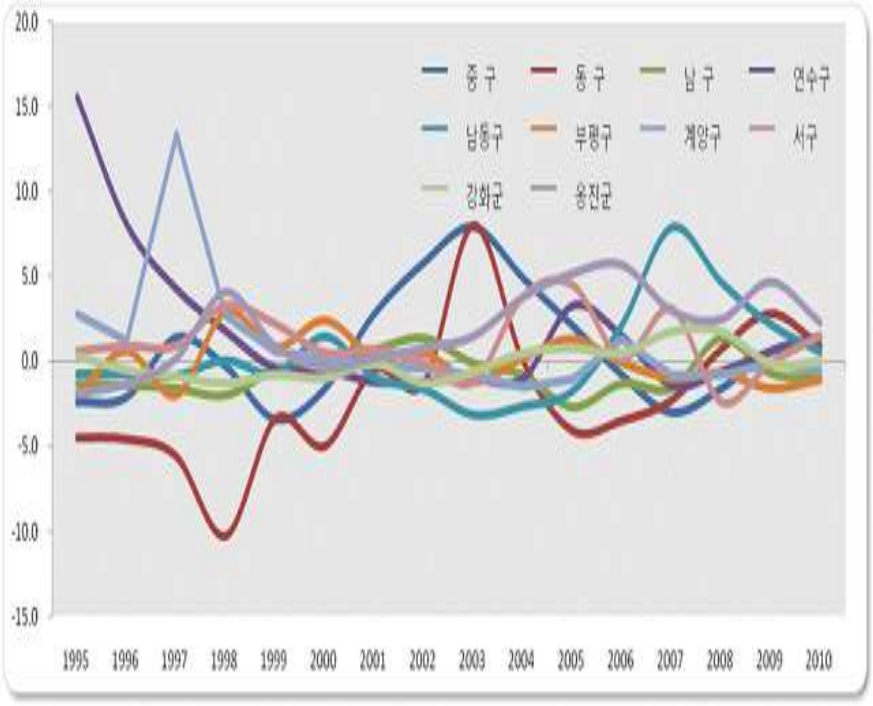
Method: Migration Projection

- In 2015, 10 out of 100 Koreans moved to different sub-provinces during the year.
- A multi-regional model based on Origin-Destination migration matrix is used (Feeney, 1973). It considers not only the size of migration but also the direction of migration.
- The matrix for provincial projections is composed of 17 origin-province by 17 destination-provinces for both sexes and ages from 0 to 100 and over.

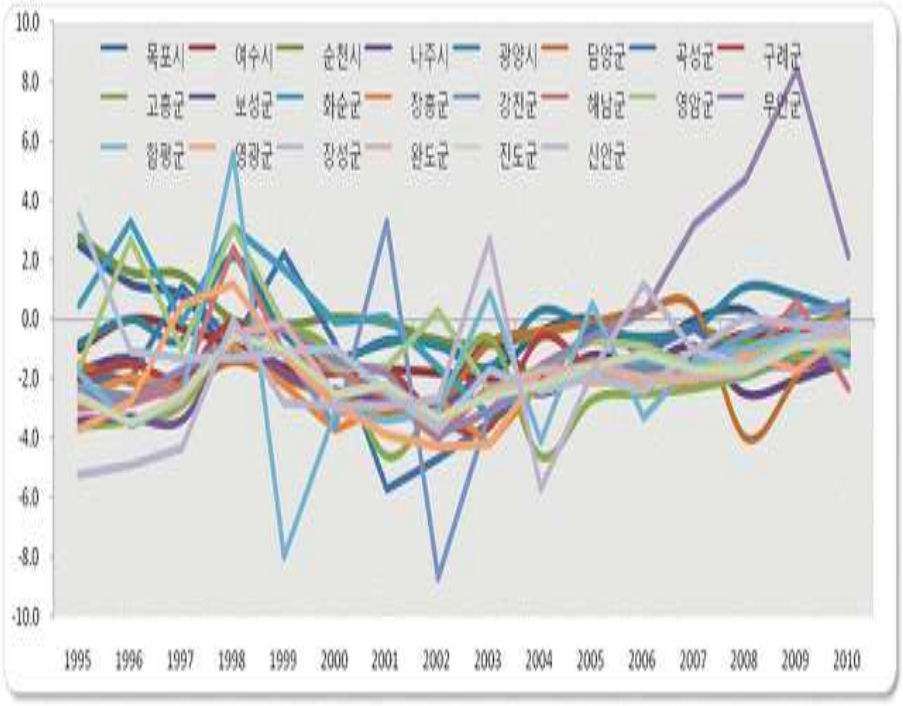
< Figure 5> Sub-Provincial Migration Rates, 1995~2010

- Trends: decrease in inter-migration rates among sub-provinces

[Net-Migration Rates for P1, 1995~2010]



[Net-Migration Rates for P2, 1995~2010]



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The Origin-Destination metrics

- To solve the problem of having too many data arrays constructing the Origin-Destination metrics, the dimension of matrix has been reduced: 1) migration of a sub-province to other sub-provinces within the province and 2)the total migration to all sub-provinces in other provinces.

$$NM_i = (InM_{Intra\,i} + InM_{Inter\,i}) - (OutMI_{Intra\,i} + OutM_{Iter\,i})$$

: net-migration of sub-province i, i=sub-provinces, 1,2,…, J-1, J=otherwise

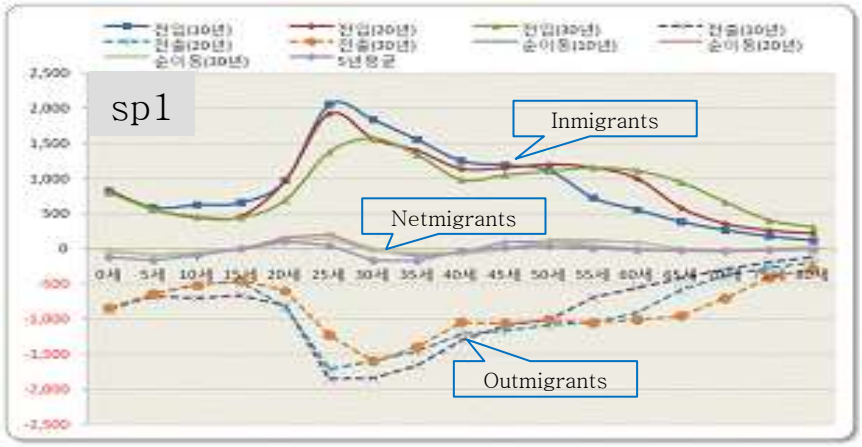
: intra-province inmigration of sub-province i,

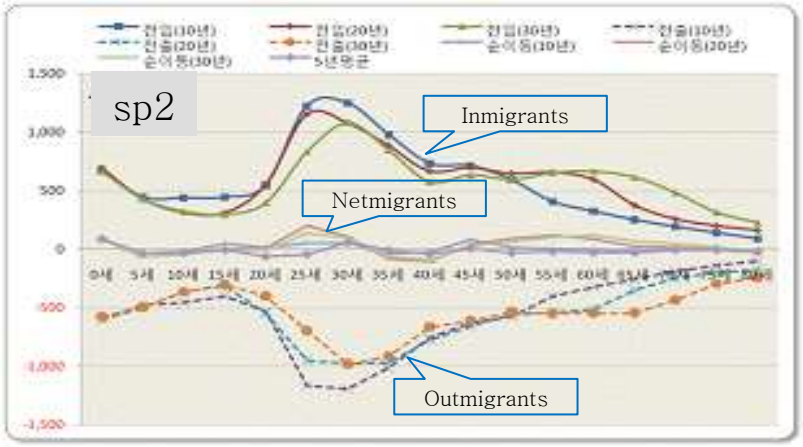
: inter-province inmigration of sub-province i,

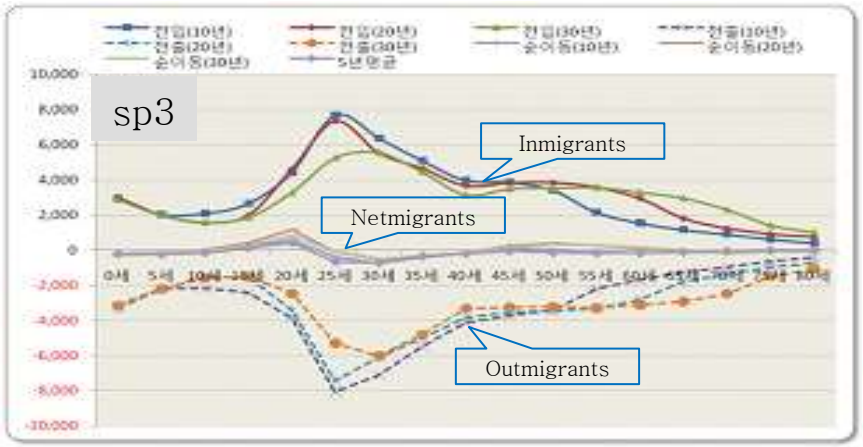
: intra-province outmigration of sub-province i,

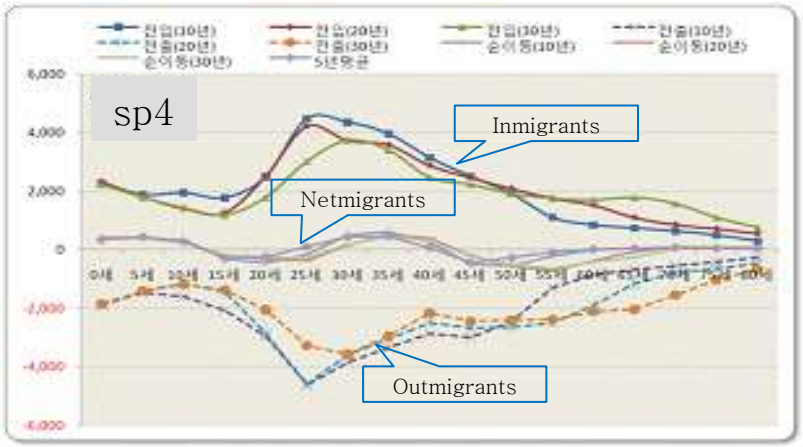
: inter-province outmigration of sub-province i, (J)

< Figure 6> Sub-Provincial Net Migration, 2010~2030









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Method: Migration Projection

- In Korea, regional development programs such as city planning or civil construction evolve dynamically, having a great influence on population growth. To improve the validness of this projections, especially in short term, our framework includes an option of reflecting region's development planning, either confirmed or in progress, to migration projections by using controlling weights.

Small Area Population Projection Program (KOSTAT-SPP)

- To provide tools for local governments to independently conduct population projections for their sub-provinces, Statistics Korea developed a web-based program for sub-provincial population projections
- KOSTAT-SPP is a turn-key solution program, which consists of five modules: data downloading, projecting cohort components, uploading projected data, compiling, and result and visualization.

<table>
<tr><td>Observed Data</td><td>Components Projection</td><td colspan="3">Results from Cohort Component Method (consistency)</td></tr>
<tr><td>Fertility rates
Death Rates
Migration Rates</td><td>Fertility Rate
Death Rate
Migration Rate</td><td>Base Population</td><td>Births
Deaths
Migrants</td><td>Projected Population</td></tr>
<tr><td>KOSIS (Statistics Korea Data Base Portal Site)</td><td>R program (Standardized and regionally customized)</td><td colspan="3">Web-Based Program(KOSTAT-SPP)</td></tr>
</table>

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Small Area Population Projection Program (KOSTAT-SPP)

- In data downloading, births, deaths, and migration data can be downloaded from Statistics Korea Data Base web portal (KOSIS).
- The module of projecting cohort components has a function of components projection of fertility, mortality and migration in a regionally customized program with free statistical package R
- In a module of uploading, one can upload projected fertility, mortality, and migration.
- Through a module of compiling, projected fertility, mortality, migration, and base population data are combined for predicting future population by age and sex.

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Small Area Population Projection Program (KOSTAT-SPP)

- In a module of result and visualization, tables and visual charts are generated. Finally, these sub-provincial projection results are controlled to national and provincial level of population projection results.
- The sum of projected births, deaths, and migration for sub-provinces are adjusted to those of the provincial projections results by sex and age.
- Then, the sum of population by sex and age for sub-provinces are regulated to those of the province, for keeping internal consistency with national and provincial population projections.

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<Table 6>. Program Menu of KOSTAT-SPP

Data Uploading	Projecting Cohort Components	Projection Results	Notice
Base Population	Internal Migration Weight	Population by Sex and Age	Information
Sex Ratio at Birth	Demographic Balance Equation	Births, Deaths, Migrants	Q & A
Age-Specific Fertility Rate		Demographic Indicators	
Age Specific Survival Probability			
Origin-Destination Migration Matrix			

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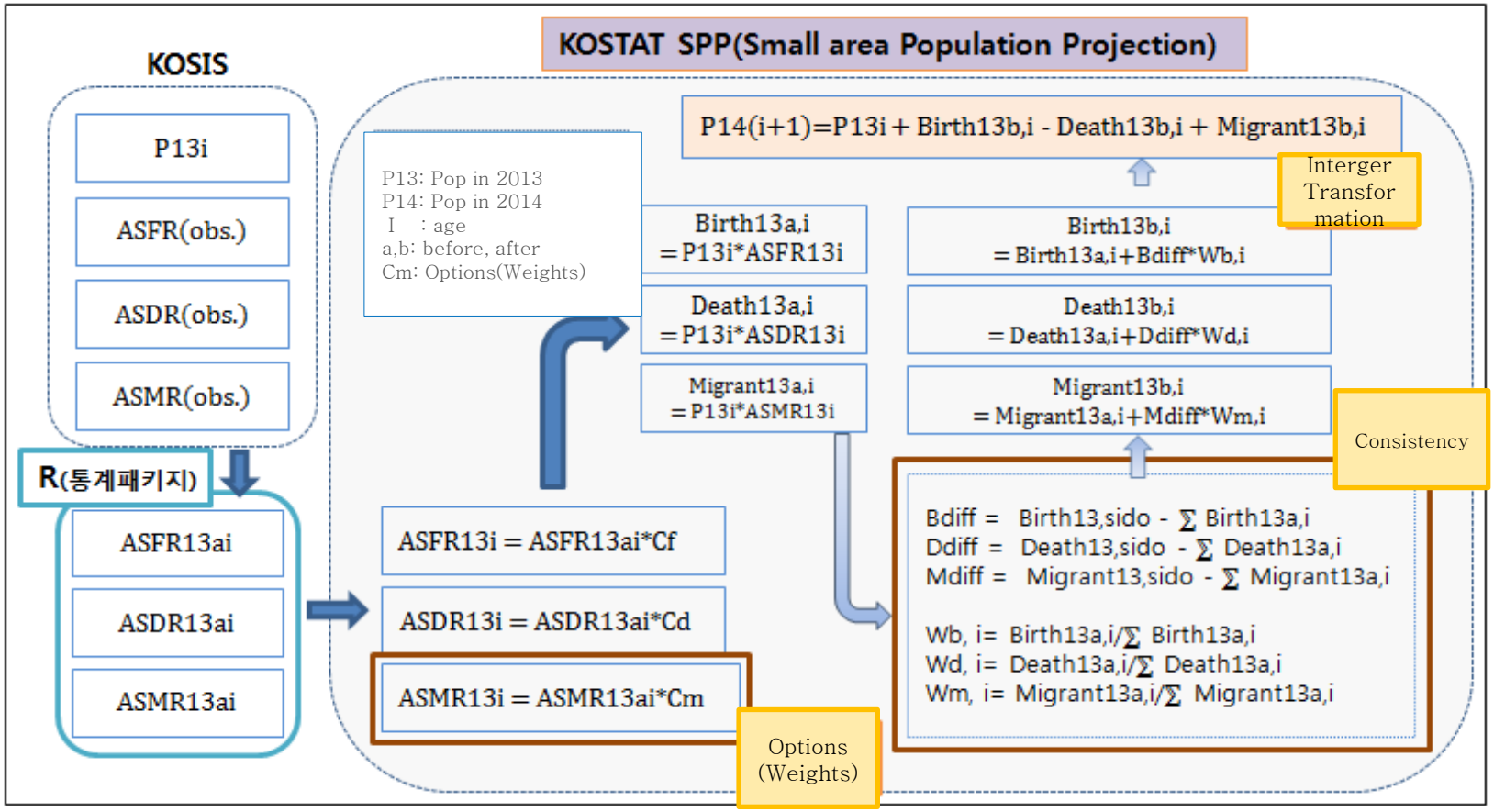
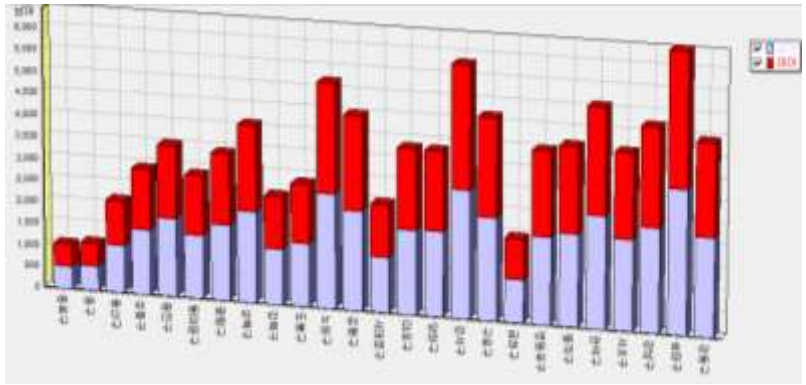
<Figure 7> KOSTAT-Small area Population Projection Program(KOSTAT-SPP)

◇ Process of KOSTAT-SPP

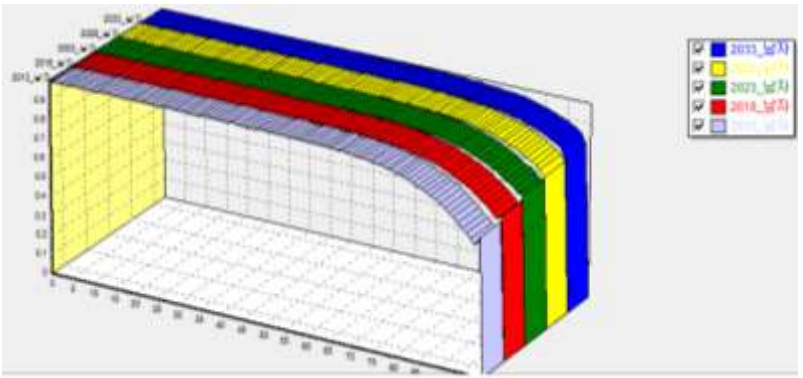


<Figure 8> Charts from KOSTAT-SPP

<Births>

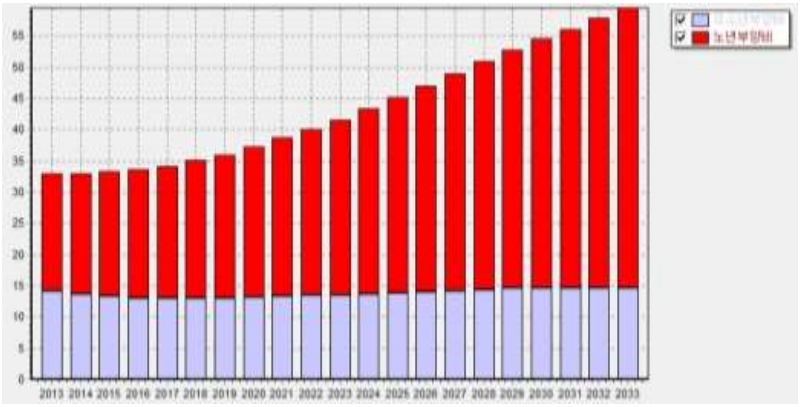


<Probability of Survival>



<Population Pyramids>

<Dependency Ratios>



Conclusion

- Statistics Korea recently developed a population projection framework for 226 sub-provinces.
- It incorporates components projection methodologies and a web-based projection program, and comes with a user's manual.
- In this project, we found that cohort component method is available for small area population projection with large deviations of population size and rapid population changes, with the help of data adjusting techniques.
- We expect this systematic framework for sub-provincial population projection could facilitate evidence based policy administration by providing reliable forecast of regional population

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