

Forecasting the age structure of the scientific workforce in Australia

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Ideal labour force model

$$P_{x+1,t+1} = P_{x,t} - D_{x,t} - R_{x,t} + G_{x,t} - C_{x,t} + N_{x,t}$$

x = Age
 t = Year

$P_{x,t}$ = number of equivalent full-time workers

$D_{x,t}$ = number of deaths

$R_{x,t}$ = number of retirements

$G_{x,t}$ = number of graduates who work in science

$C_{x,t}$ = net number of people who have a career change

$N_{x,t}$ = net number of migrants

Pragmatic labour force model

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

x = Age

t = Year

$P_{x,t}$ = number of equivalent full-time workers

$q_{x,t}$ = probability of death

r_x = probability of retirement

g_x = proportion of graduates by age

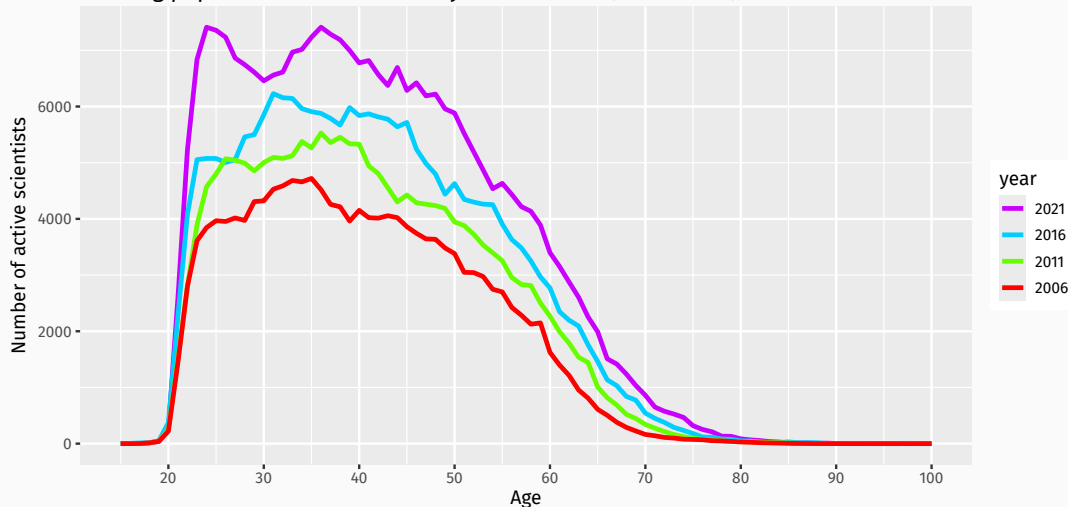
G_t = total number of graduates in science

$E_{x,t}$ = remainder

Working population: $P_{x,t}$

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

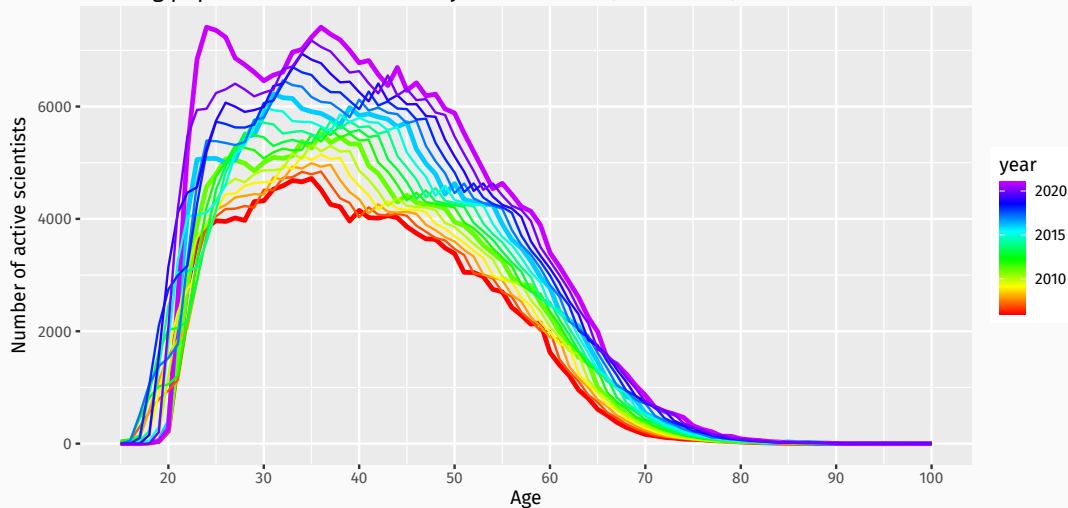
Working population: Natural and Physical Sciences (2006 - 2021)



Working population: $P_{x,t}$

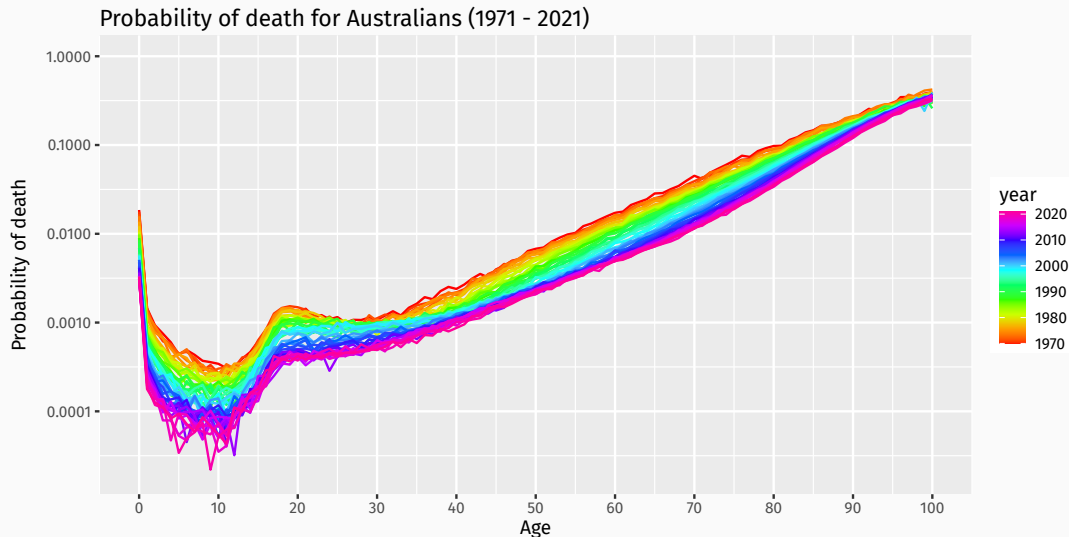
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Working population: Natural and Physical Sciences (2006 - 2021)



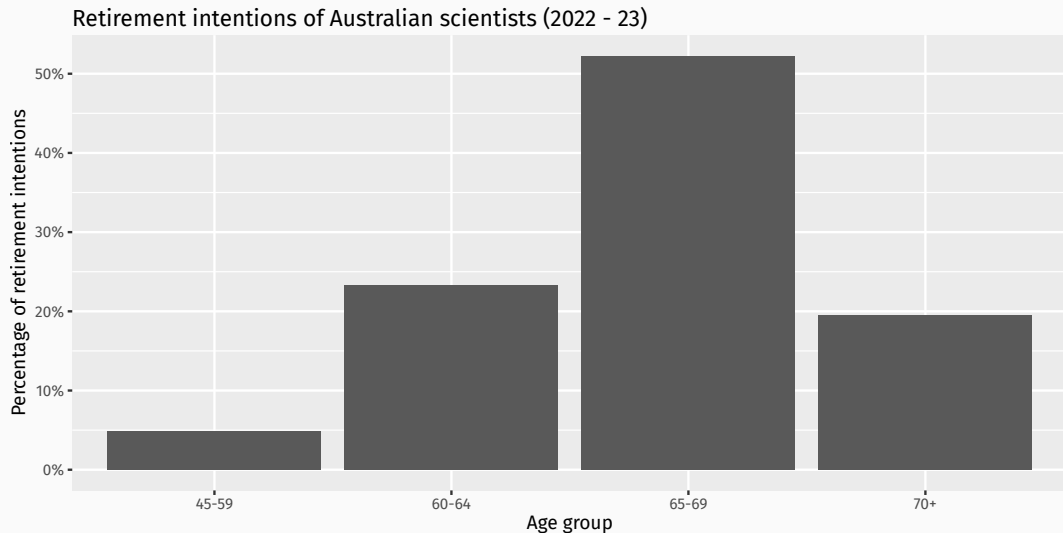
Death probability: $q_{x,t}$

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$



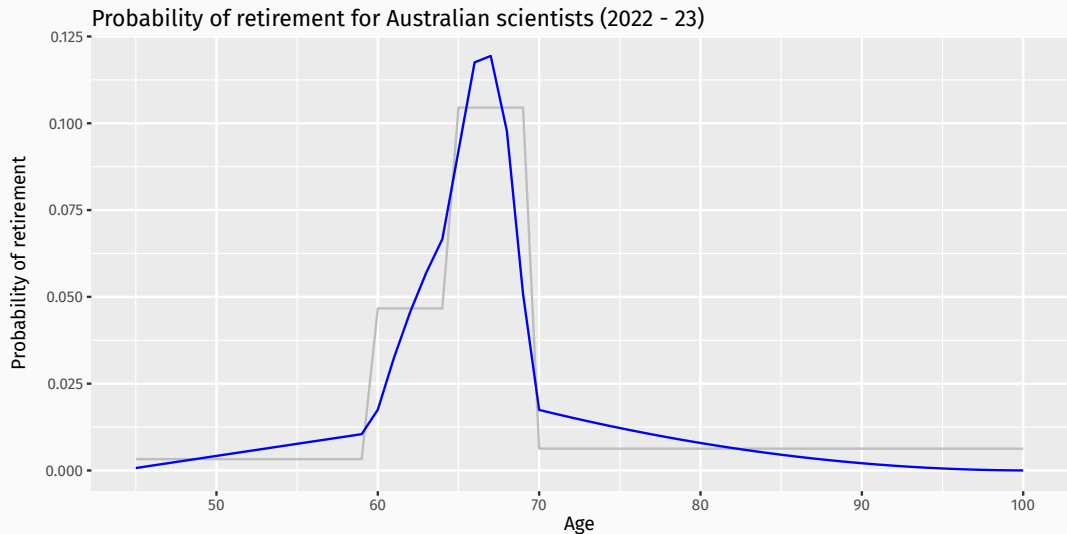
Retirement rates: r_x

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$



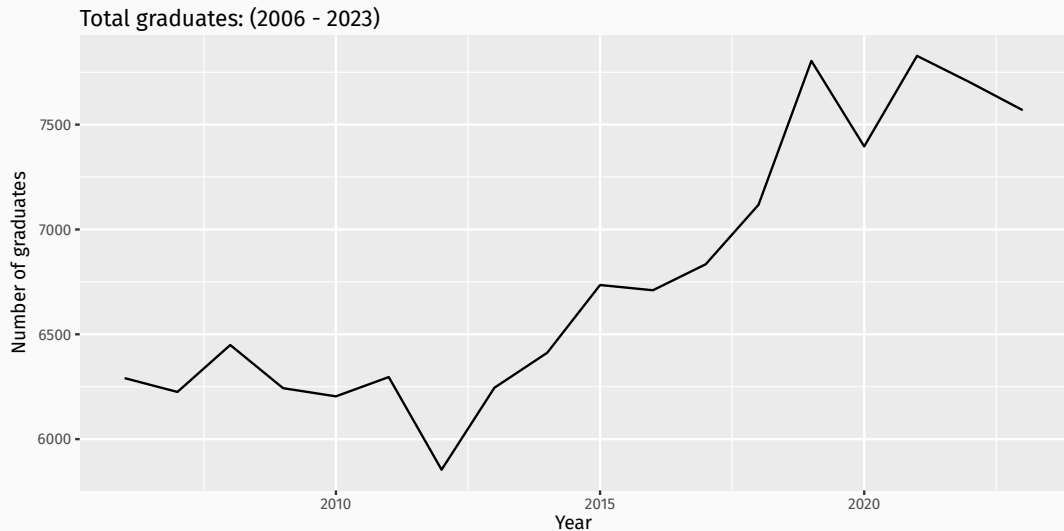
Retirement rates: r_x

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Graduate completions: G_t

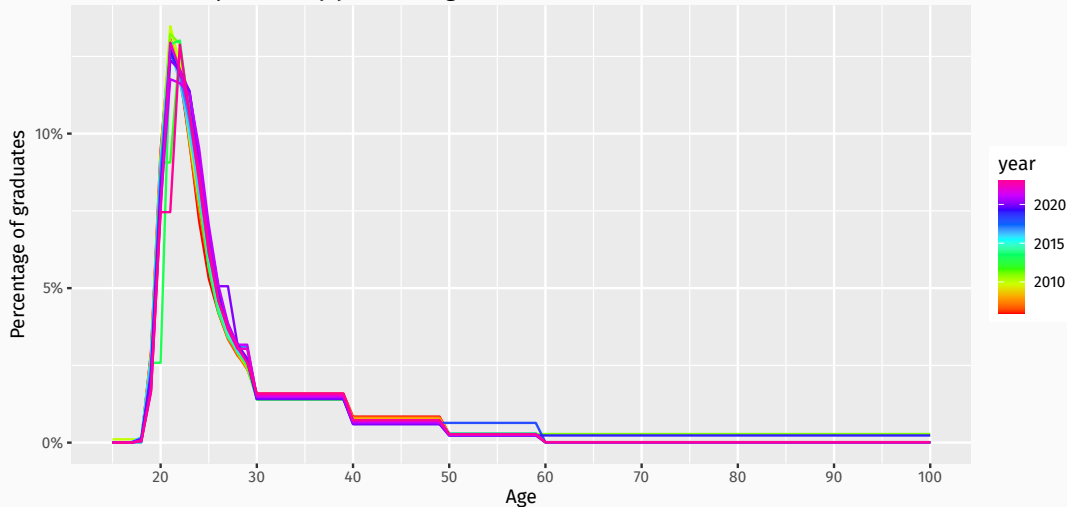
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Graduate completions: g_x

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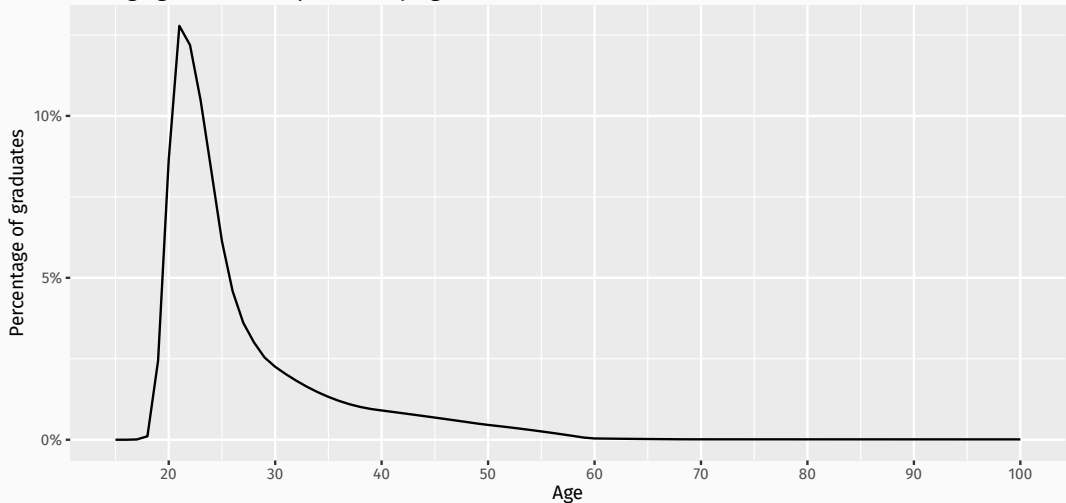
Graduate completions by year and age (2006 - 2023)



Graduate completions: g_x

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

Average graduate completions by age (2006 - 2023)



Remainder: $E_{x,t}$

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

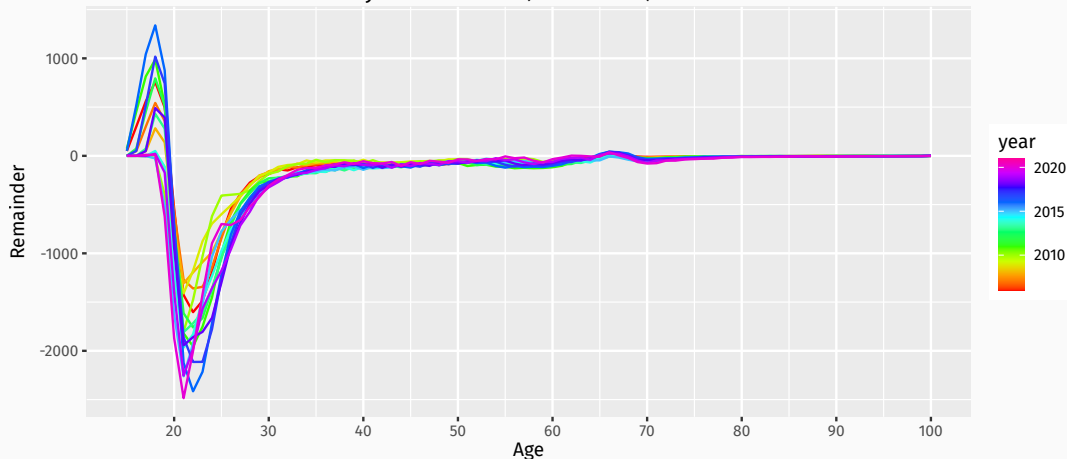
$$E_{x,t} = P_{x+1,t+1} - P_{x,t}(1 - q_{x,t} - r_x) - g_x G_t$$

Remainder: $E_{x,t}$

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Remainder: Natural and Physical Sciences (2006 - 2021)



$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

- G_t ARIMA model of total graduates by year
- $q_{x,t}$ functional time series model
- $E_{x,t}$ functional time series model

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

G_t ARIMA model of total graduates by year

$q_{x,t}$ functional time series model

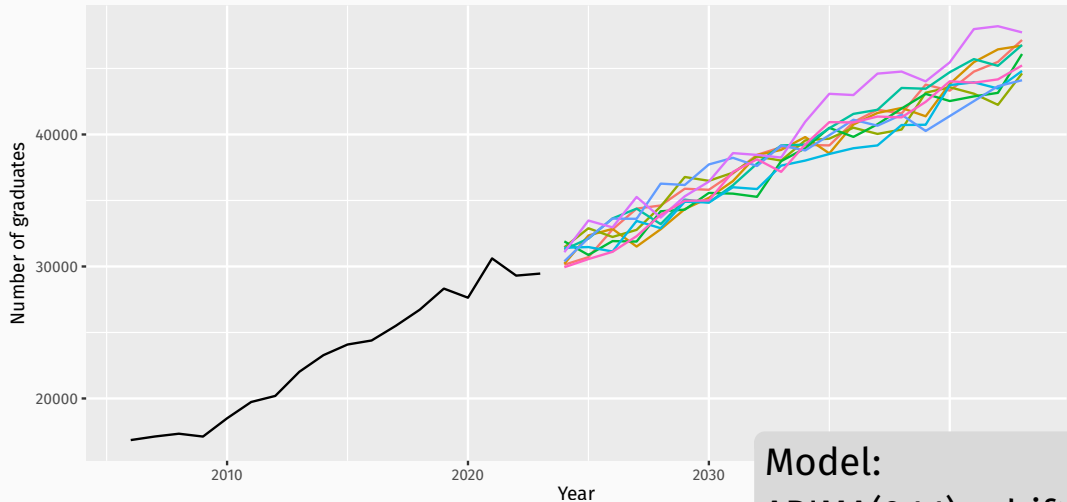
$E_{x,t}$ functional time series model

- Future sample paths of all components simulated to obtain probabilistic forecasts of $P_{x,t}$

Forecasting models: G_t

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

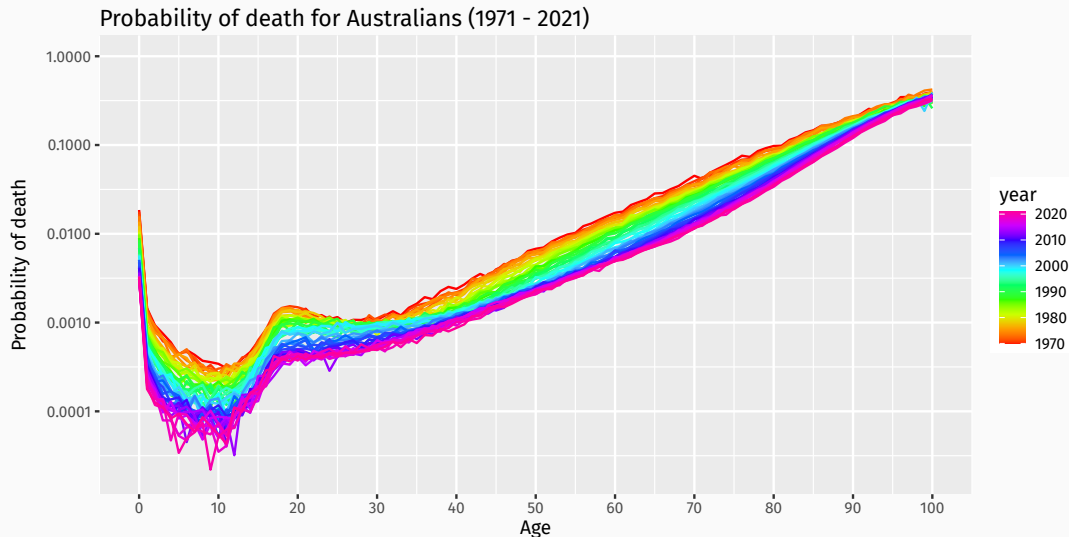
Total Science Graduates: Australia



Model:
ARIMA(0,1,1) + drift

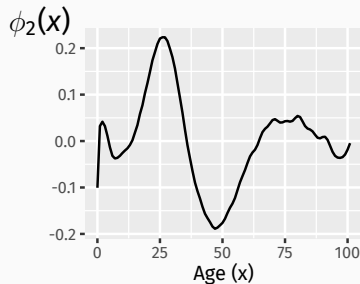
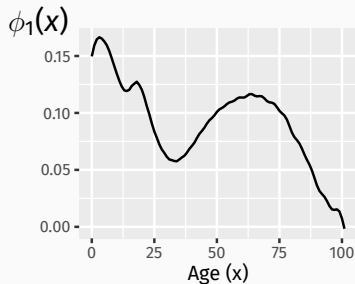
Forecasting models: $q_{x,t}$

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$



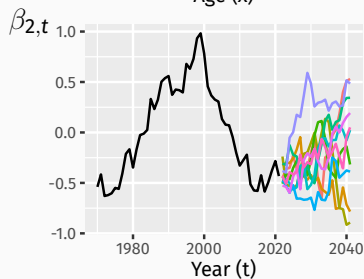
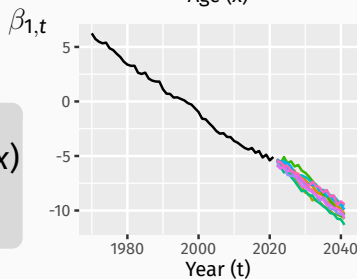
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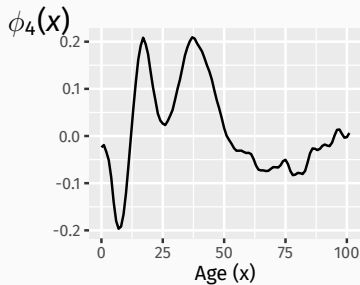
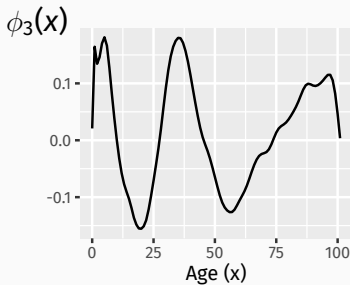
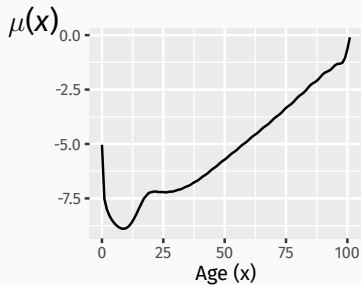
$$q_{x,t} = \mu(x) + \sum_{k=1}^6 \beta_{k,t} \phi_k(x) + \varepsilon_t(x)$$

$\beta_{k,t} \sim \text{ARIMA}$



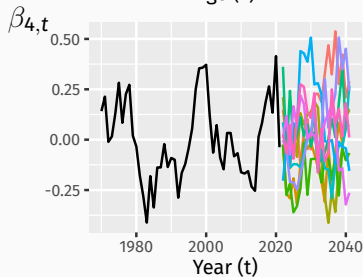
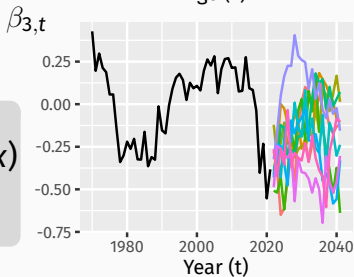
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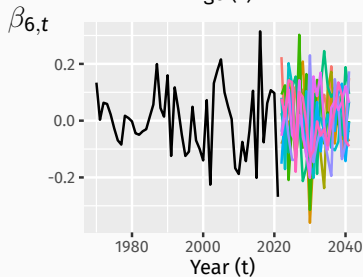
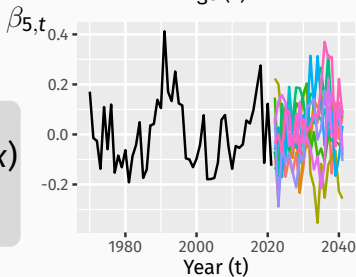
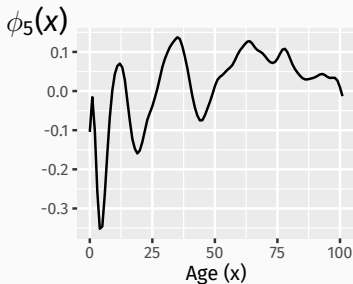
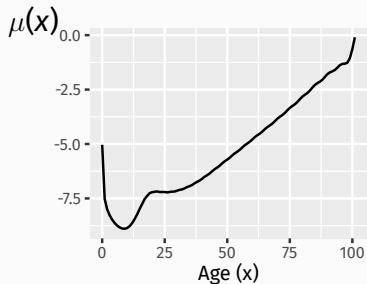
$$q_{x,t} = \mu(x) + \sum_{k=1}^6 \beta_{k,t} \phi_k(x) + \varepsilon_t(x)$$

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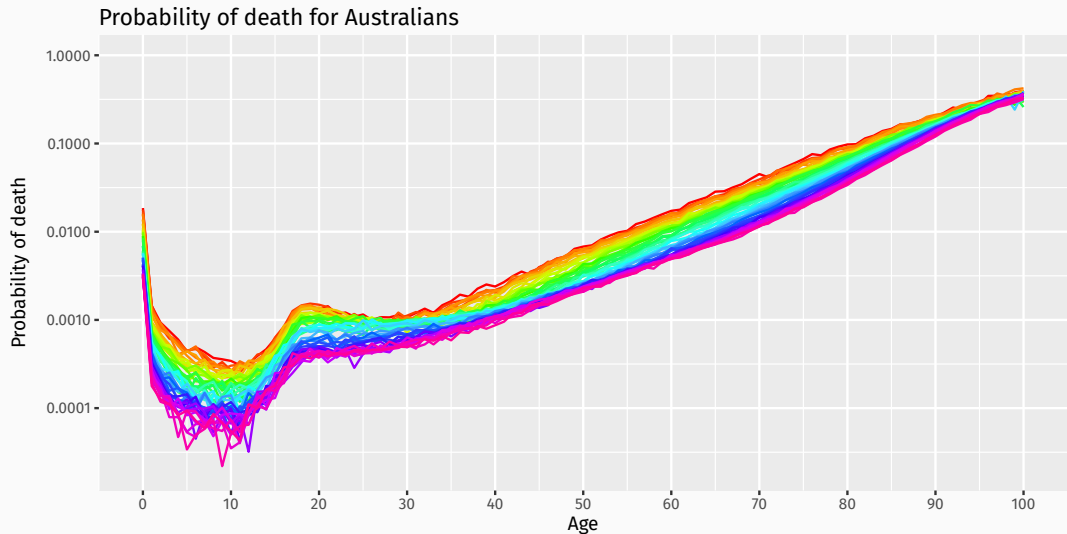


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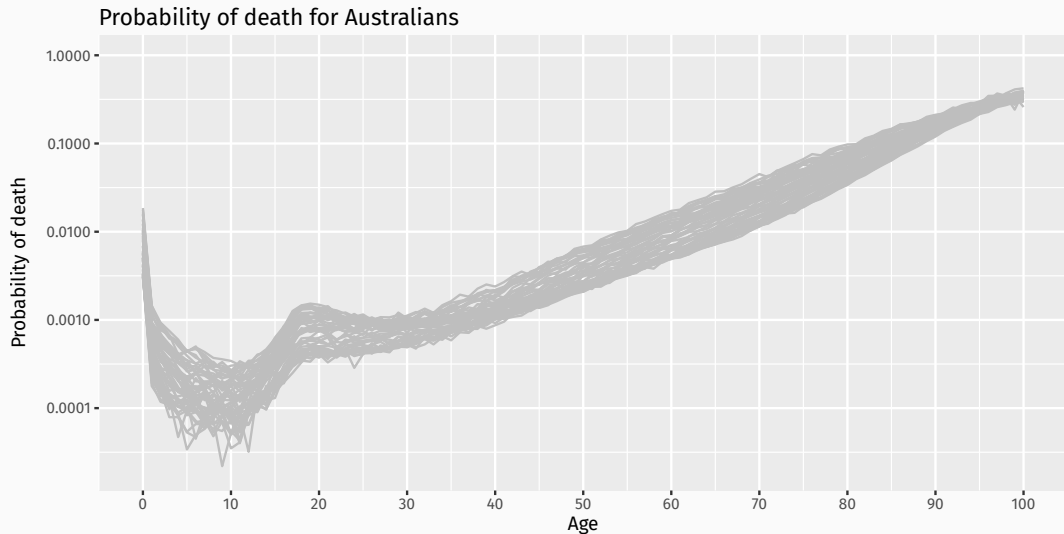
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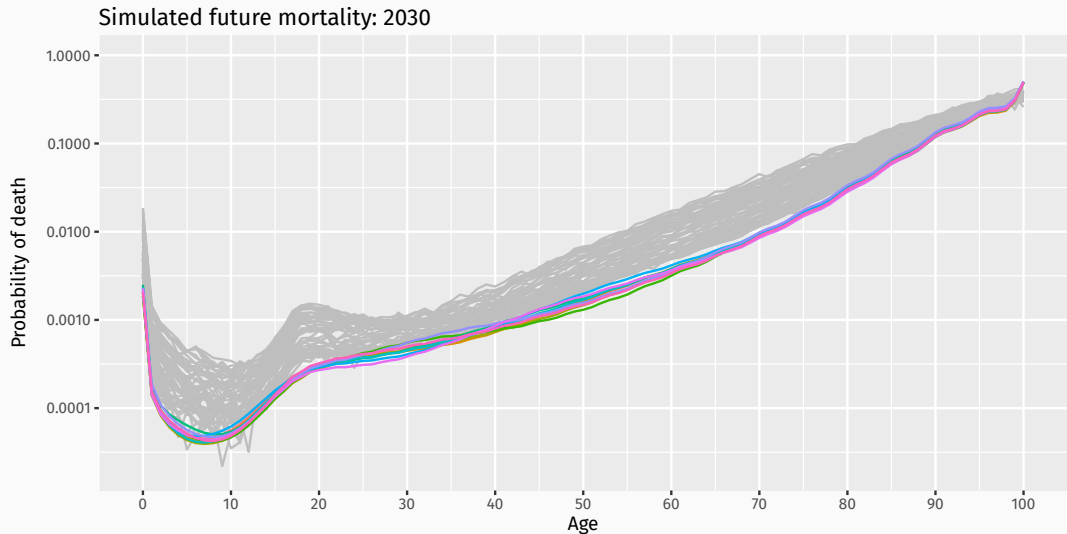
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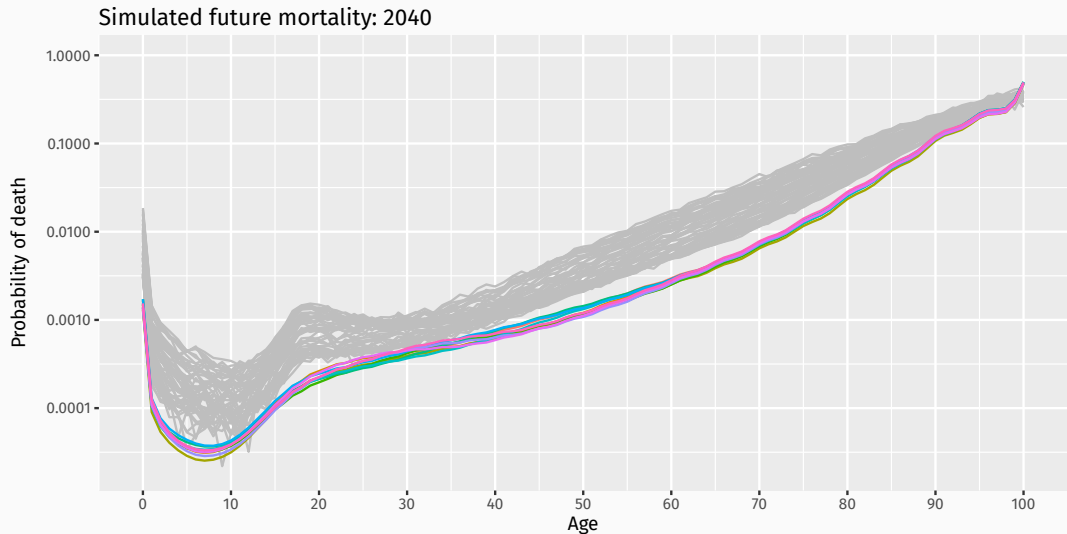
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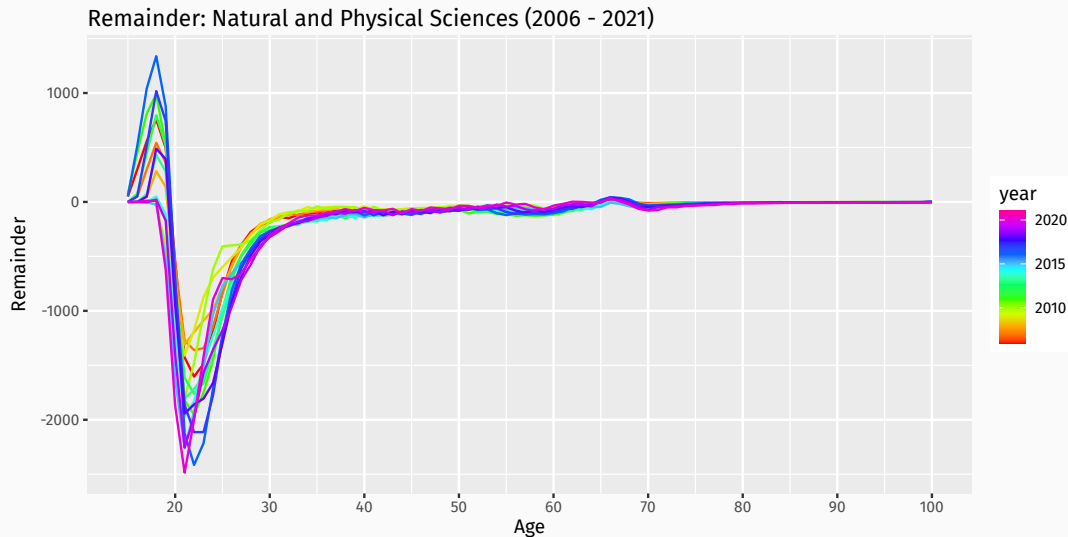
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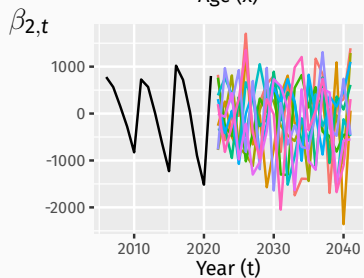
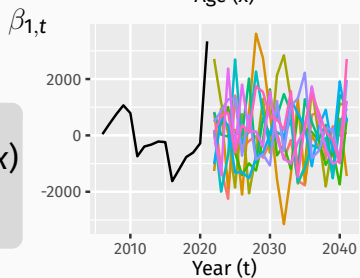
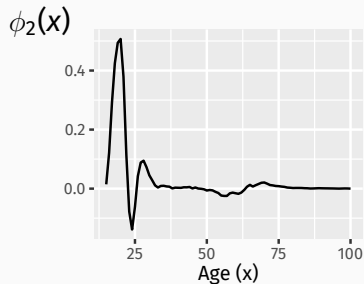
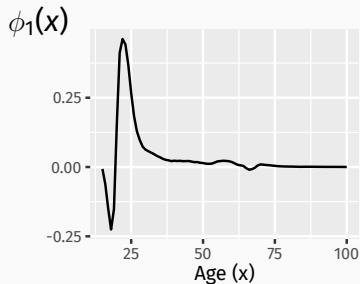
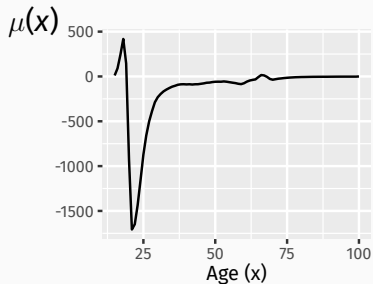
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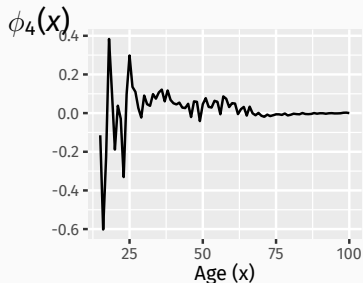
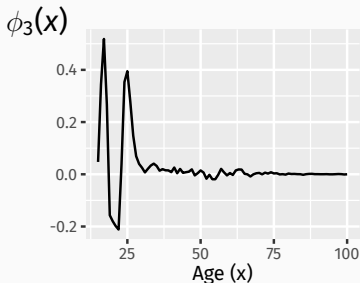
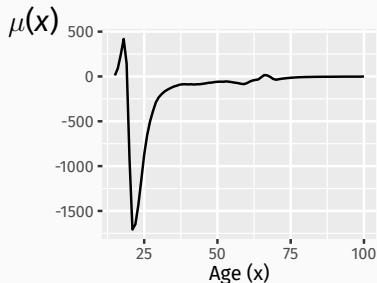


$$E_{x,t} = \mu(x) + \sum_{k=1}^6 \beta_{k,t} \phi_k(x) + \varepsilon_t(x)$$

$\beta_{k,t} \sim \text{ARIMA}$

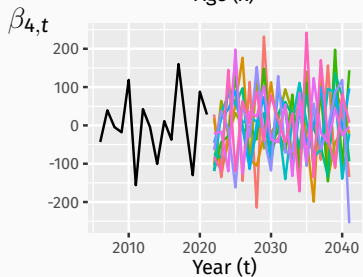
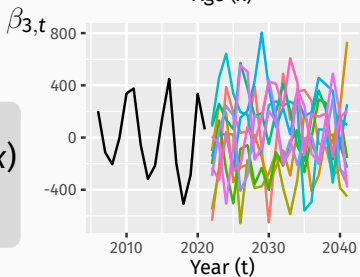
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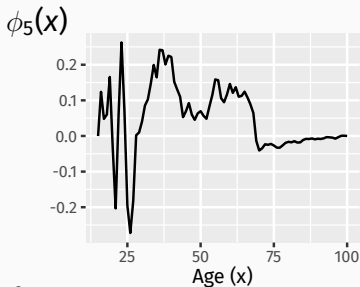
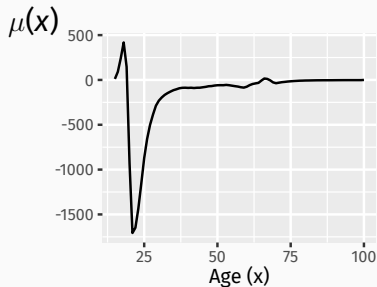
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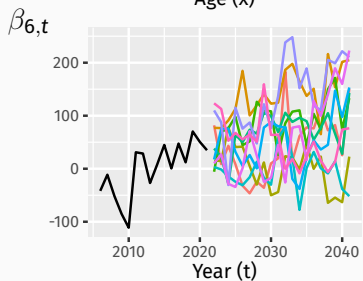
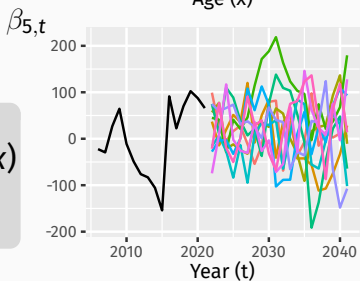
Forecasting models: $E_{x,t}$

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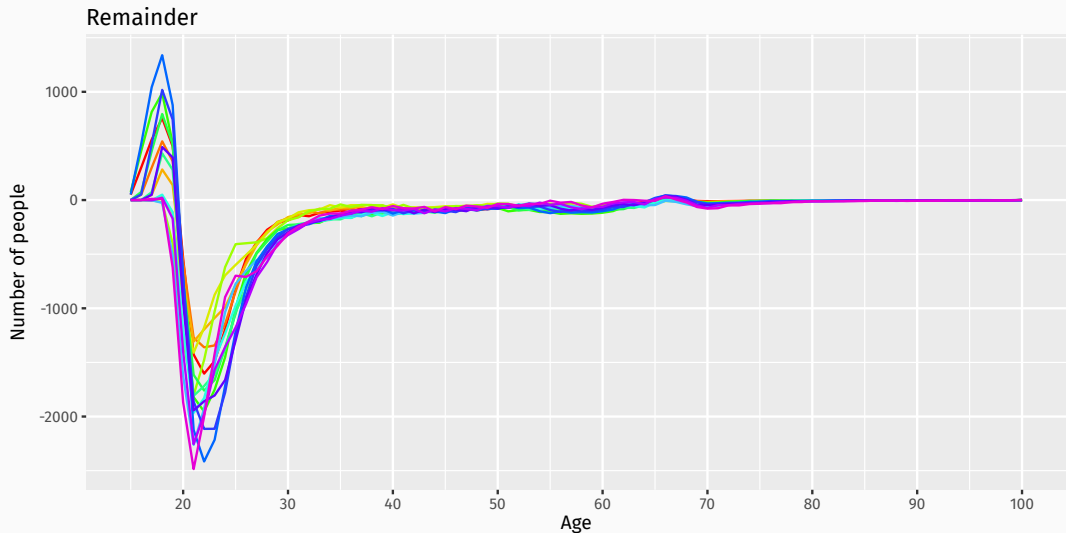
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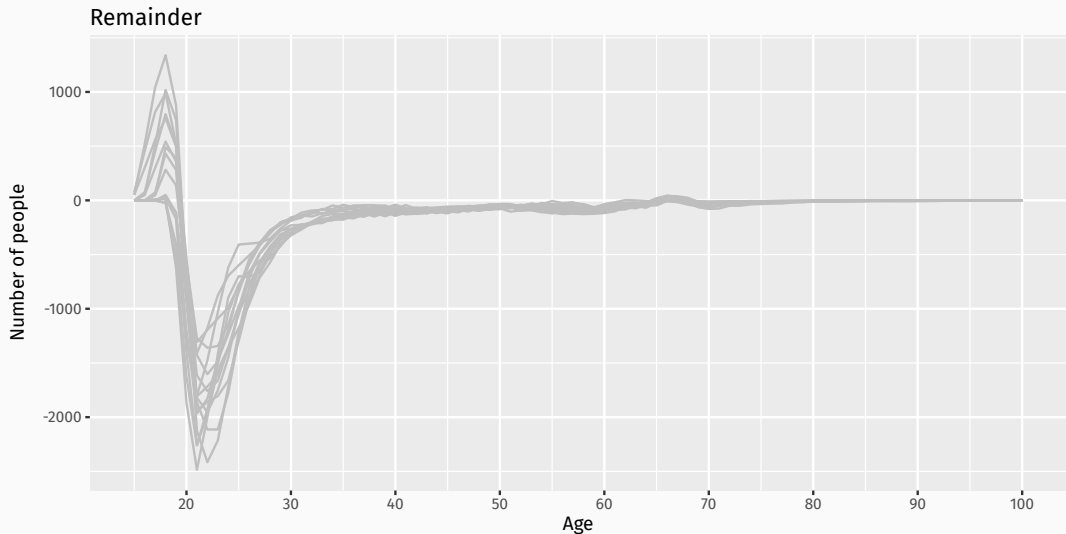
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Forecasting models: $E_{x,t}$

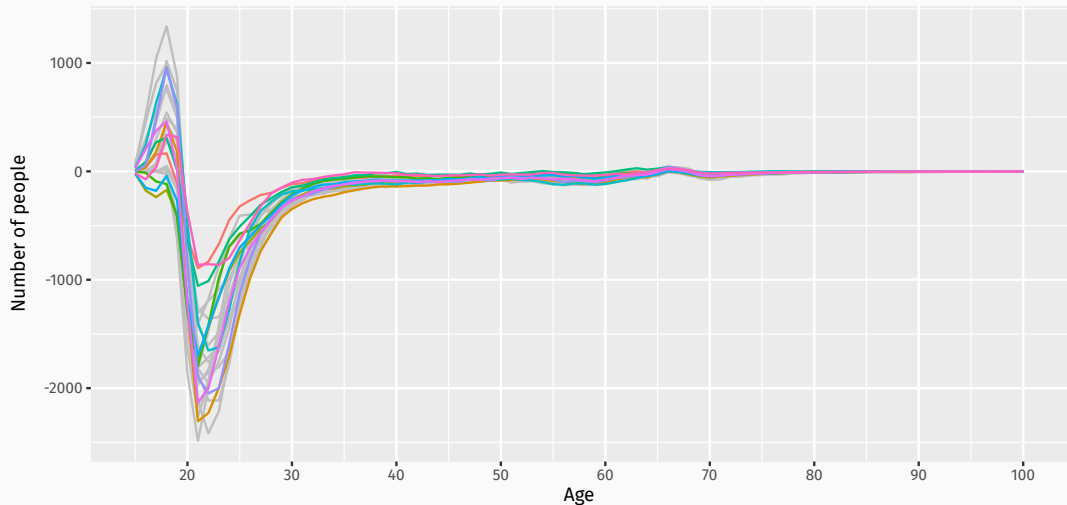
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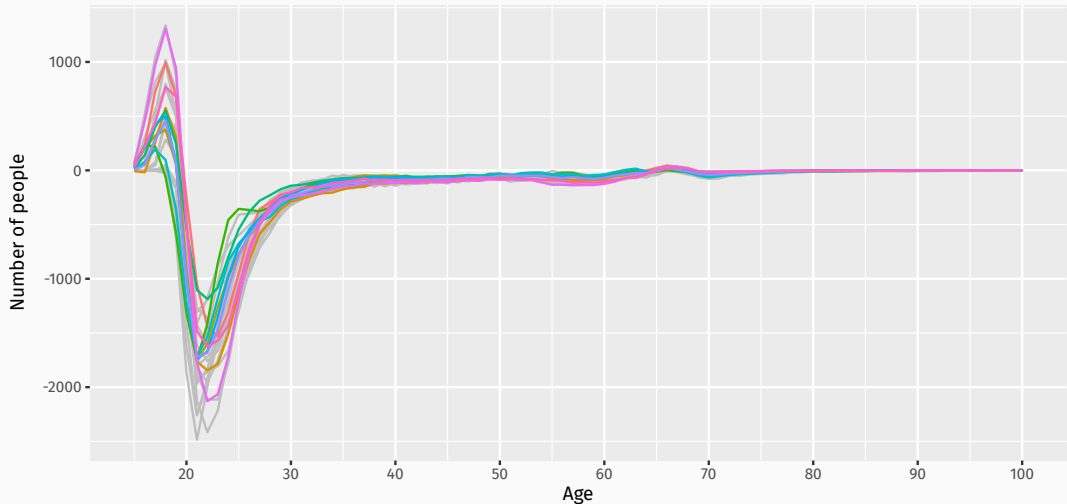
Simulated future remainder: 2030



Forecasting models: $E_{x,t}$

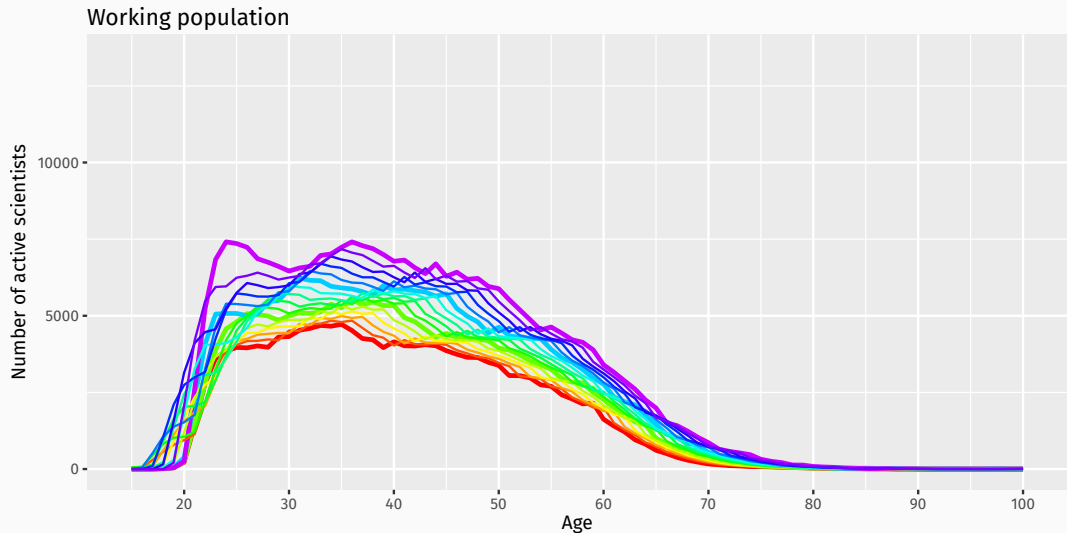
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

Simulated future remainder: 2040



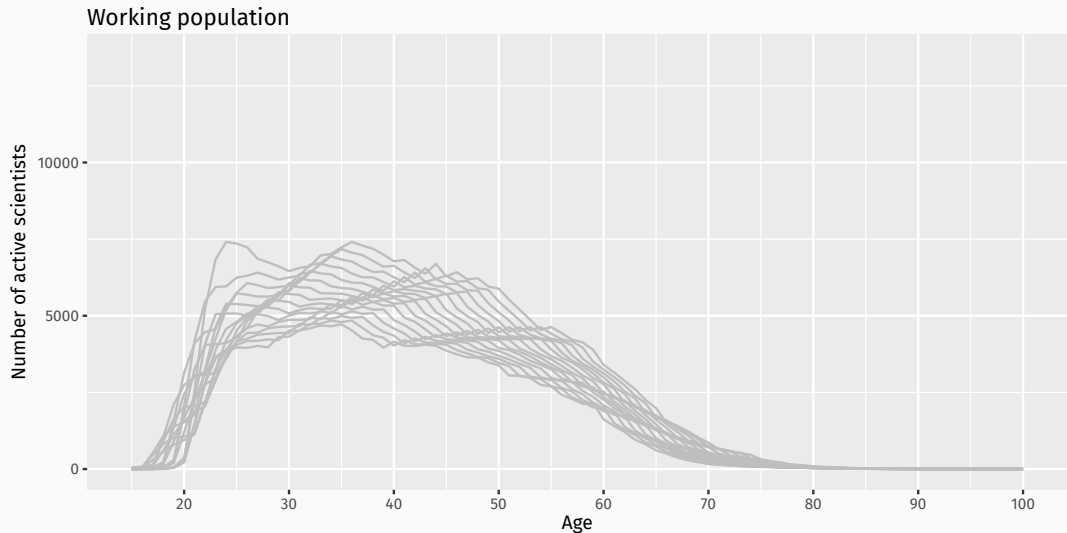
Final forecasts: $P_{x,t}$

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$



Final forecasts: $P_{x,t}$

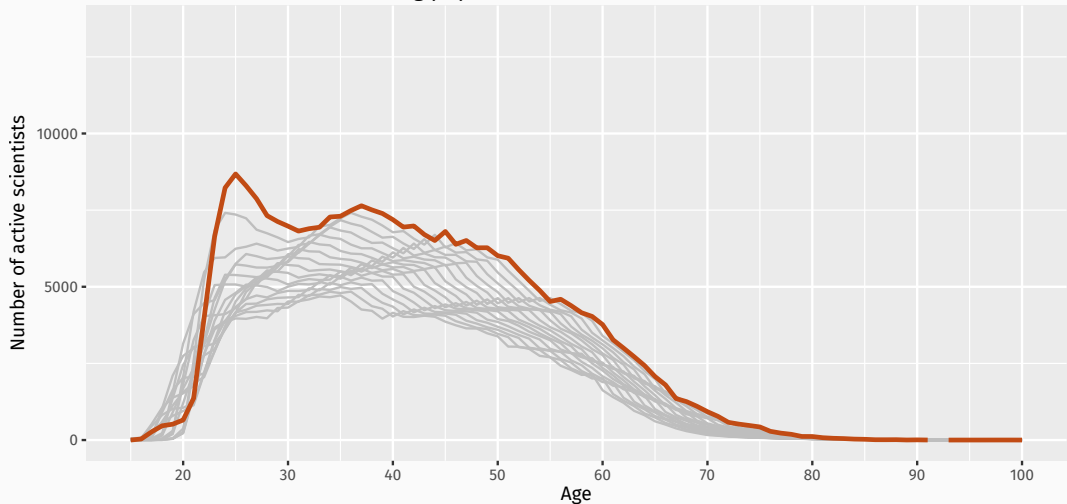
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Forecasts: $P_{x,t}$

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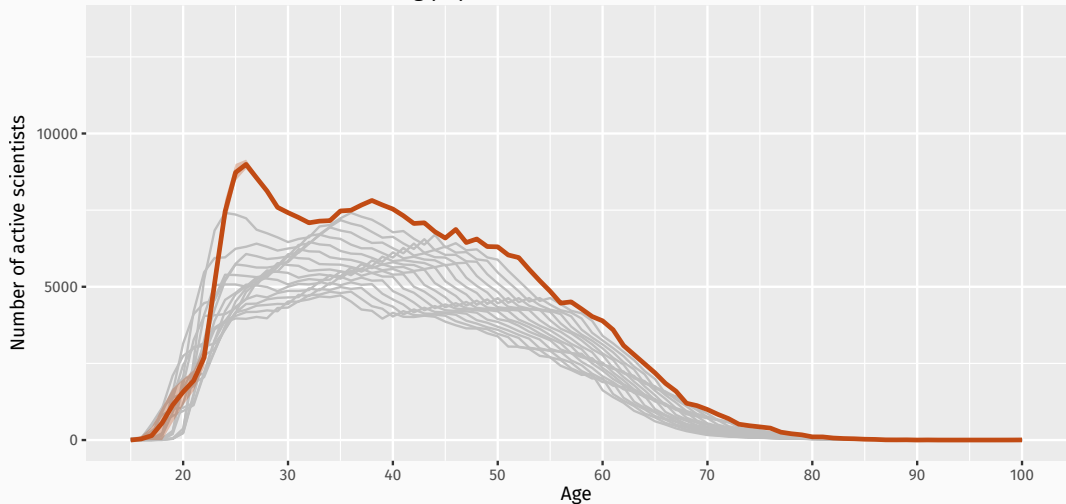
90% forecast interval for working population: 2022



Forecasts: $P_{x,t}$

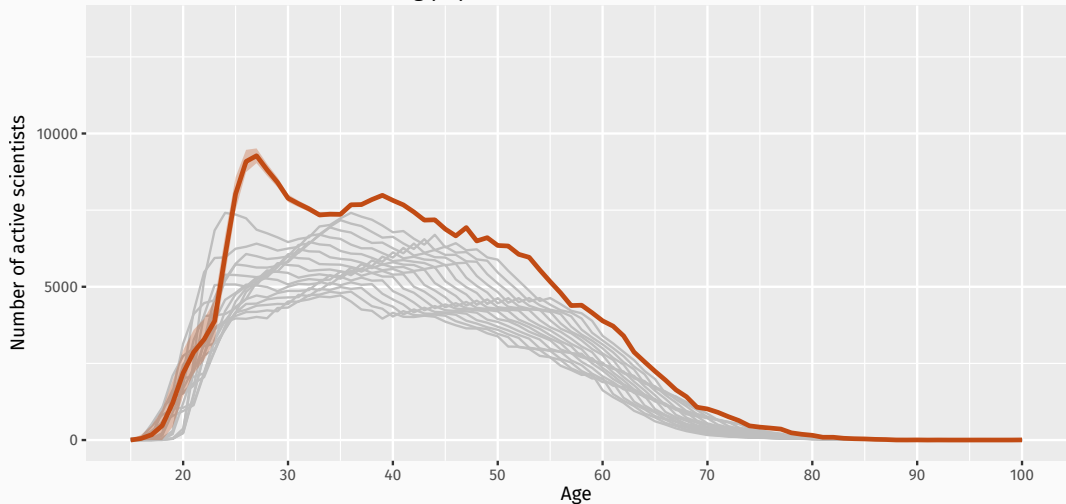
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

90% forecast interval for working population: 2023



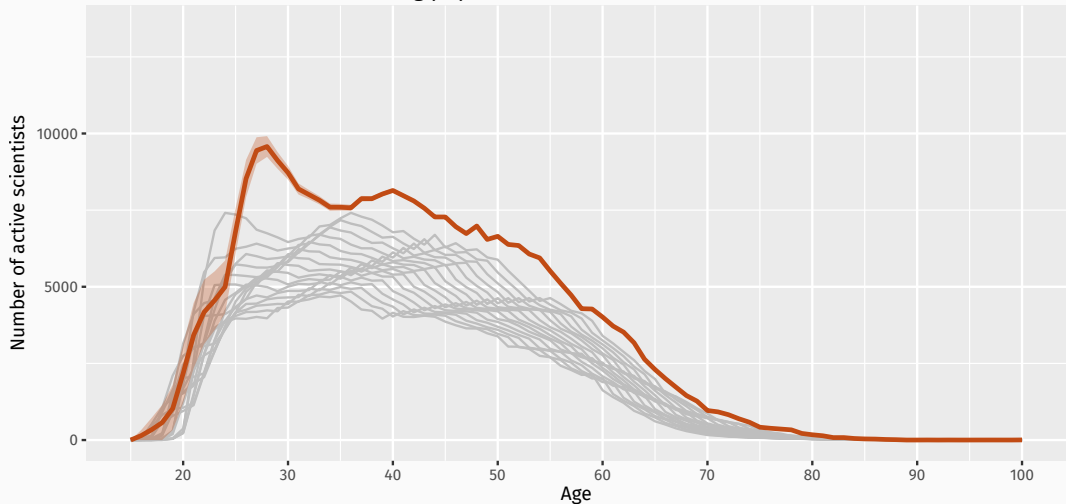
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

90% forecast interval for working population: 2024



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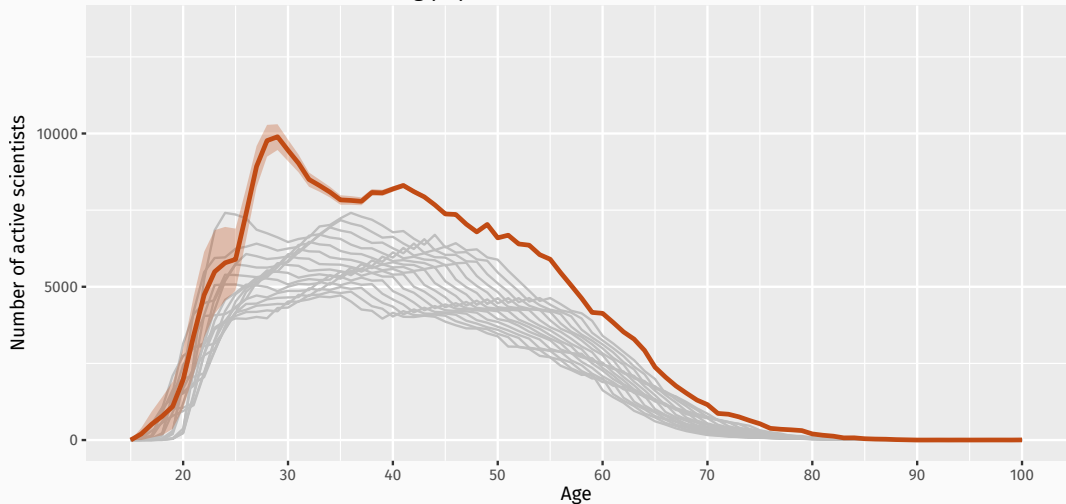
90% forecast interval for working population: 2025



Forecasts: $P_{x,t}$

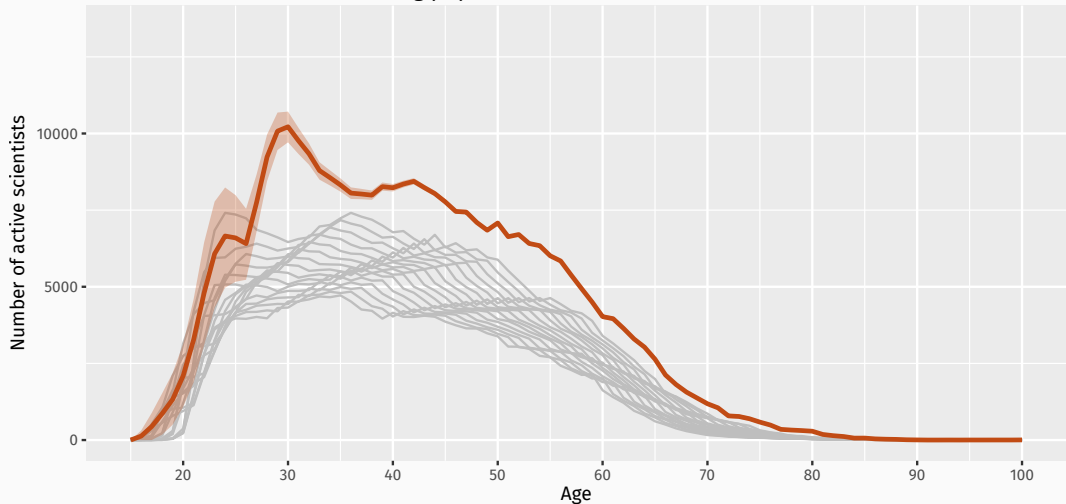
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

90% forecast interval for working population: 2026



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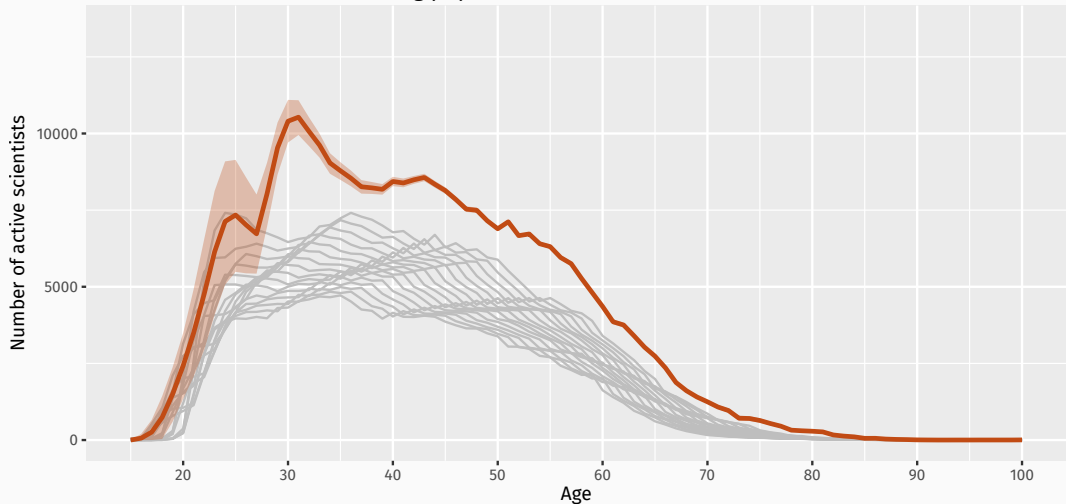
90% forecast interval for working population: 2027



Forecasts: $P_{x,t}$

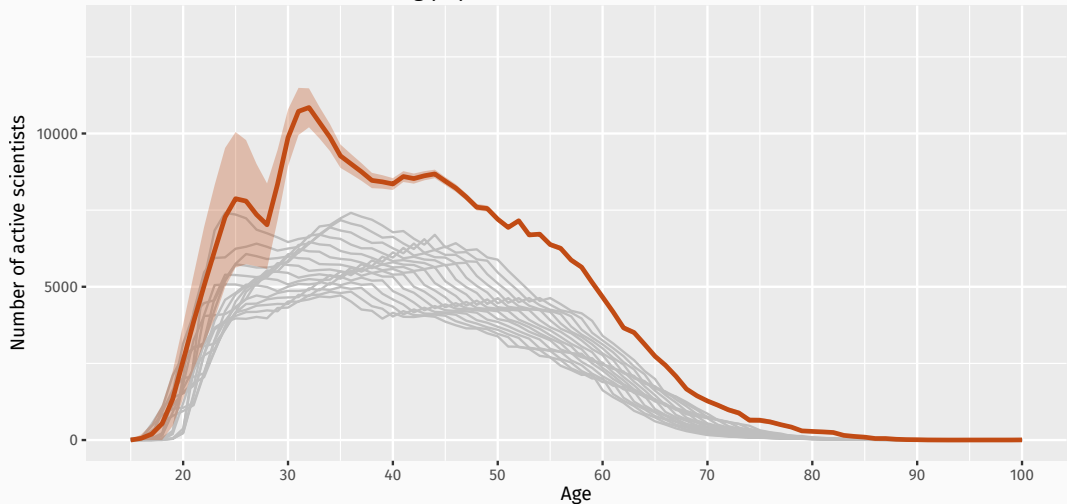
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90% forecast interval for working population: 2028



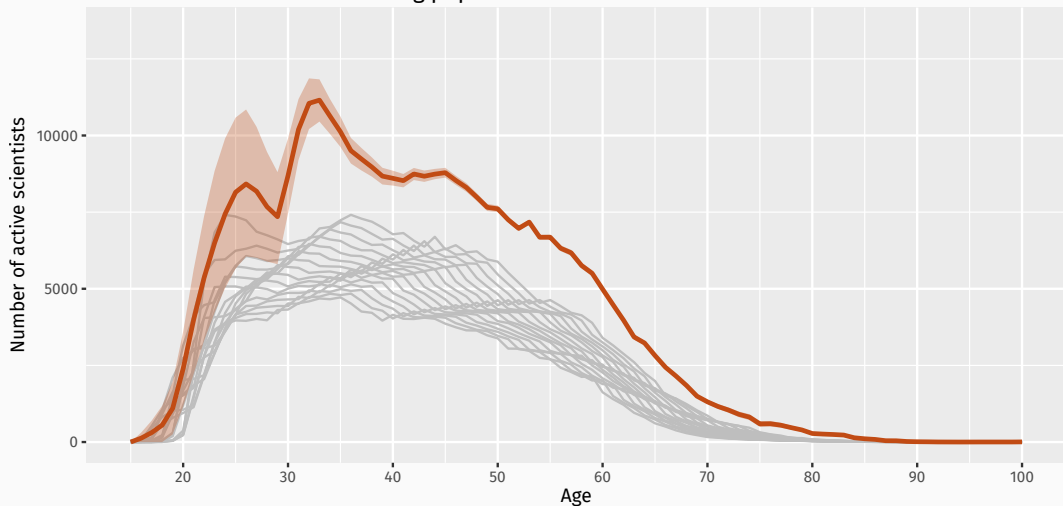
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

90% forecast interval for working population: 2029



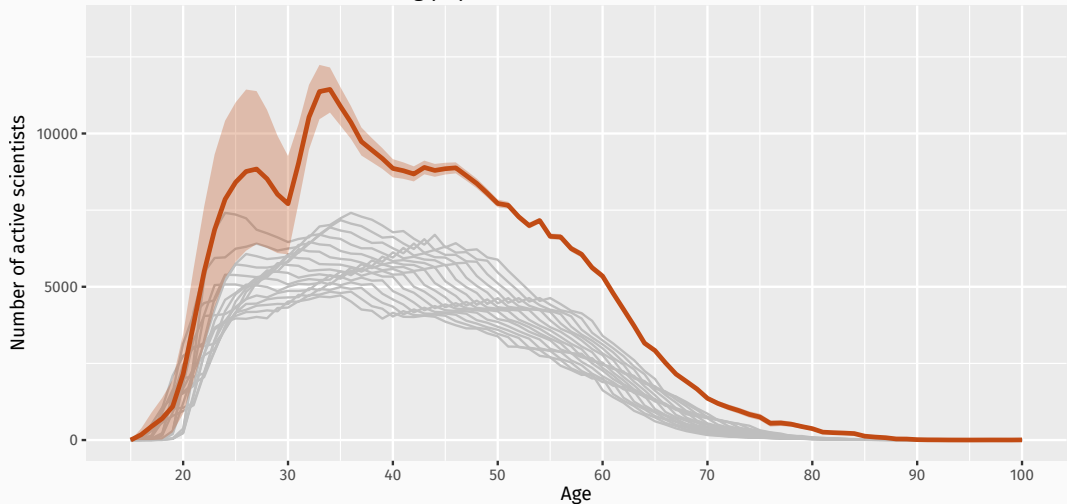
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

90% forecast interval for working population: 2030



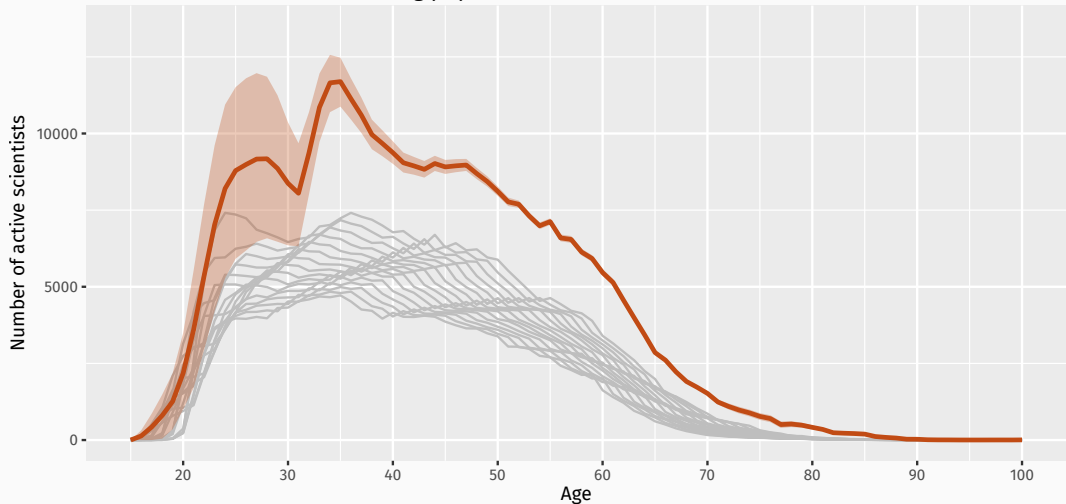
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

90% forecast interval for working population: 2031



$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

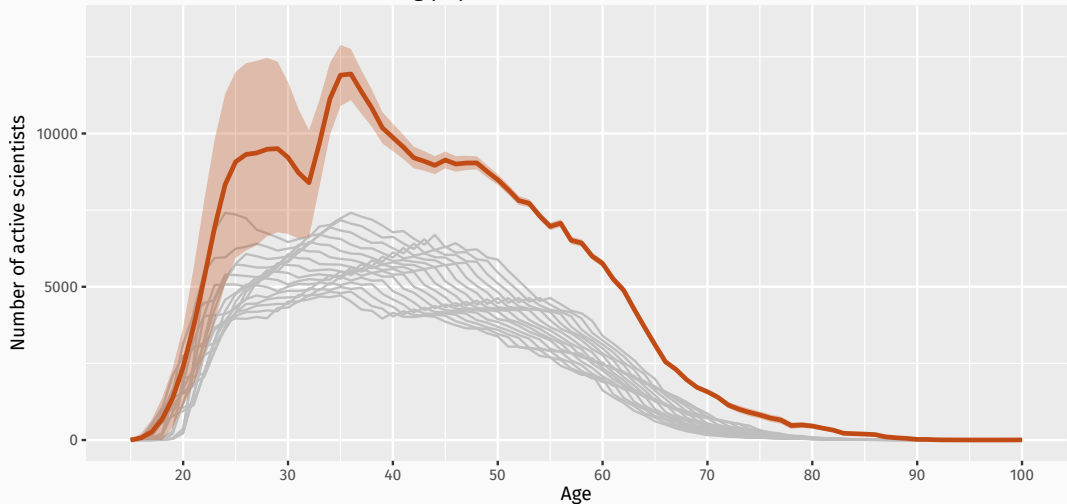
90% forecast interval for working population: 2032



Forecasts: $P_{x,t}$

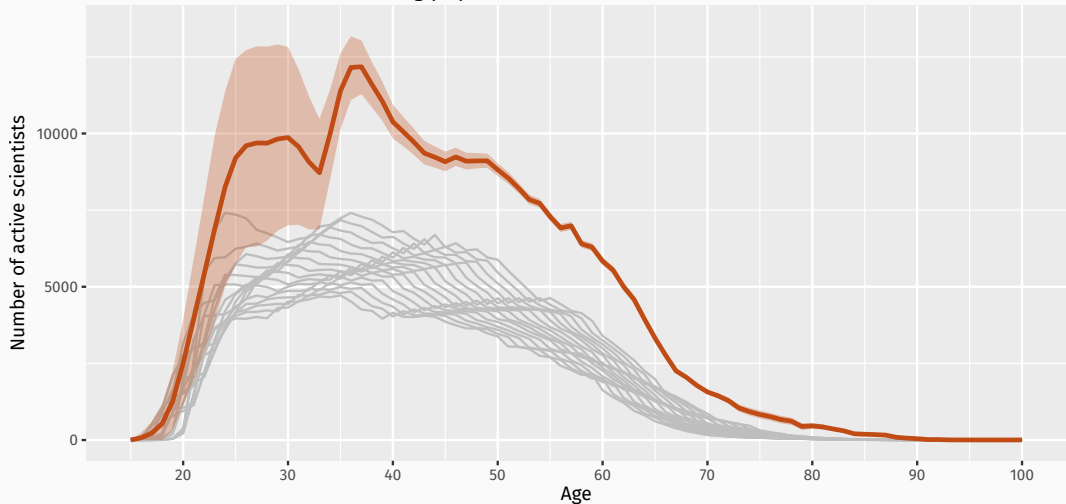
$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

90% forecast interval for working population: 2033



$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

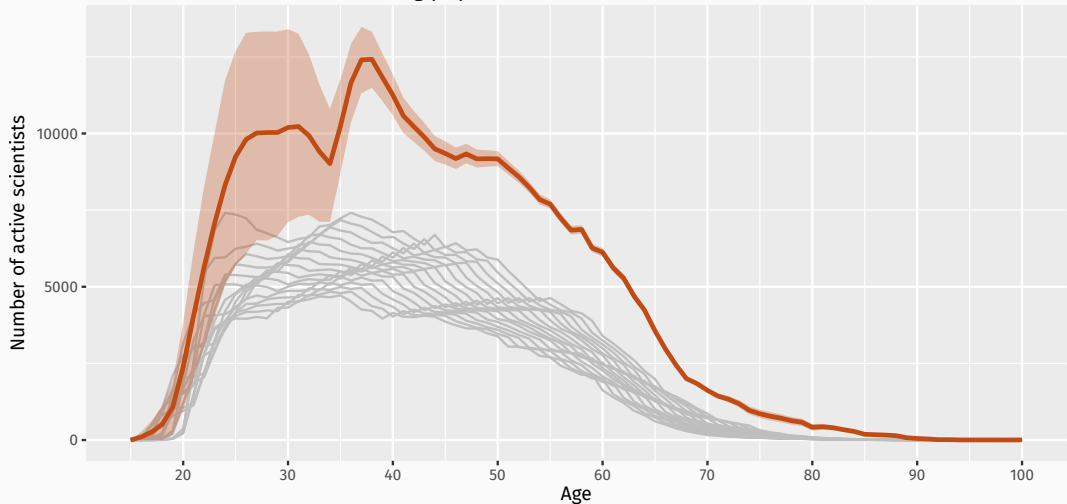
90% forecast interval for working population: 2034



Forecasts: $P_{x,t}$

$$P_{x+1,t+1} = P_{x,t}(1 - q_{x,t} - r_x) + g_x G_t + E_{x,t}$$

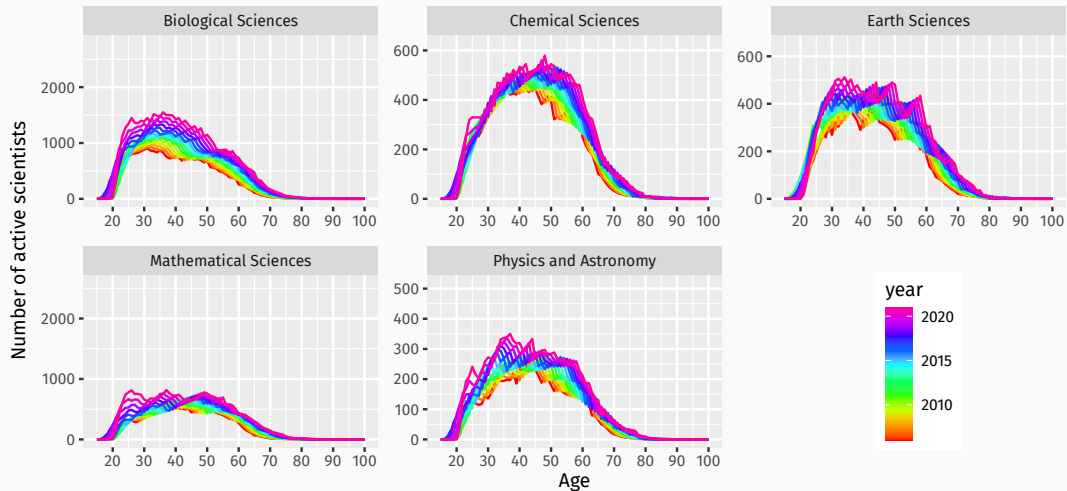
90% forecast interval for working population: 2035



Population by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

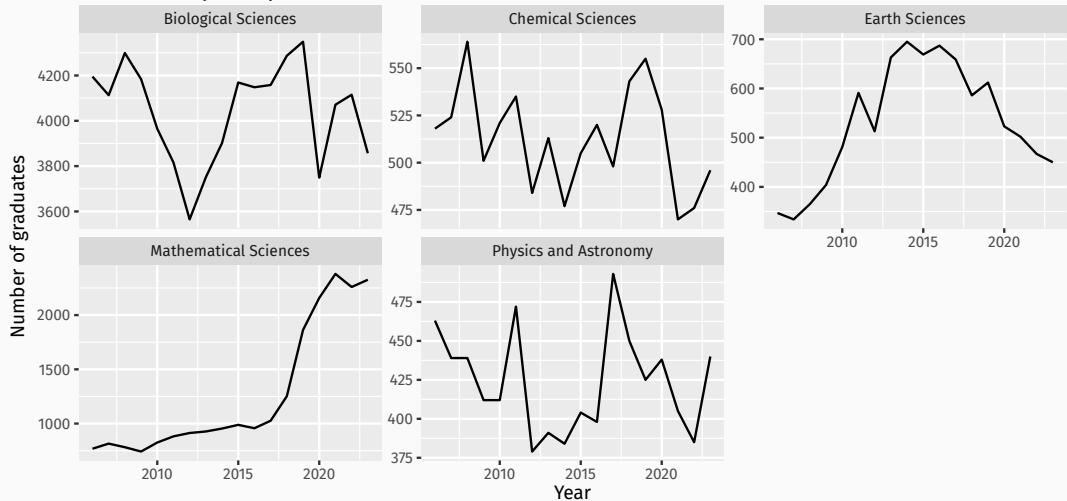
Working population by discipline



Graduates by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

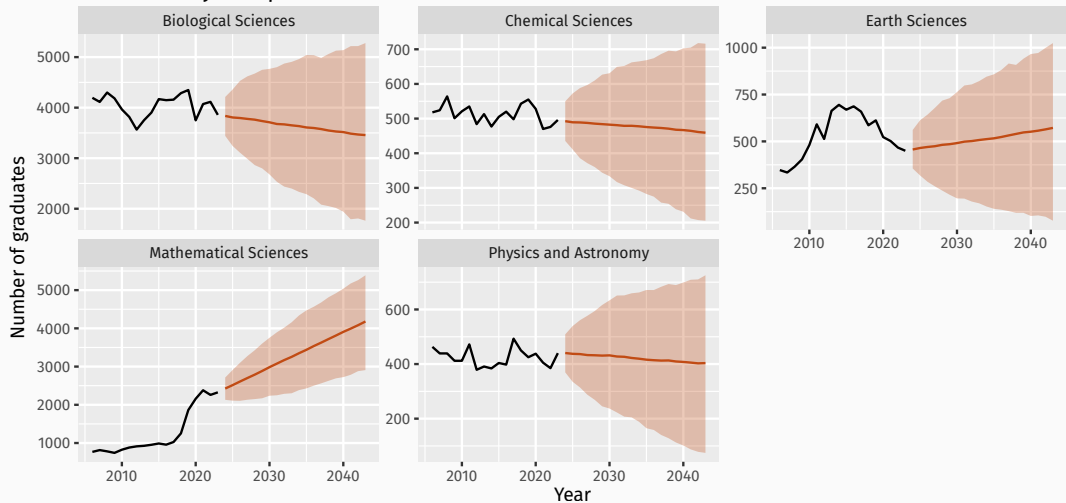
Graduates by discipline: (2006 - 2023)



Graduate forecasts

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

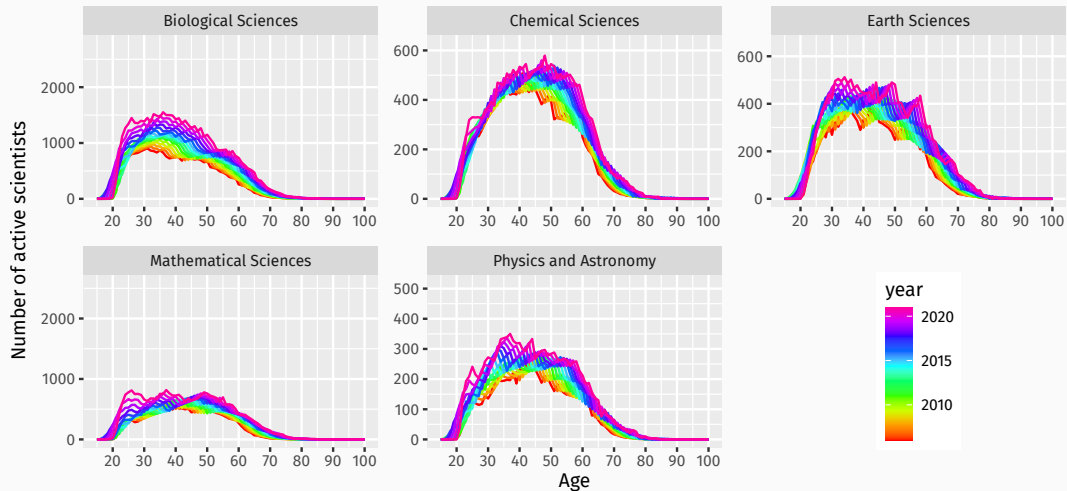
Graduates by discipline



Population by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

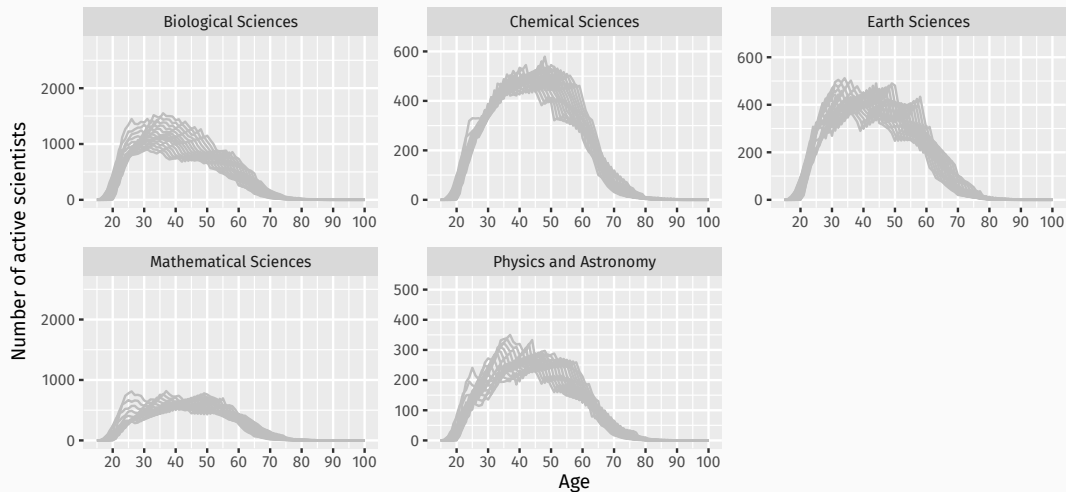
Working population by discipline



Population by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

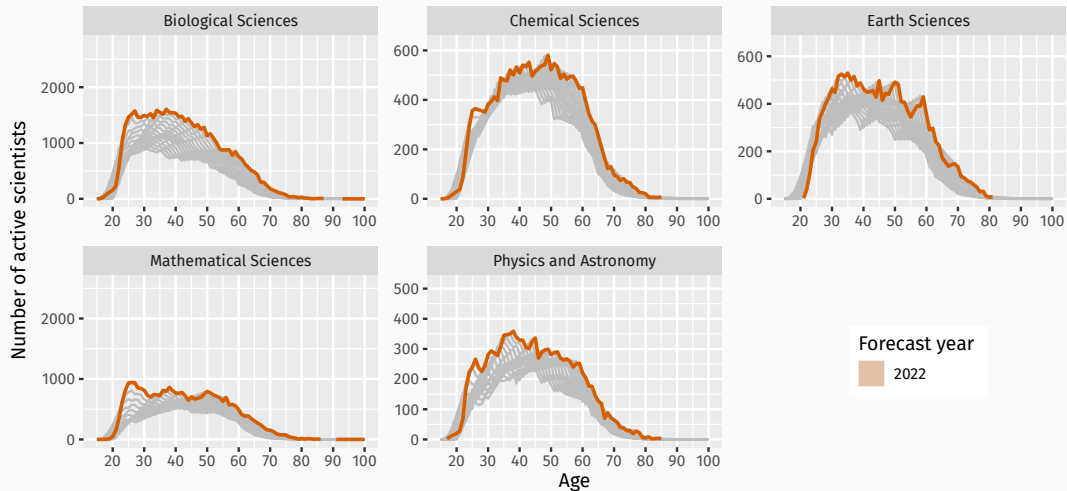
Working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

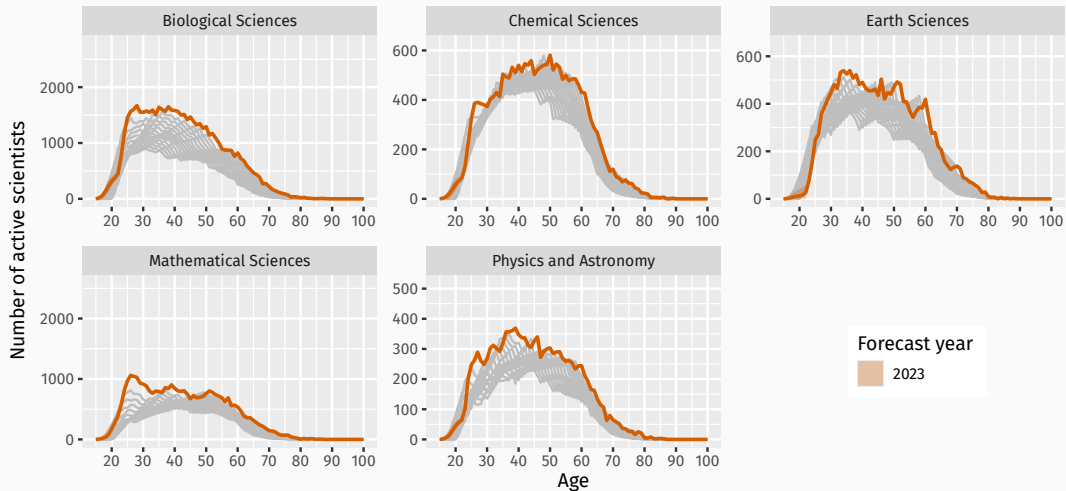
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

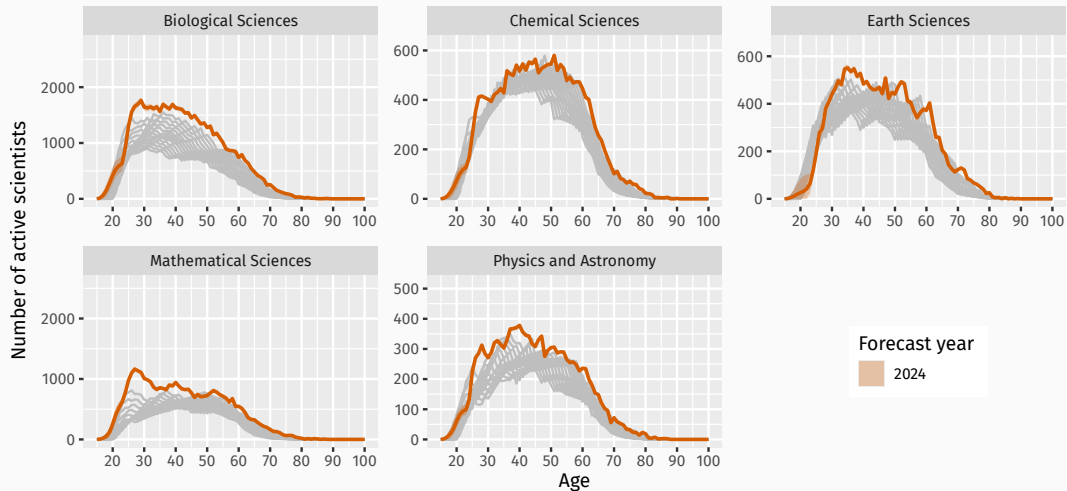
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

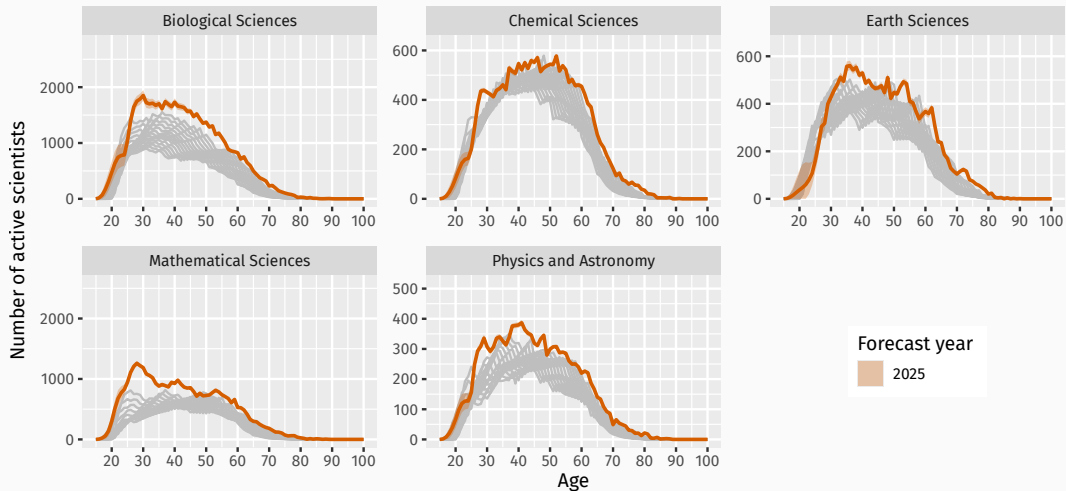
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

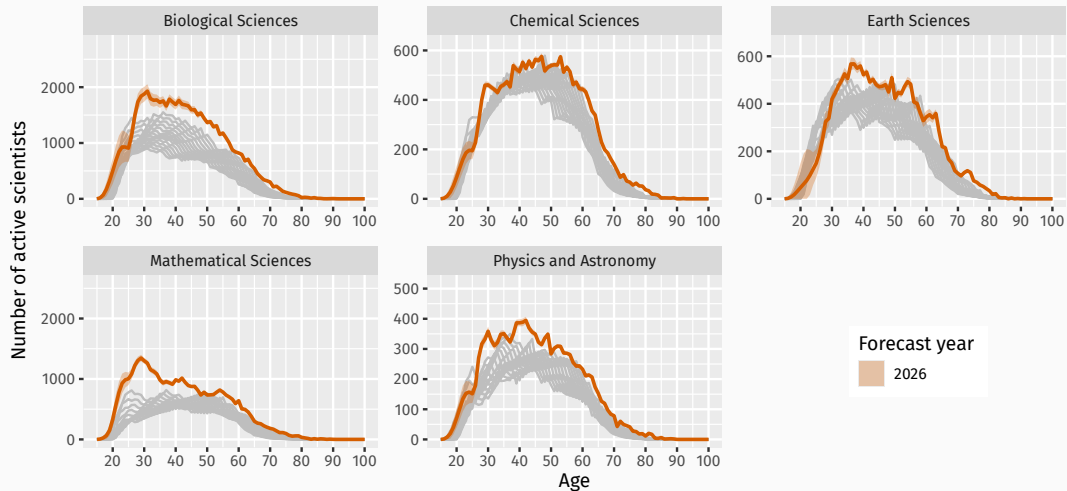
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

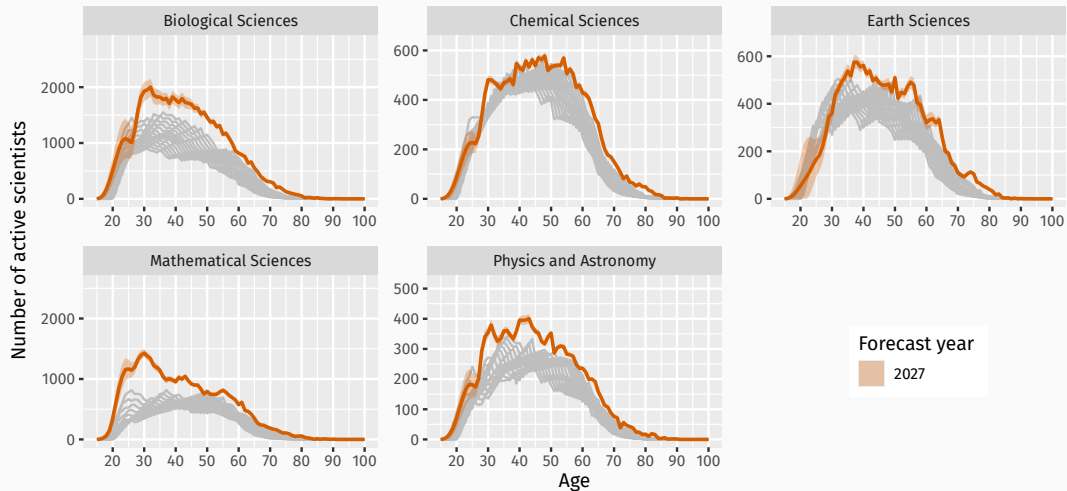
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

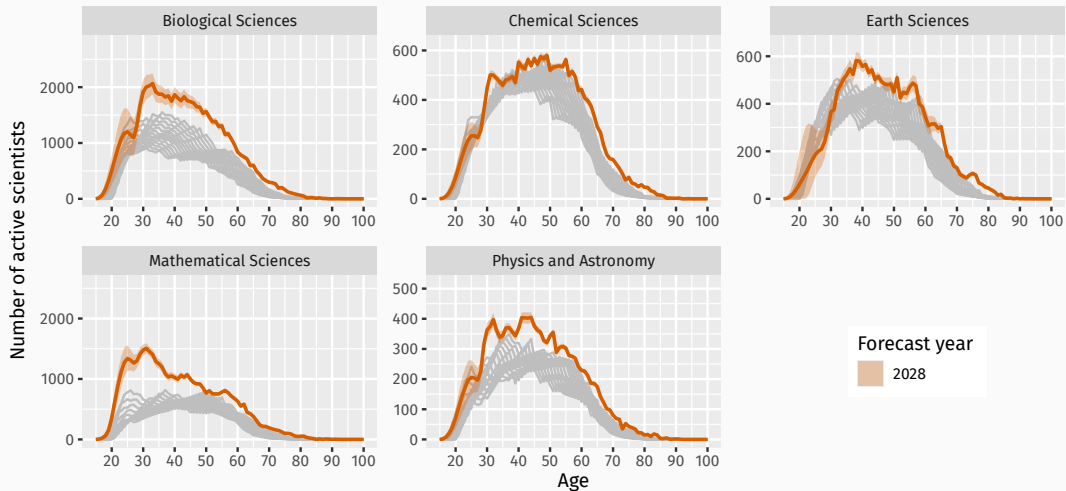
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

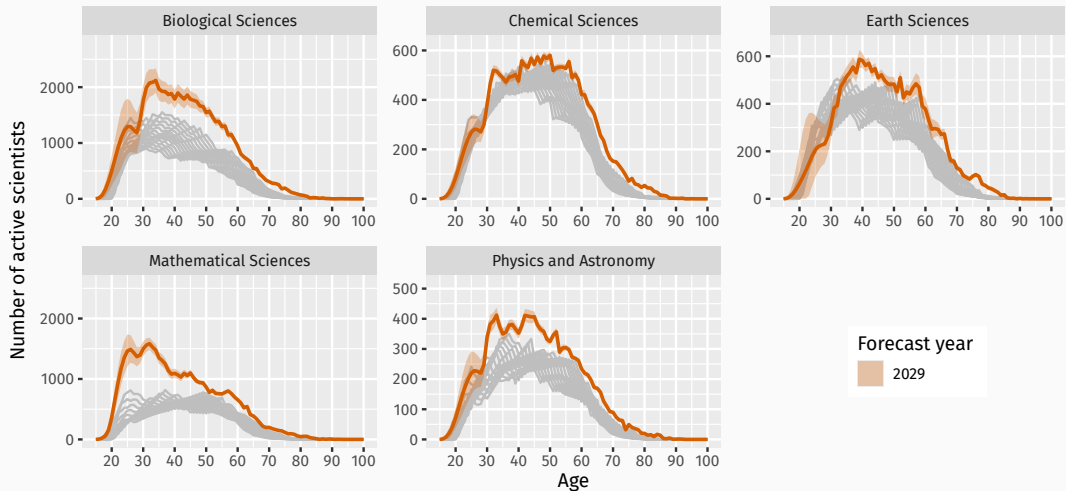
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

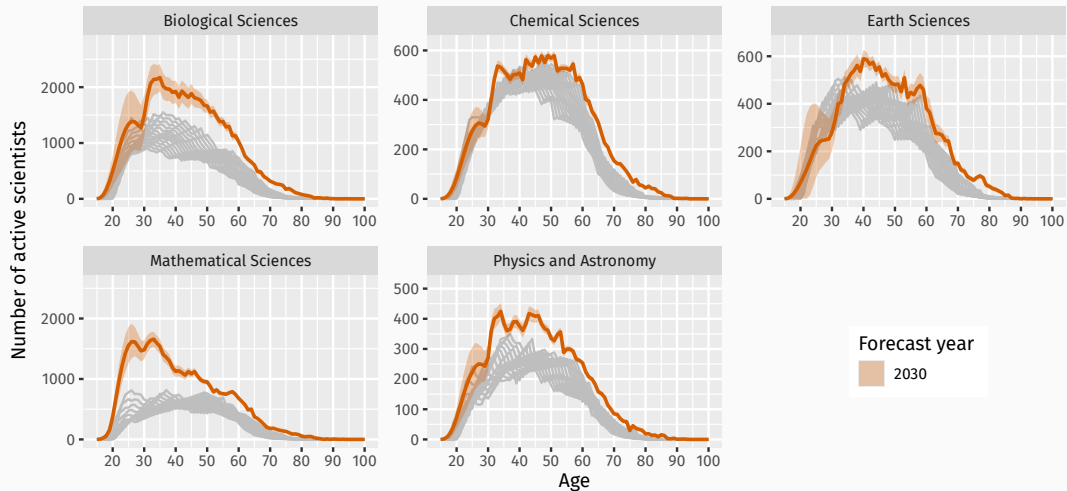
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

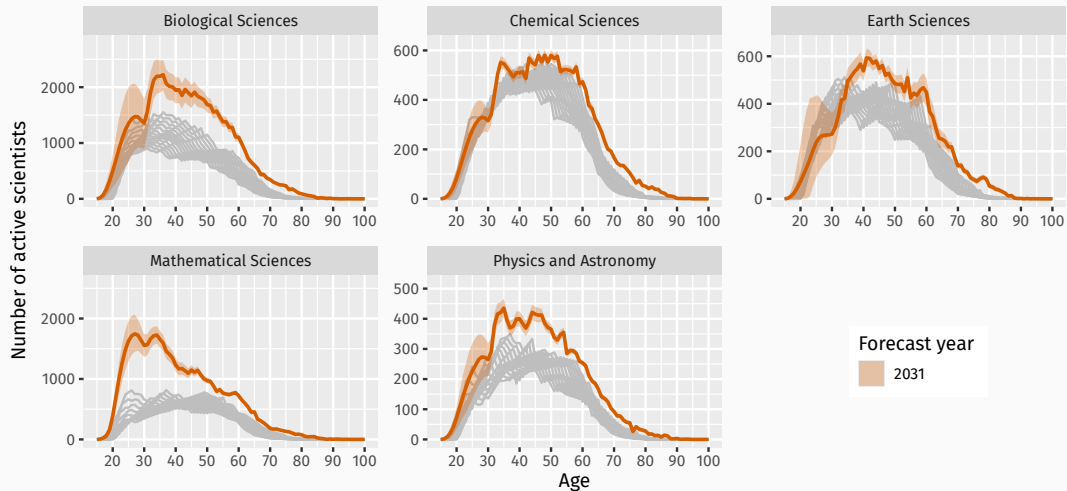
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

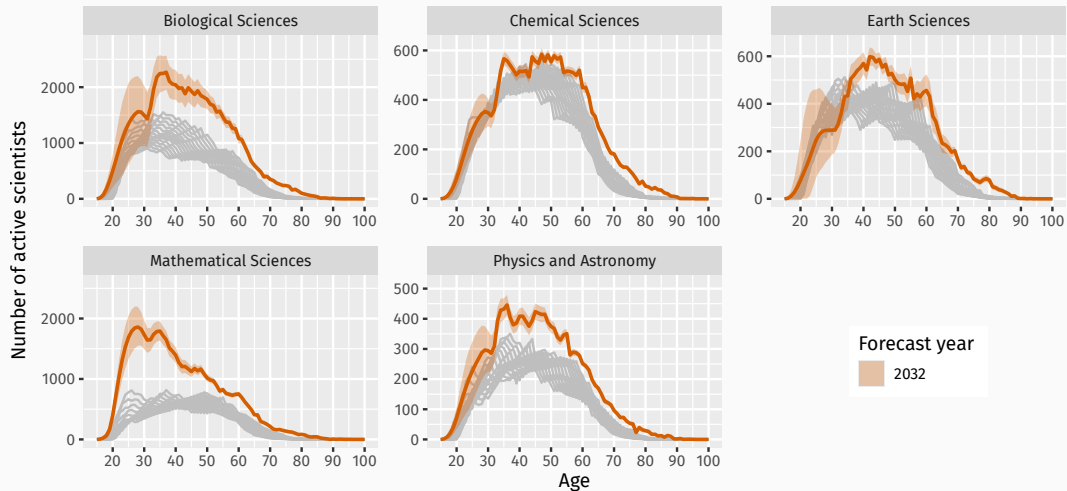
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

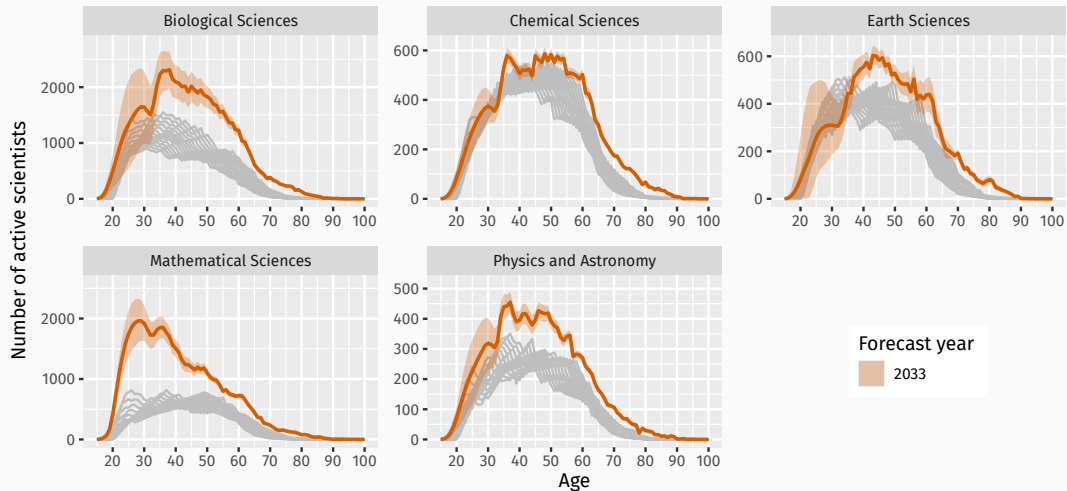
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

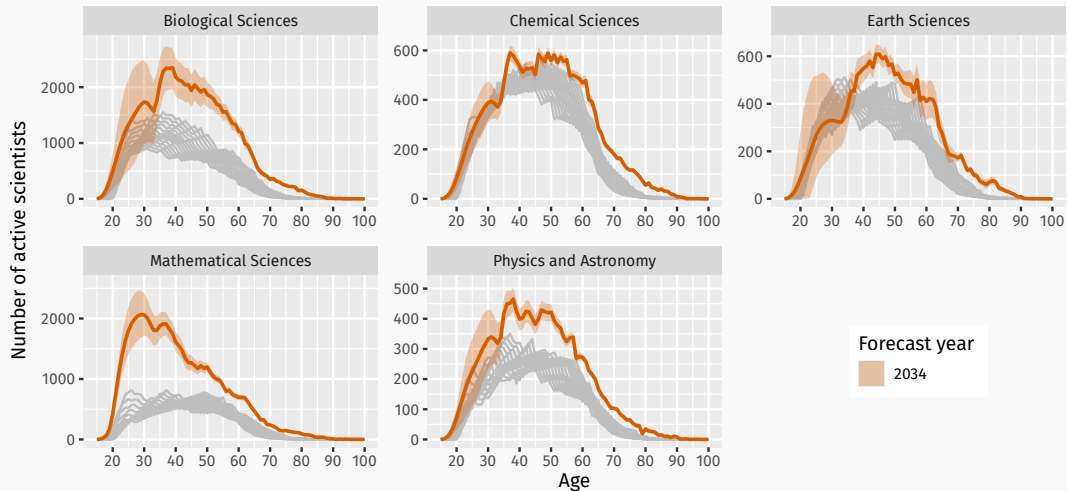
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

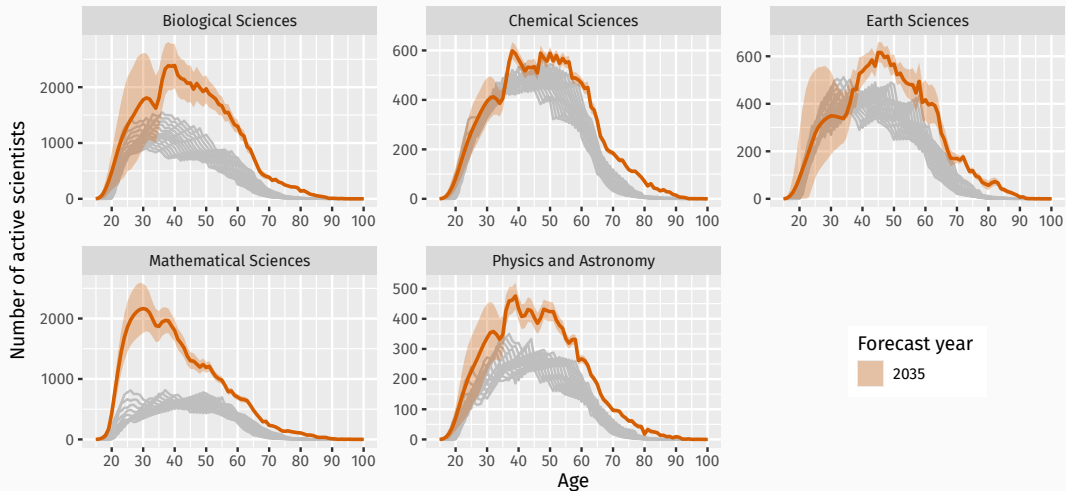
90% forecast interval for working population by discipline



Forecasts by discipline

$$P_{x+1,t+1,i} = P_{x,t,i}(1 - q_{x,t} - r_x) + g_x G_{t,i} + E_{x,t,i}$$

90% forecast interval for working population by discipline



More information

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