Efficient Food Standards for Radioactive Caesium Based on Cost-Benefit Analysis of the Regulation

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1 Introduction

After the Fukushima Daiichi nuclear accident in March 2011, the Japanese government determined provisional regulation values for radioactive substances and began to regulate the distribution of contaminated agricultural products. Since April 2012 stricter food standards—100Bq/kg for the sum of Cs-134 and Cs-137 in food in general— have been applied. Under the regulation, a number of agricultural products are still not allowed to be supplied, and several countermeasures have been carried out to prevent the products from containing radiocaesium exceeding the standard.

The regulation has incurred costs to the society.

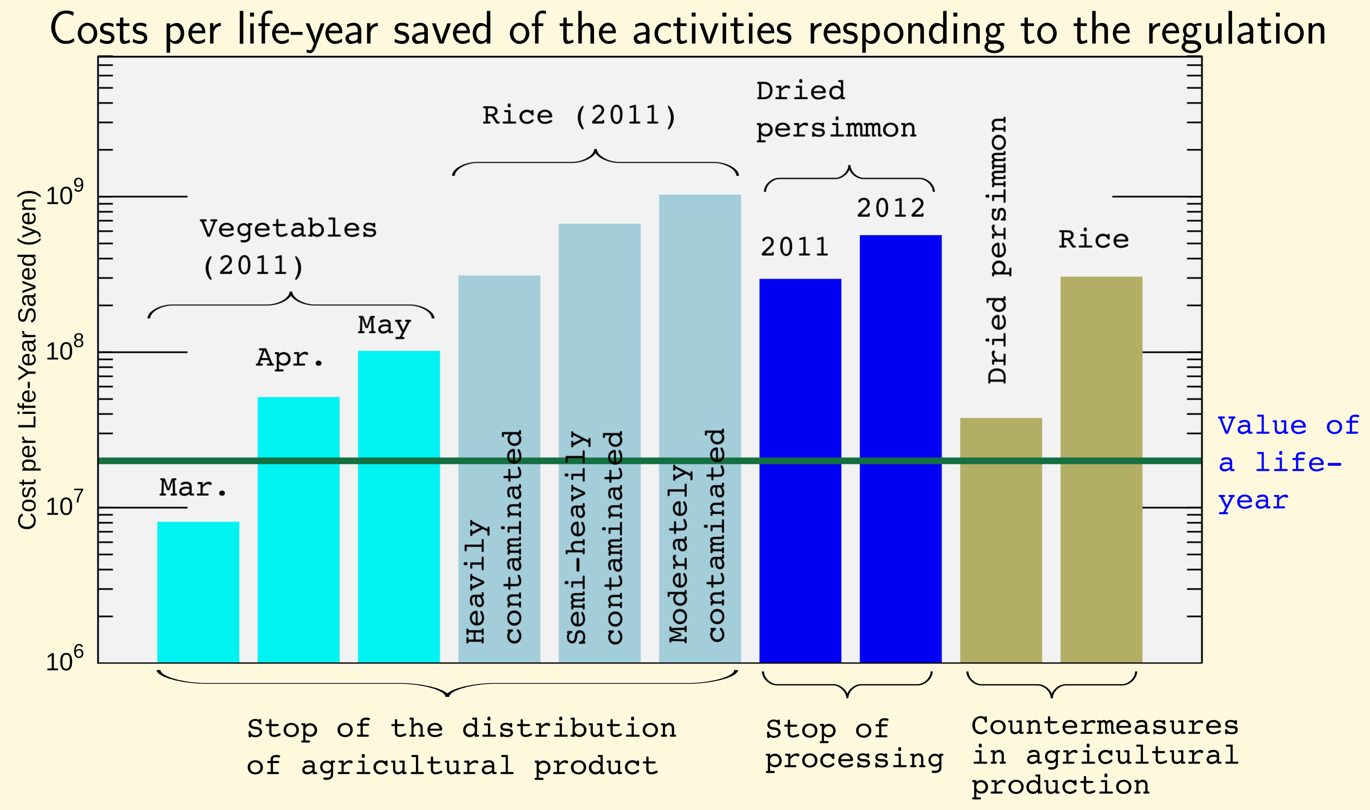
Questions:

- Does the present regulation of food contamination deserve its costs?
- What are the appropriate values for standard with regard to radioactive caesium in foods?

2 Results

2.1 Costs and Benefits of the regulation

Costs per life-year saved of the activities responding to the regulation



2.2 Efficient standard values

(Bq/kg)

	To stop production or distribution	Taking countermeasures into account		
		2012	2015	2019
Vegetables	1000	100		
Rice	720	390		
Dried persimmon	3600	420	200	100
Present standard	100			

'To be efficient' means costs do not exceed benefits.

3 Method

3.1 Cost per life-year saved (CPLYS)

1. To stop production or distribution

$$\text{CPLYS} = \frac{\text{Sales reduction [yen/kg]} - \text{Saved cost [yen/kg]}}{\text{Avoided loss of life-expectancy(LLE) [y/kg]}}$$

LLE = (Unit LLE from intake of radiocaesium [y/Bq]) × (Conc. [Bq/kg])
Unit LLE: 2.0×10^{-8} y/Bq for Cs-134, 1.4×10^{-8} y/Bq for Cs-137

2. Countermeasures in agricultural production
   - Rice

     Fertilization with potassium silicate and zeolite; deep cultivation
     - Effect: reduction in caesium concentration in rice by 99 Bq/kg at the maximun
     - Cost: 870,000 yen/ha or 200 yen/kg-rice
   - Dried persimmon

     Bark washing in winter 2011
     - Effect: increase in decay constant by 0.344, or 17 person-years of LLE reduced over 19 years
     - Cost: 620 million yen for 1700 tonne of dried persimmon

3.2 Efficient Values for Food Standard

1. Stop of production or distribution of products
   - Efficient regulation should meet:

     (Value of a life-year (VLY)) × (LLE reduction) ≧ (Cost of regulation)
     (LLE reduction) ≧ (Standard value) × (unit LLE)

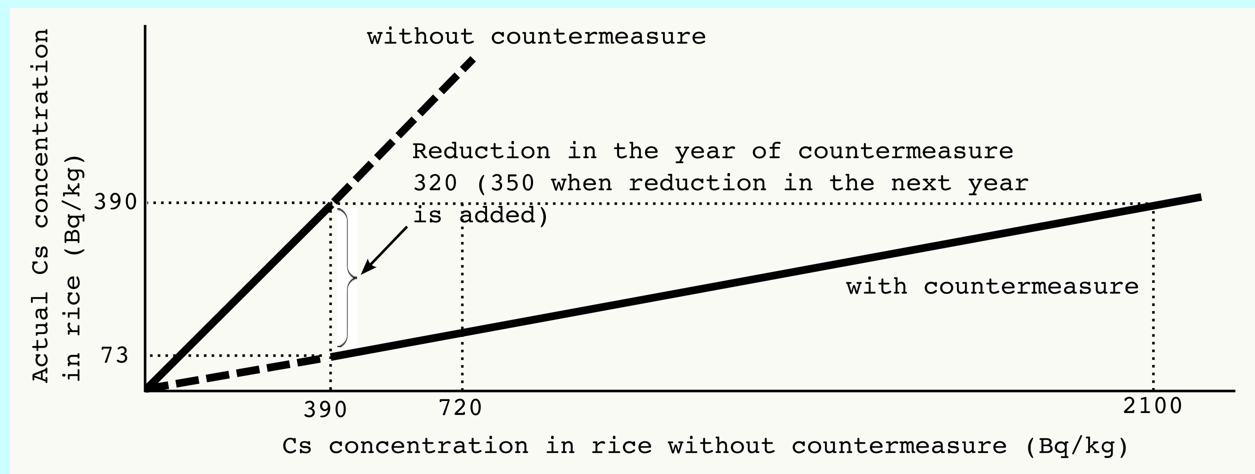
     $$\Rightarrow \text{(Standard value)} \geqq \frac{\text{(Cost of regulation)[yen/kg]}}{\text{(VLY)[yen/y]} \times \text{(Unit LLE)[y/Bq]}}$$

2. Countermeasures in agriculture
   - Efficient countermeasure should meet:

     (VLY) × (LLE reduction) ≧ (Cost of countermeasure)
   - Vegetables

     No countermeasure is needed for meeting the present standard limit; 100Bq/kg is efficient.
   - Rice
     - Cost: 110yen/kg (potassium chloride), VLY: 2×10^7yen, Unit LLE: 1.6×10^{-8}y/Bq
       $\Longrightarrow$ When reduction in concentration is not less than 350Bq/kg, countermeasure is efficient.
     - Reduction coefficient: 1.67 (the year of fertilization), 0.58 (the next year)
       $\Longrightarrow$ When the concentration without countermeasure ($\bar{x}$) is not less than 390 Bq/kg, the reduction in the year of the countermeasure and in the next year is not less than 350 Bq/kg.
     - If the standard is set at 390 Bq/kg,
       - ∗ the countermeasure will be carried out when $\bar{x}$ is 390 to 2100 Bq/kg,
       - ∗ the production will be given up when $\bar{x}$ is greater than 2100 Bq/kg, and
       - ∗ the production will be carried out without countermeasure when $\bar{x}$ is 390 Bq/kg and below,

       all of which are efficient.



   - Dried persimmon
     - Cost: 360 yen/kg
       LLE reduction: 7.4×10^{-8} year per 1Bq of Cs-137 in the initial year
       $\Longrightarrow$ When the radiocaesium in 2011 was not less than 450Bq/kg, the countermeasure would have been efficient taking the effects over the 20 years into account. The concentration in the next year would have been 240Bq/kg with the countermeasure and 340Bq/kg without it.
     - So the standard value of 340Bq/kg would have encouraged the countermeasure on the orchards producing dried persimmon with radiocaesium greater than 340Bq/kg in 2012.
     - But, the radiocaesium concentration above 470Bq/kg in 2012 could not have been reduced to 340Bq/kg by the countermeasure. It, however, is not efficient to give up the production of dried persimmon with Cs concentration not greater than 3600Bq/kg.
     - So, the efficient regulation would be:
       - ∗ to mandate the orchards that would have produced dried persimmon with 340 to 3600Bq/kg of Cs in 2012 (450 to 4800Bq/kg in 2011) to implement the countermesure, and
       - ∗ to ban the distribution of dried persimmon with greater than 3600Bq/kg of Cs.
     - A single standard value would not be able to achieve this situation.
     - Actually, the countermeasure was implemented on all the orchards, so the standard value of 3600Bq/kg would be sufficient to bring about an efficient regulation, but a stream of declining standard values—420Bq/kg in 2012, 200Bq/kg in 2015, 100Bq/kg in 2019 for example—would not cause any loss to the society, because the maximum Cs value in 2012 was 414Bq/kg.