

# The Socially Optimal Recycling Rate

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# Recycling Policy

USA

34%

- Resource Conservations and Recovery Act (1976)
- Encourage individual states to set goals
- California (75% by 2020); Texas (40% reduce and recycle)

EU27

39%

- The Packaging Directive (1994, 2004, 2005)
- First 15%, then 55% to 80% material recycled by 2009

Japan

20%

- The Law for the Promotion of Sorted Collection and Recycling of Containers and Packaging (1997)
- Increase the recycling rate from 11% to 24%

Municipal Costs

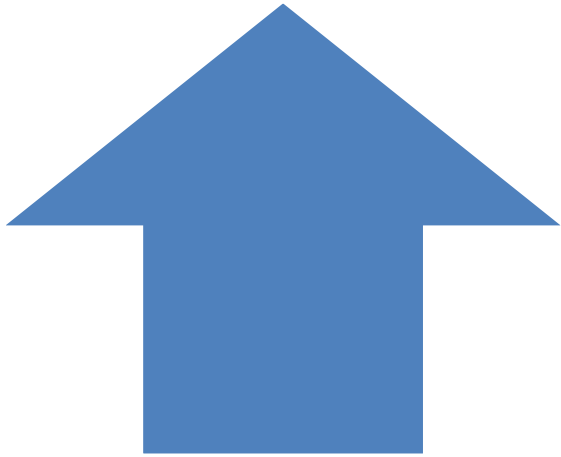
Household Recycling  
Costs

Social Costs

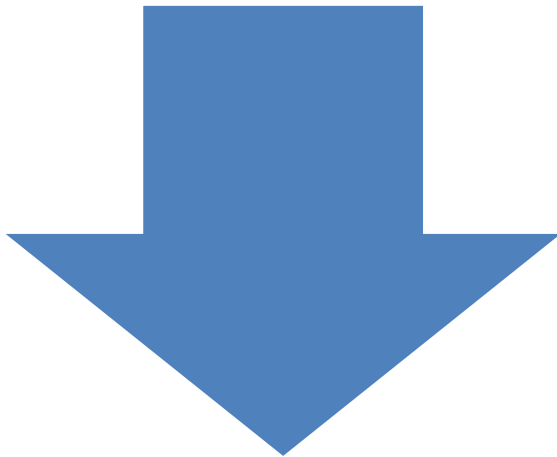
External Disposal  
Costs

External Recycling  
Benefits

# By Increasing the Recycling Rate



Social costs rise as households and municipalities must prepare and collect recyclable materials



Social costs fall as private and external benefits of recycling rise and private and external costs of waste disposal fall

Municipal Costs

Household Recycling  
Costs

Social Costs

External Disposal  
Costs

External Recycling  
Benefits

Waste Collection Costs

Recyclables Collection  
and Processing Costs

Municipal  
Costs

Private Disposal Costs  
(Landfill or Incineration)

Less Revenue from Sale  
of Recyclable Materials

# Municipal Data Source: Japan

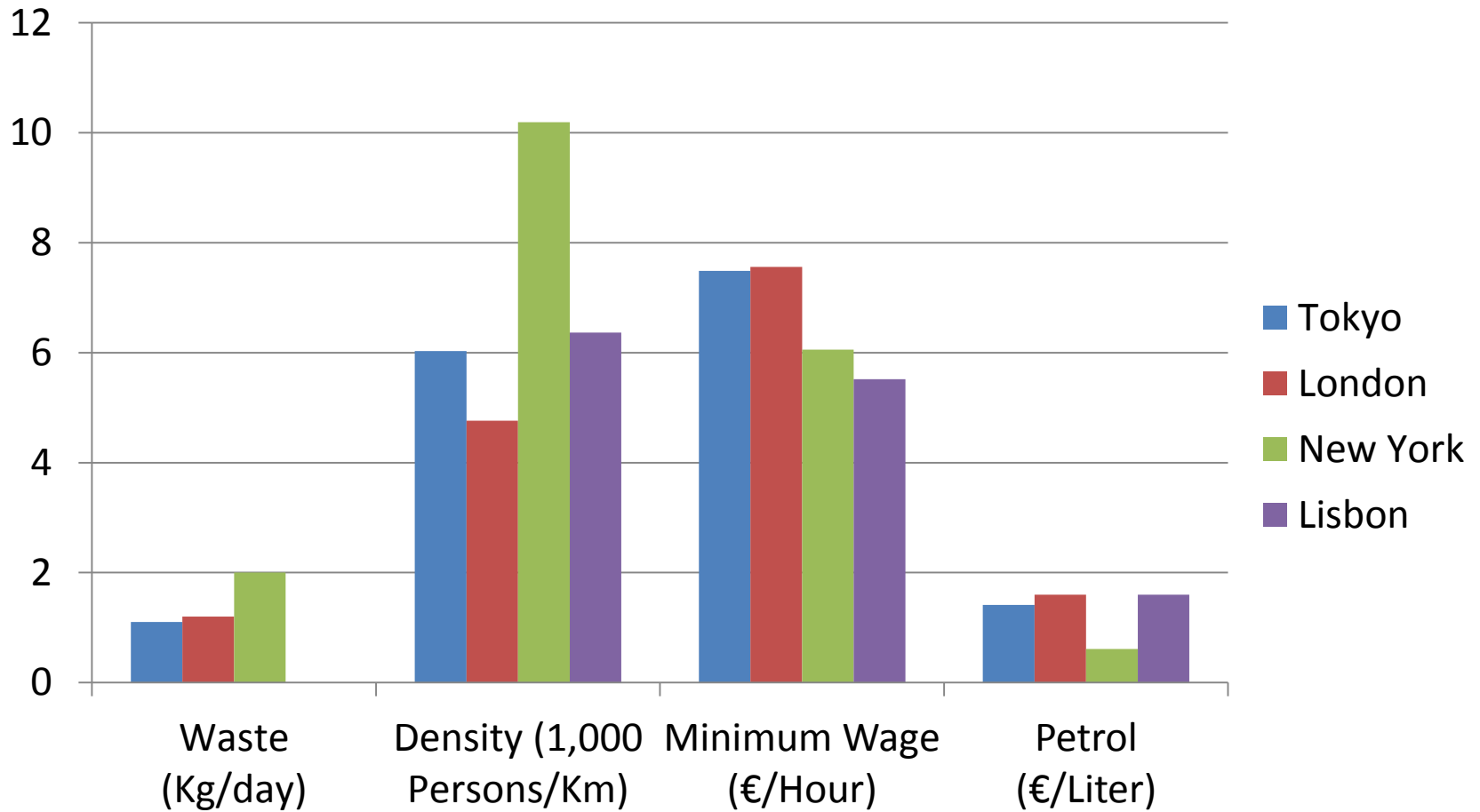


Five-year panel (2005-2009)

Represent 84 largest municipalities

Includes many necessary variables

# Broad Comparisons





# Municipal Data

Variable	N	Mean	Standard Dev.	Min	Max
Recycling Rate (%)	420	19.31	7.59	3.90	48.53
Municipal Costs	420	€65.7 M	€68.2 M	€713,822	€448.2 M
Total Waste (Tons)	420	268,872	274,027	27,710	1,926,718

Municipal Costs

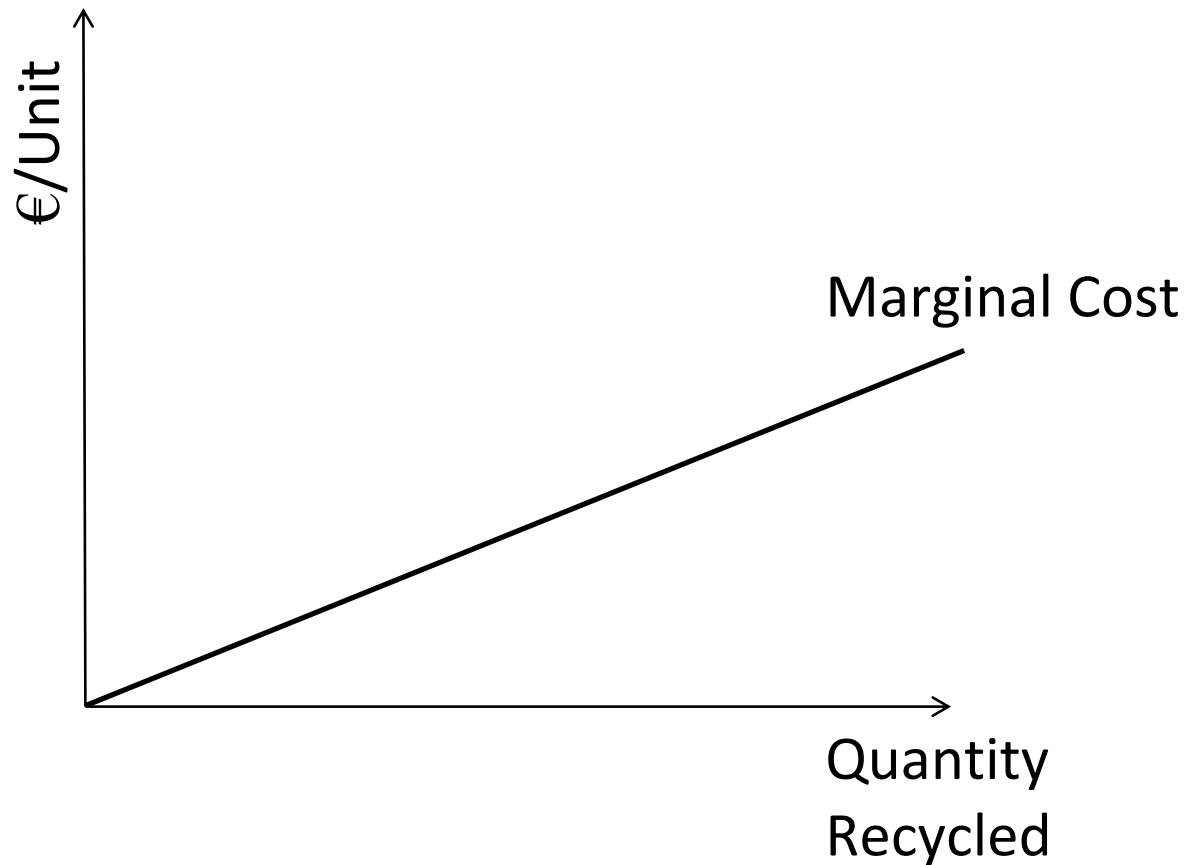
Household Recycling Costs

Social Costs

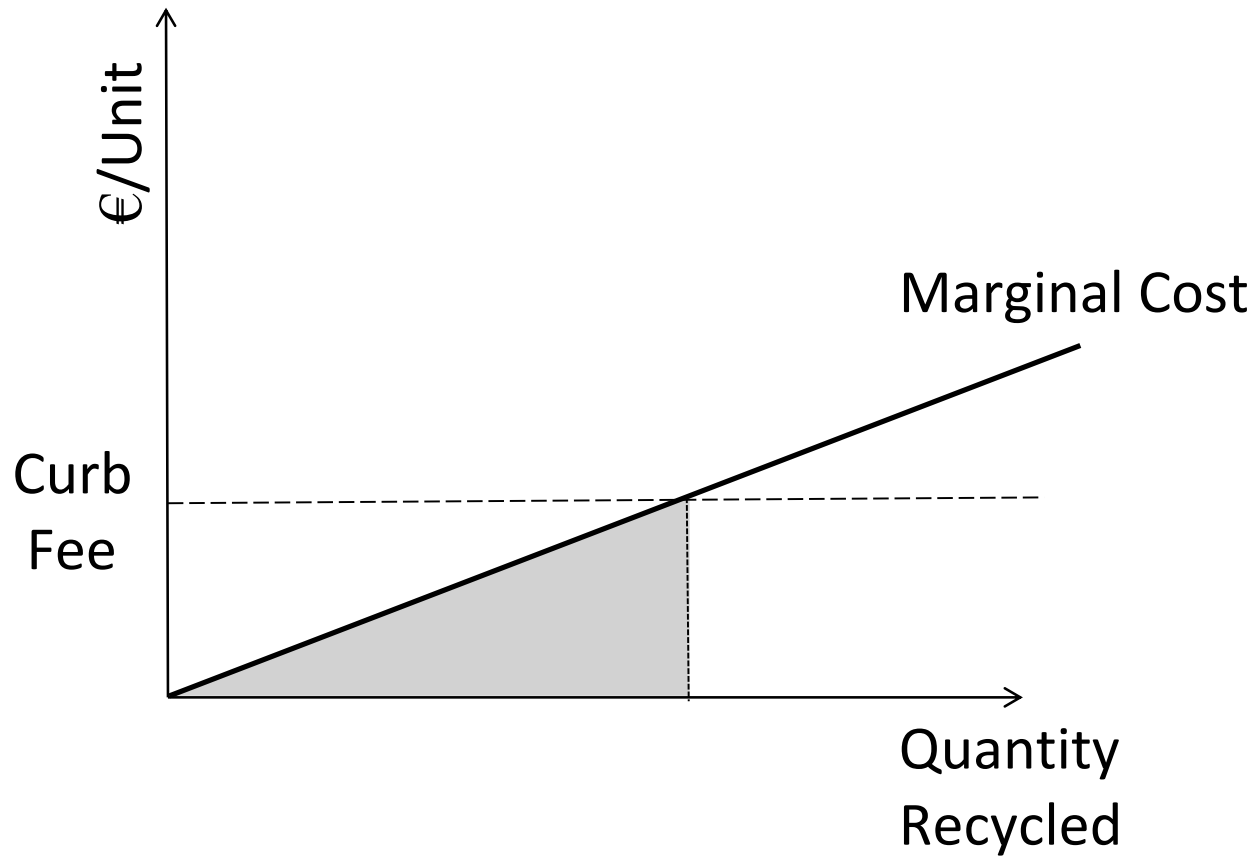
External Disposal Costs

External Recycling Benefits

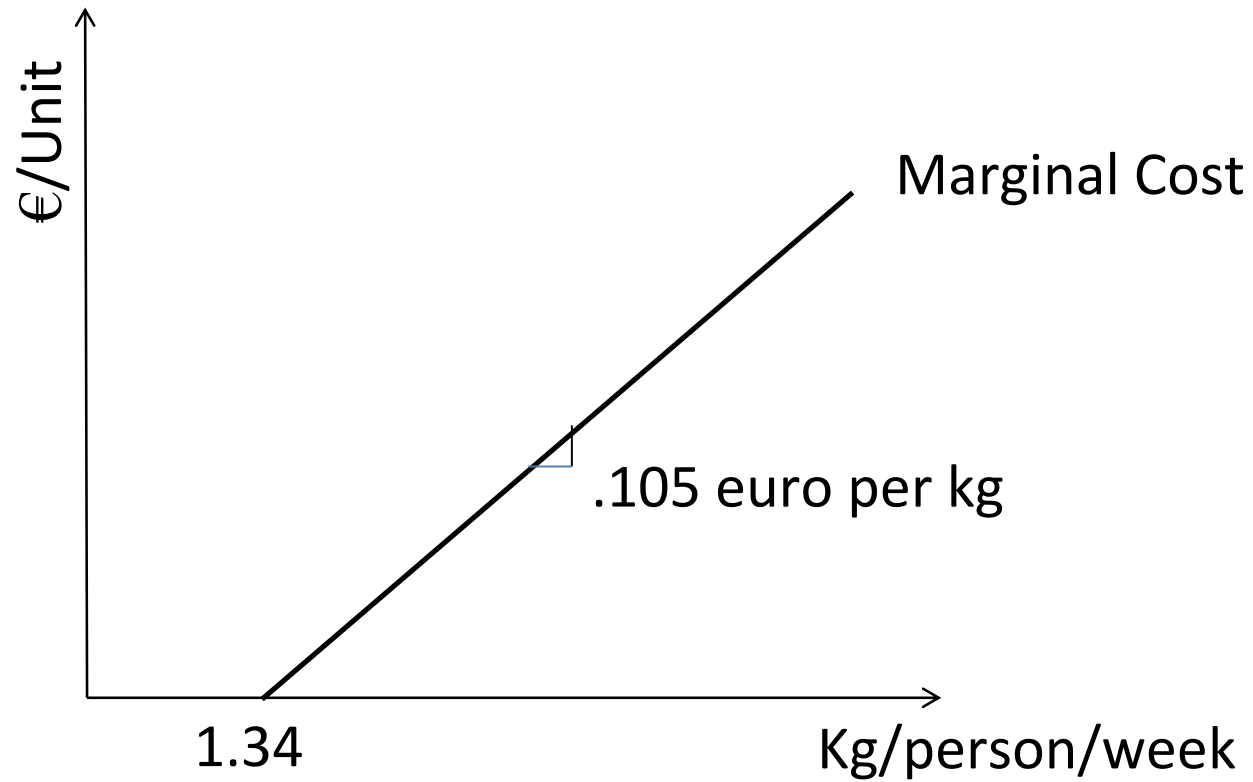
# Household Recycling Costs



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# Household Recycling Costs



Household recycling costs average €2.13 million per municipality per year (€3.5 per person per year)

In relative terms, these costs to households amount to about 3% of municipal costs

Due to rising marginal costs of recycling, household costs may become more important as recycling rates rise

Municipal Costs

Costs to Households

Social Costs

External Disposal  
Costs

External Recycling  
Benefits

# External Costs of Waste Disposal



Davies and Doble (2004): €3.85 per ton (climate change emissions and waste transportation externalities)

Defra (2004): €3.40 per ton (nuisance effect to neighboring properties)

Porter (2002): €11.60 for landfills; €15.45 for incinerators

Dijkgraaf (2008): €30 per ton for incineration



# External Cost of Disposal



Based on this literature, assume €8/ton for landfill disposal and €30/ton for incineration

External disposal costs average €8.2 million per municipality per year

In relative terms, external disposal costs amount to about 12.5% of municipal waste costs

Municipal Costs

Costs to Recycling  
Households

Social Costs

External Disposal  
Costs

External Recycling  
Benefits

# A switch from virgin to recycled inputs reduces:

Emissions of  
Climate Change  
Gasses

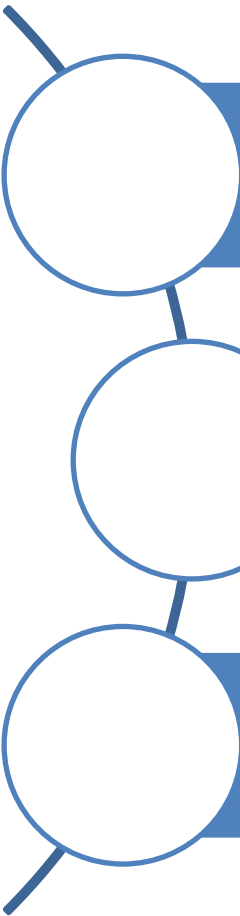
Emissions of  
Acidifying  
Compounds

Emissions of  
Nitrifying  
Compounds

Damage to  
the Natural  
Environment

Releases of  
Toxic  
Substances

# External Benefits of Recycling



Cleary (2009) compares the results of twenty peer-reviewed papers that use Life-Cycle Assessment

For use in this study, these benefits need to be monetized for the recycling of each material

Craighill and Powell (1996) accomplish this task

# Craighill and Powell (1996)

Aluminum:  
€1,367/ton

Glass:  
€145/ton

Paper:  
€175/ton

Steel:  
€184/ton

PET, HDPE,  
and PVC: <0

# External Benefits of Recycling



External benefits of recycling average €22.7 million per municipality per year



In relative terms, external recycling benefits amount to about 35% of municipal costs

Municipal Costs

+ Household  
Recycling Costs

Social Costs =

+ External  
Disposal Costs

- External  
Recycling Benefits

# The Optimal Recycling Rate



Statistically regress the social cost on the recycling rate (flexible functional form)

Control for total quantity of waste, wages, and the number of recyclable materials collected

Use estimated coefficients to predict social cost for every possible rate of recycling (0 to 100)

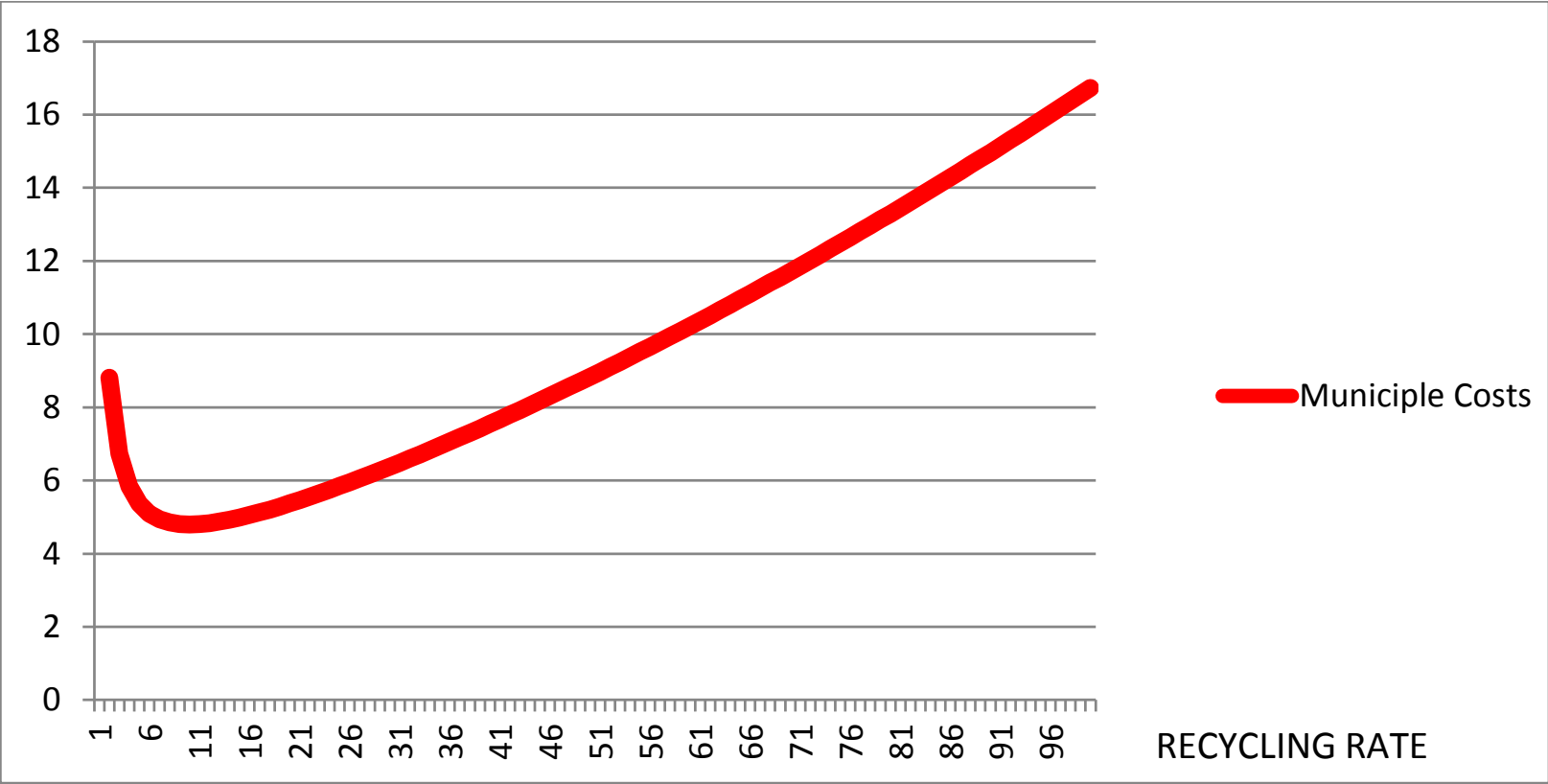


# Regression Results

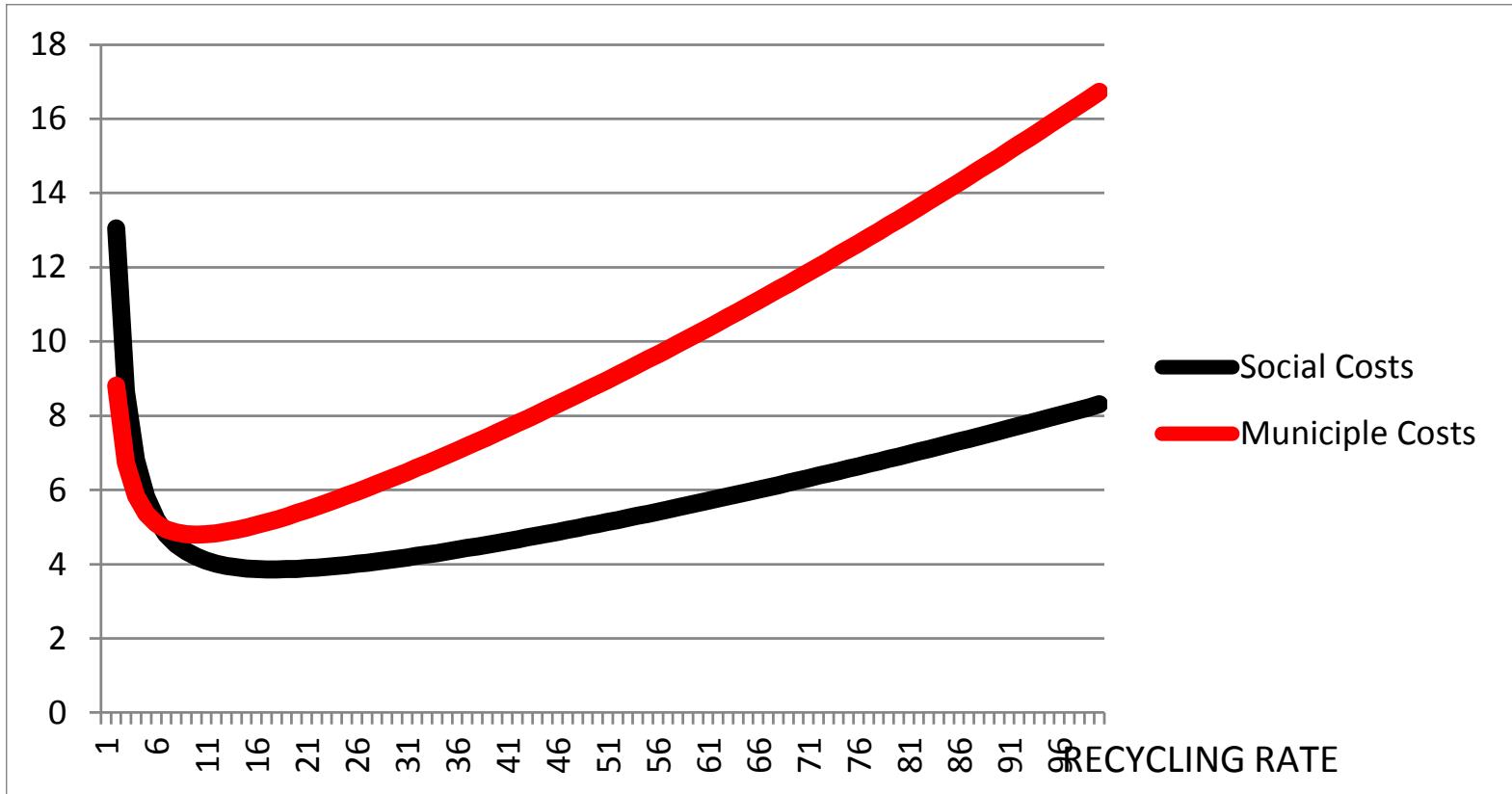
Variable	Coefficient	Standard Error	Significance
Ln(RECRATE)	-1.325	0.452	1% level
[Ln(RECRATE)]^2	0.231	0.084	1% level
Ln(WASTE)	-0.397	0.138	1% level
NUMB	0.009	0.005	10% level
Ln(WAGE)	0.107	0.063	10% level
CONSTANT	20.839	1.975	1% level

N = 419; R<sup>2</sup> (within) = 0.065; R<sup>2</sup> (between) = 0.660; R<sup>2</sup> (overall) = 0.618

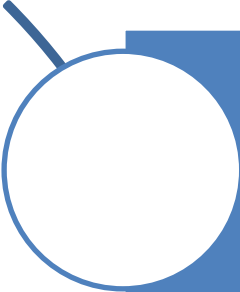
# Municipal Recycling Costs (Billion Yen)



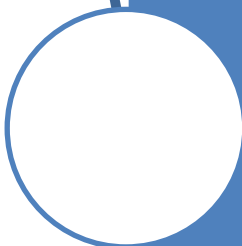
# Social Recycling Costs (Billion Yen)




# For the average municipality...



Increasing the recycling rate from 10% to 18% decreases the social cost of waste management by €5.28 per person per year



Any recycling above 18% is estimated to increase the social cost of managing waste



The social cost of recycling 48%, the highest recycling rate observed in the sample, increases social costs by about €18.8 per person per year

# Sensitivity Analysis

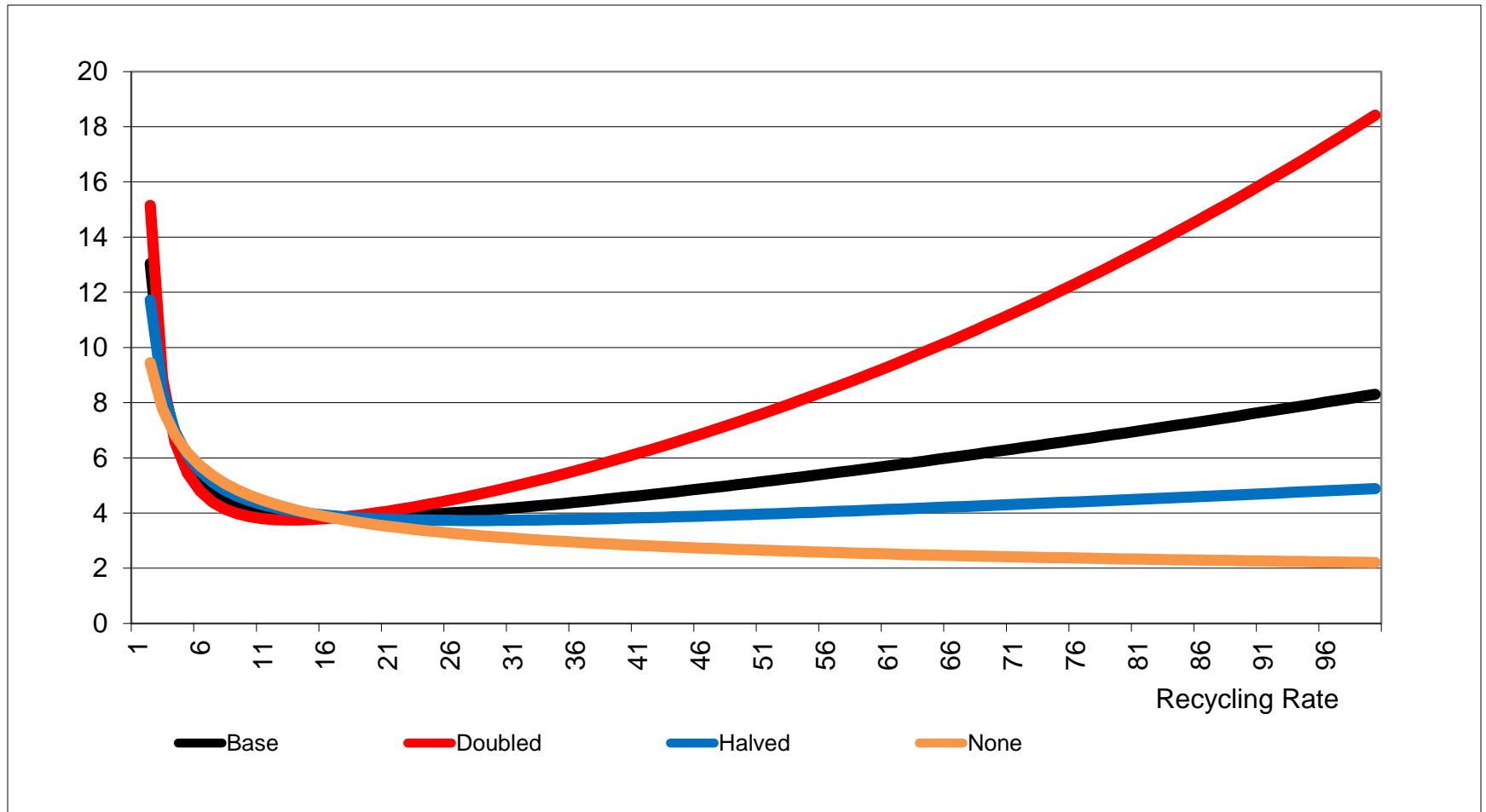


Each of the three sources of external costs/benefits of recycling involved assumptions and uncertainty

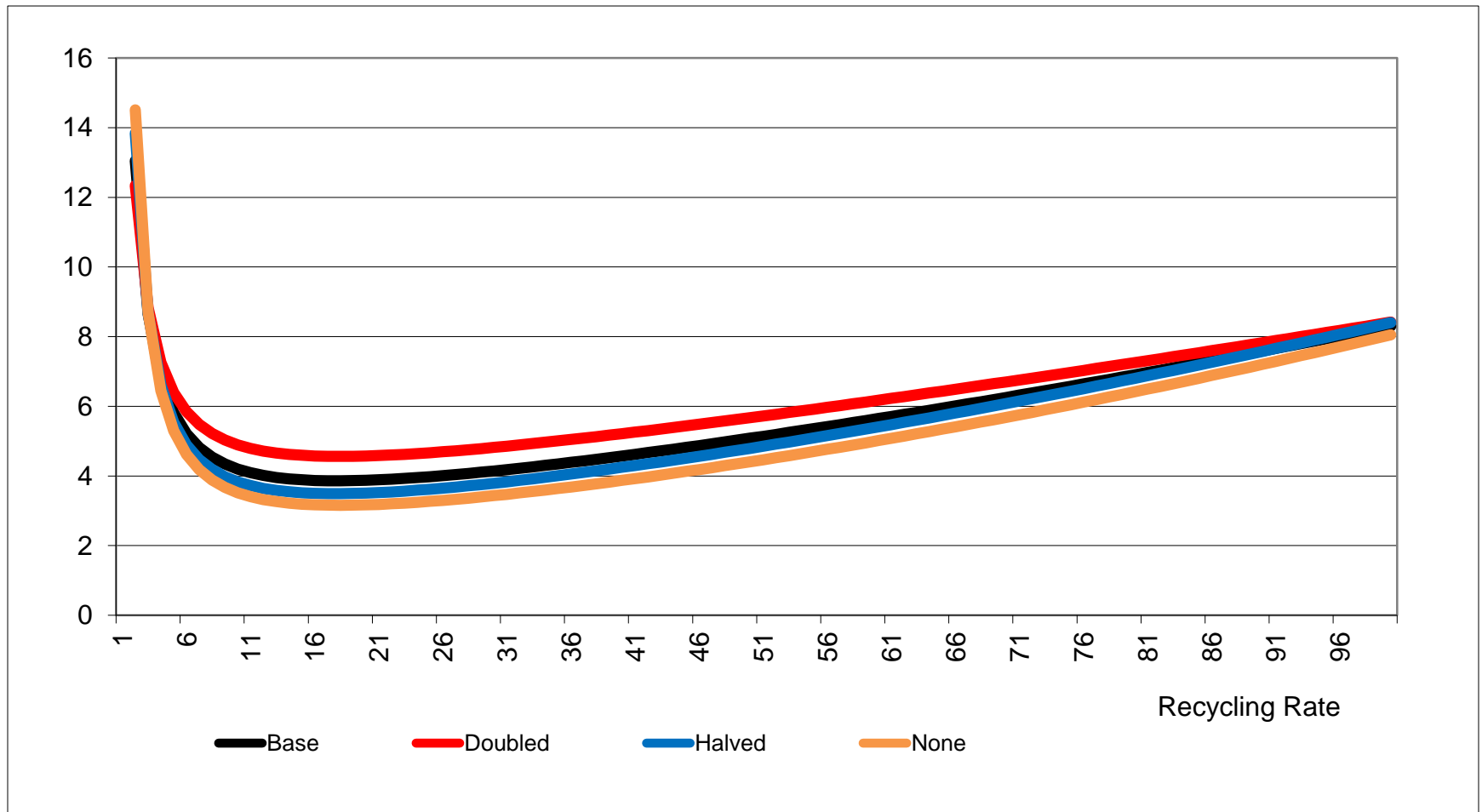
Of interest is how sensitive the main result is to changes in each of these three measures

First double, then halve, and then eliminate each of the three external sources of social cost

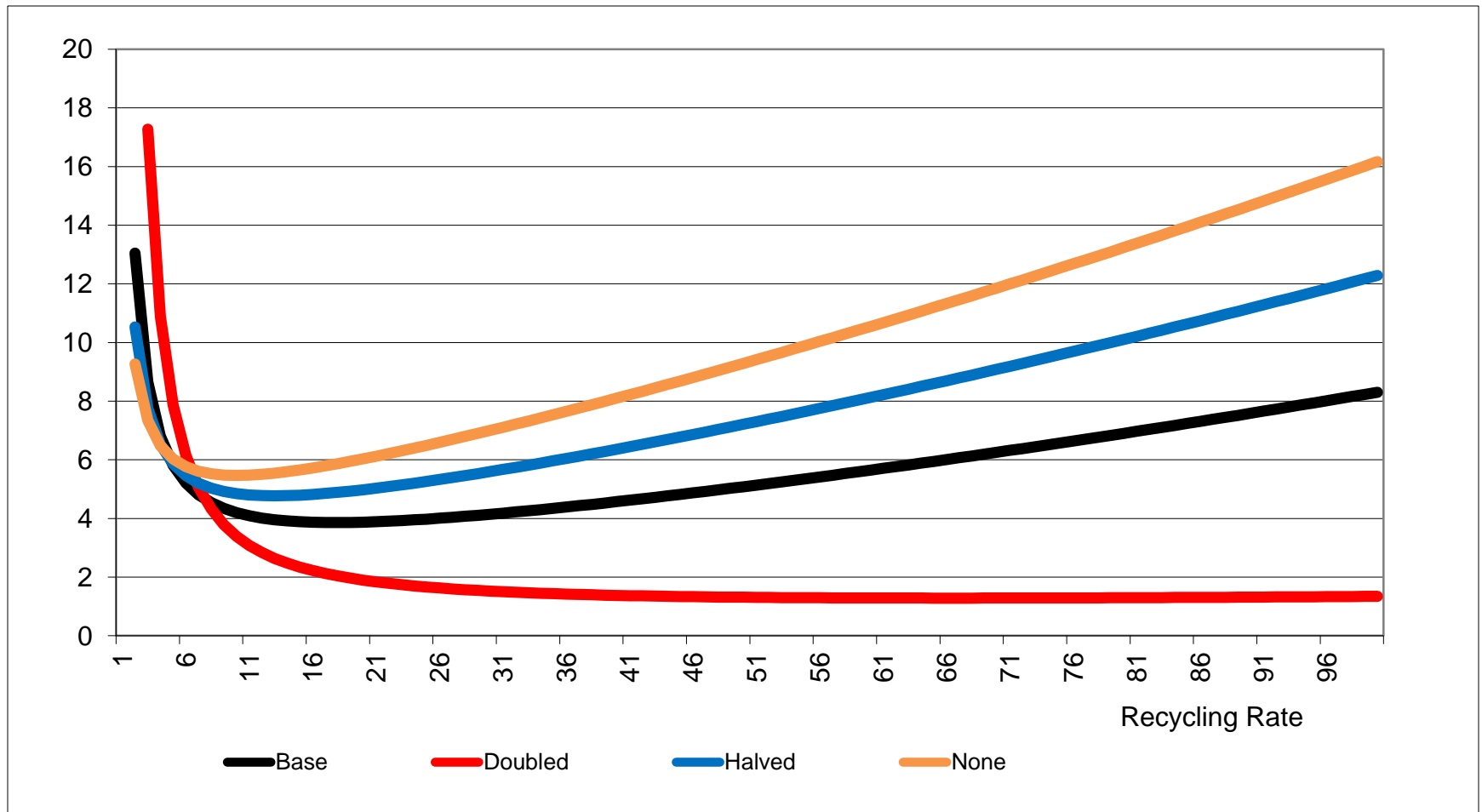
# Varying Household Recycling Costs (Billion Yen)



# Varying the External Costs of Waste Disposal (Billion Yen)



# Varying the External Benefits of Recycling (Billion Yen)





# The Recycling of Specific Materials

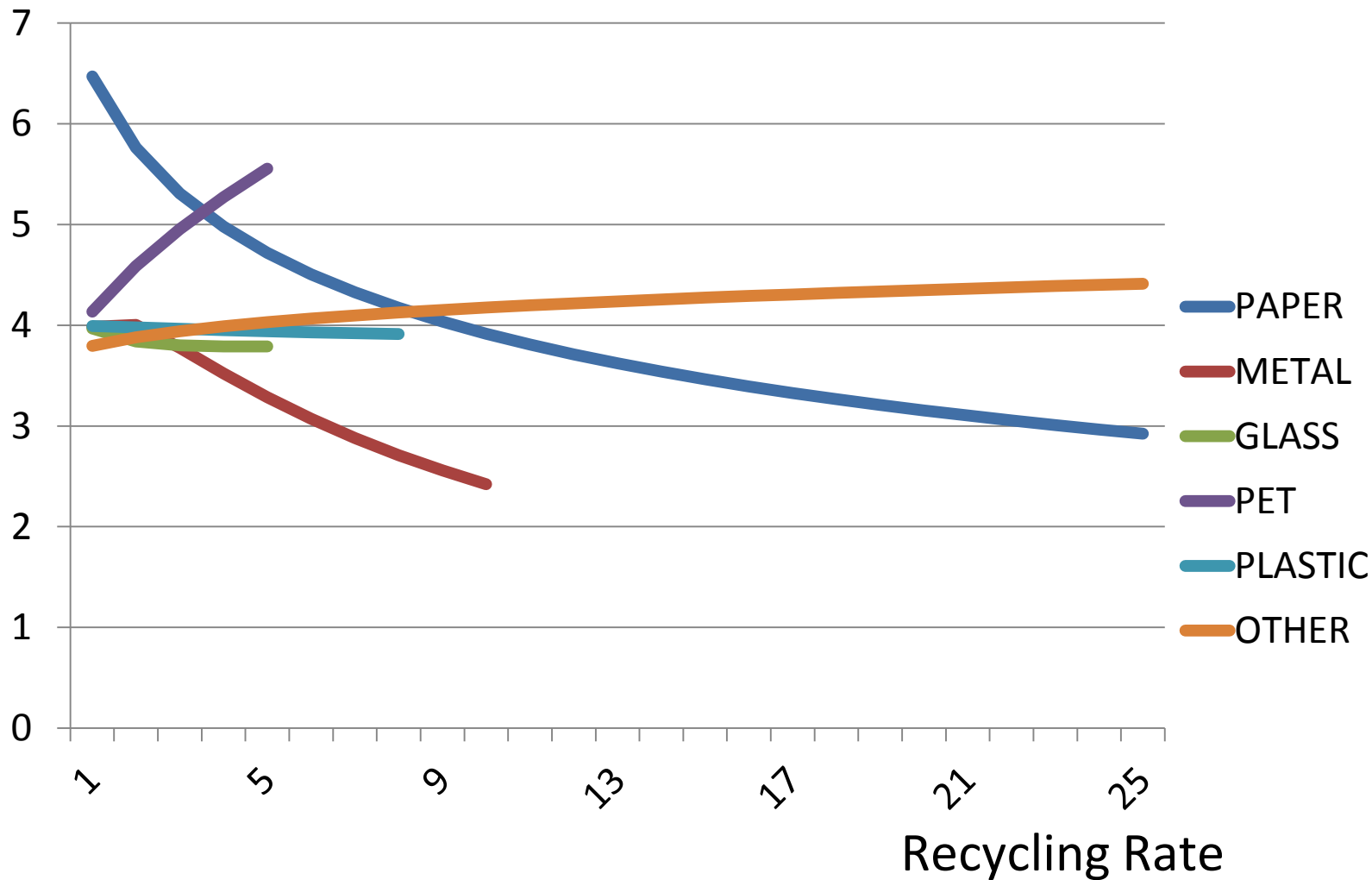


The aggregate recycling rate may not be the appropriate policy target

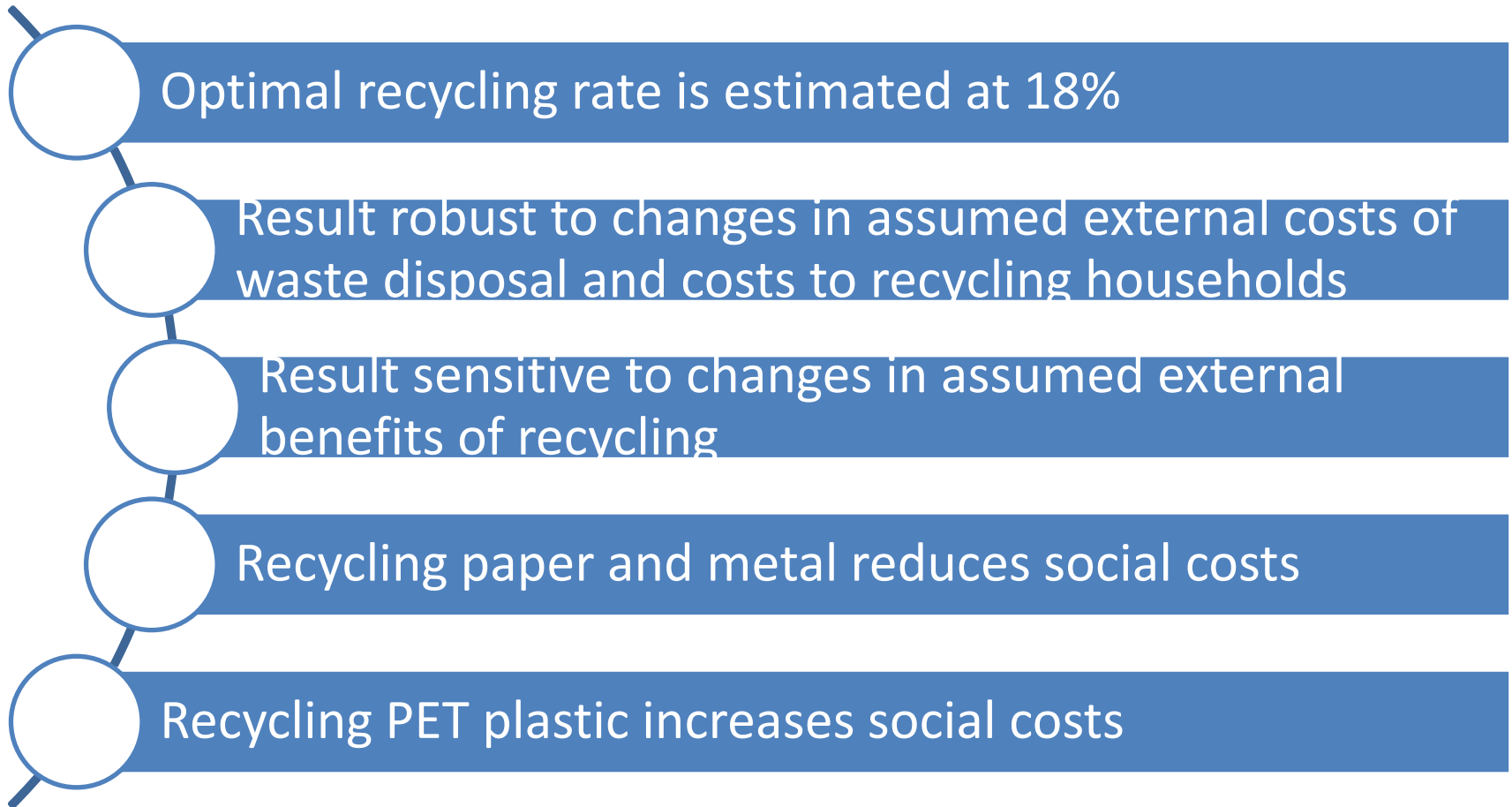
The optimal recycling rate may instead depend on the material being recycled

Data on six materials: metal, paper, glass, PET plastic, other plastics, and “other” materials

# Social Costs (Billion Yen)



# Conclusions

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- Optimal recycling rate is estimated at 18%
  - Result robust to changes in assumed external costs of waste disposal and costs to recycling households
  - Result sensitive to changes in assumed external benefits of recycling
  - Recycling paper and metal reduces social costs
  - Recycling PET plastic increases social costs

# Weaknesses



Source reduction not considered

External cost/benefit assumptions are linear

Not applicable to developing countries

Distributional effects not considered

# Policy Implications



Reconsider goals that encourage large aggregate recycling rates

The cost of recycling the wrong amount is rather small

Focus policy on specific materials rather than on aggregate quantities

Realize that the external benefits of recycling are the driver to waste management policy rather than disposal costs

# Thank You

