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Setting an optimal fuel tax and R&D subsidy for cleaner cars

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Transport and mobility leuven

Introduction

diverging fuel taxes

Introduction

Examples

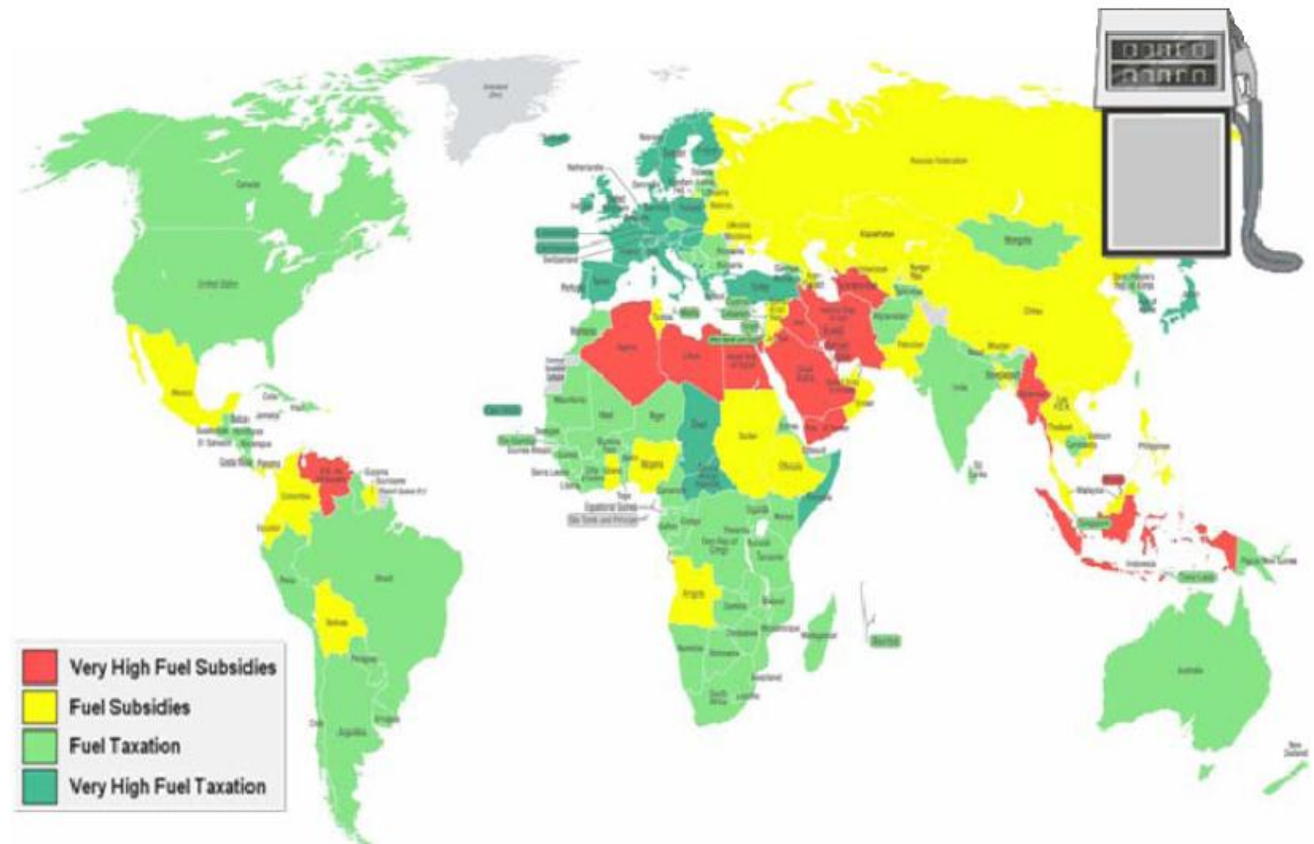
Model

Theoretical Analysis

Numerical example

Conclusions

Comparison of fuel taxes and subsidies worldwide



Source: International Fuel Prices 2005, Dr Gerhard P. Metschies. Deutsche Gesellschaft für Technische Zusammenarbeit **GTZ** GmbH. *(www.gtz.de/fuelprices)*

Introduction

diverging fuel standards

Introduction

Examples

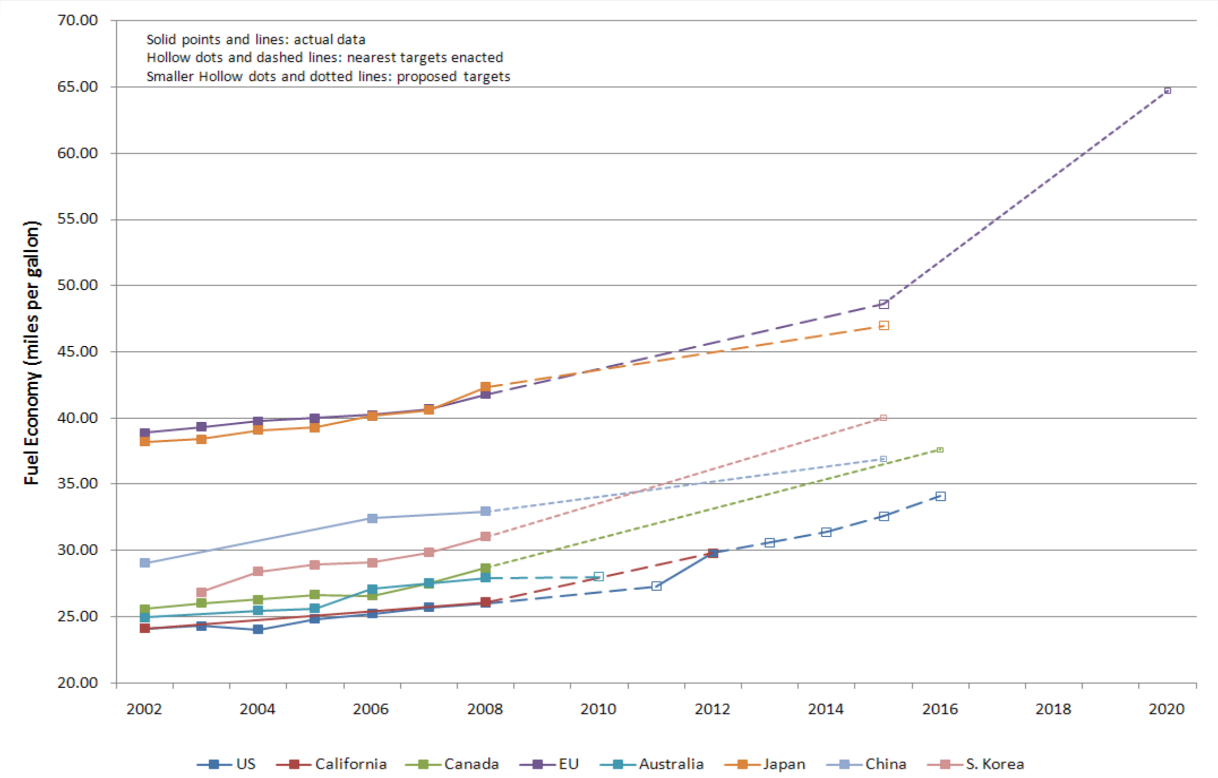
Model

Theoretical Analysis

Numerical example

Conclusions

Comparison of actual and projected fuel economy for new vehicles



Source: An, F., and A. Sauer. 2004. Comparison of Passenger Vehicle Fuel Economy and GHG Emission Standards Around the World. Pew Center on Global Climate Change, Washington, DC; Updated data obtained from www.pewclimate.org, July 2010.

Introduction

Arguments for different policies

- Significant differences in CO_2 policies in the car market.
  - Political economy:
    - Lobbying
    - Differences in preferences: Valuing the environmental damage
  - Environmental policy as trade instrument
    - Strategic behavior of governments
    - Example: Subsidies to national car companies.
  - Multiple externalities
    - Local pollution, global pollution and R&D spillovers
  - Degree of competition within the market

INTRODUCTION

Research focus

Introduction

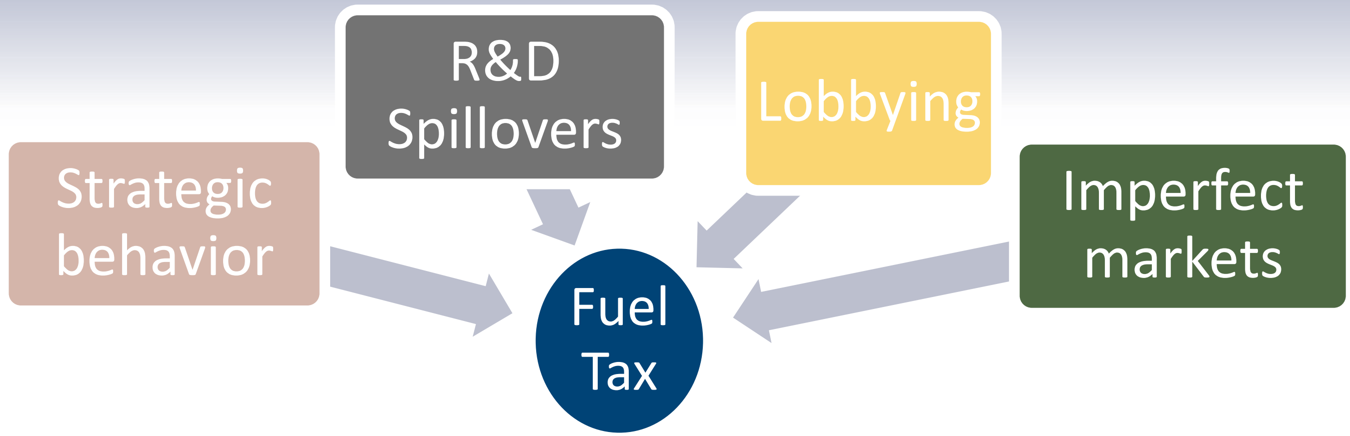
Examples

Model

Theoretical Analysis

Numerical example

Conclusions



- What is the *aggregate* effect on the optimal government policy?
- What is the *relative importance* of the different effects when setting a fuel tax (or subsidy for R&D)?
- *How do these effects enforce each other?*

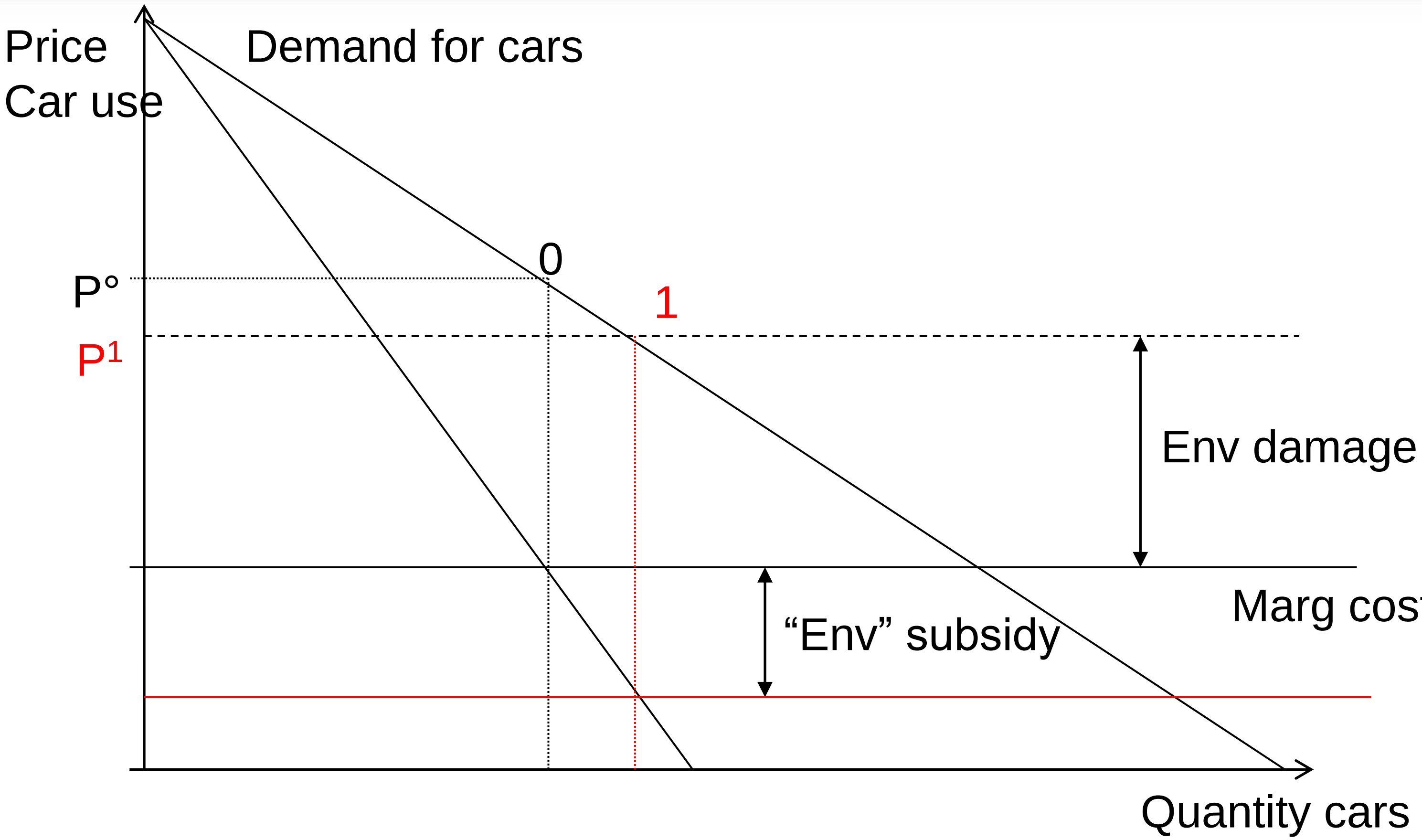
→ Within the car market

Outline

- Introduction
- Intuitive Examples
- Model
- Theoretical Analysis
- Numerical example
- Conclusions & Further Research

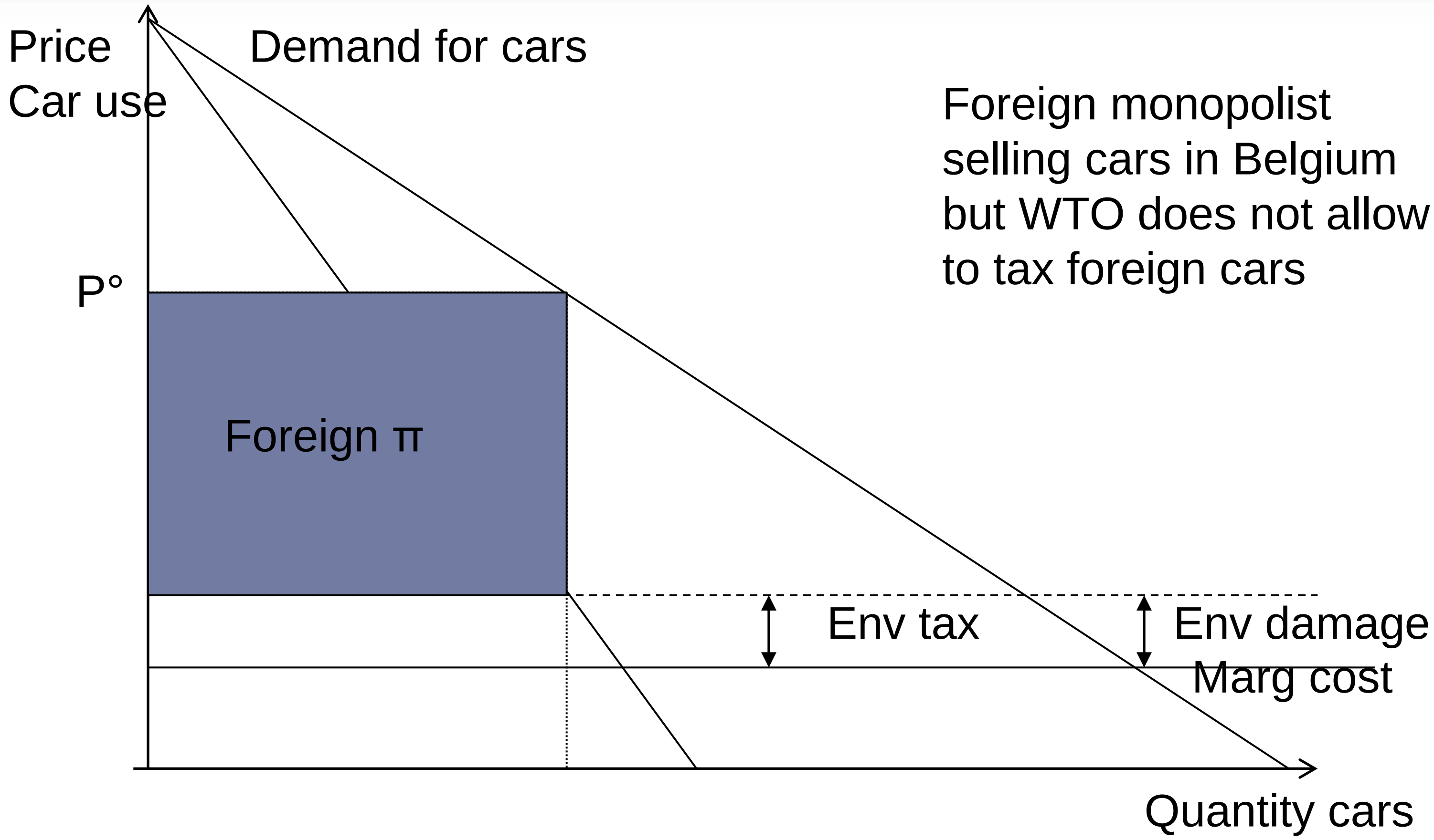
Intuitive examples

Imperfect markets



Intuitive examples

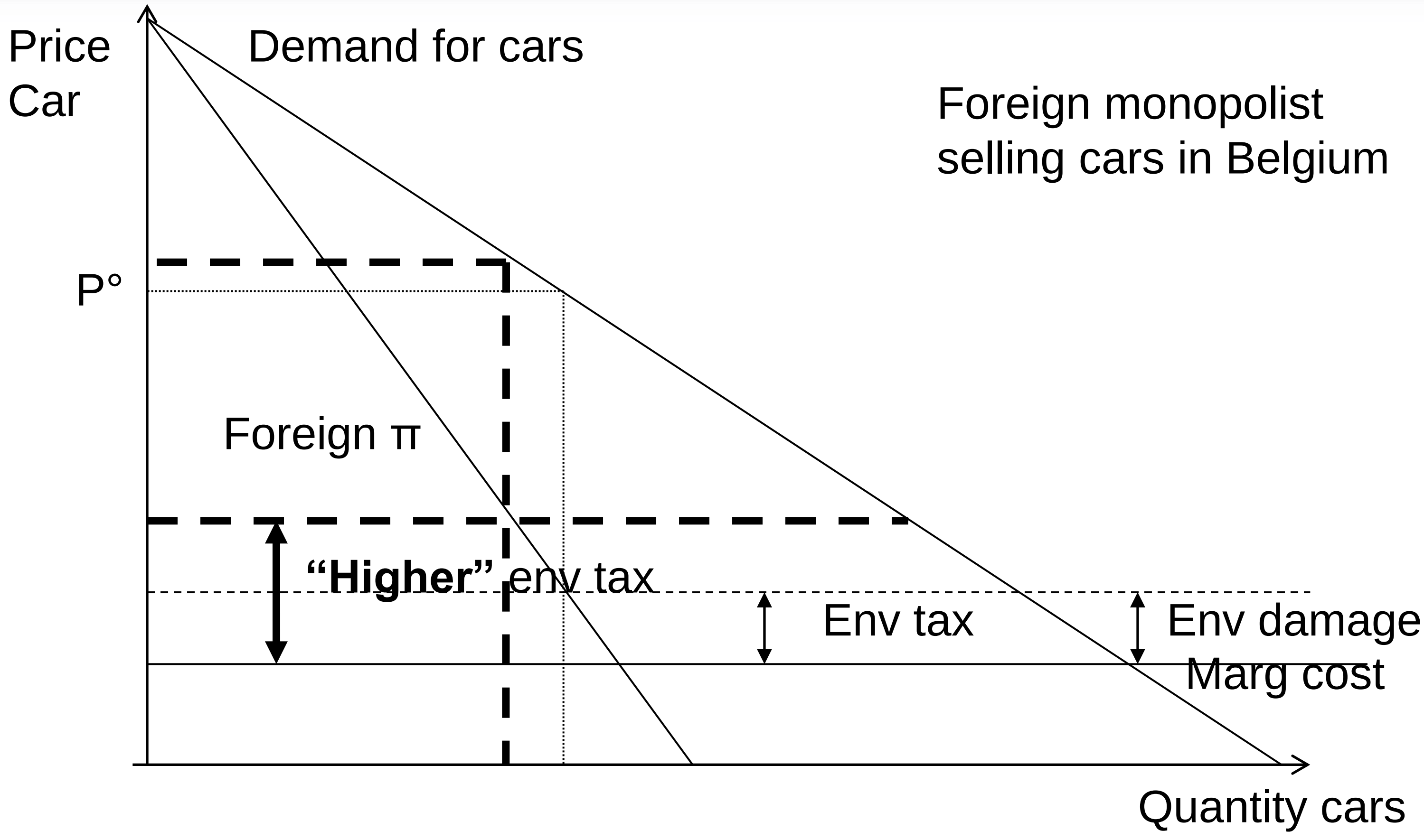
Strategic behavior



Foreign monopolist selling cars in Belgium but WTO does not allow to tax foreign cars

Intuitive examples

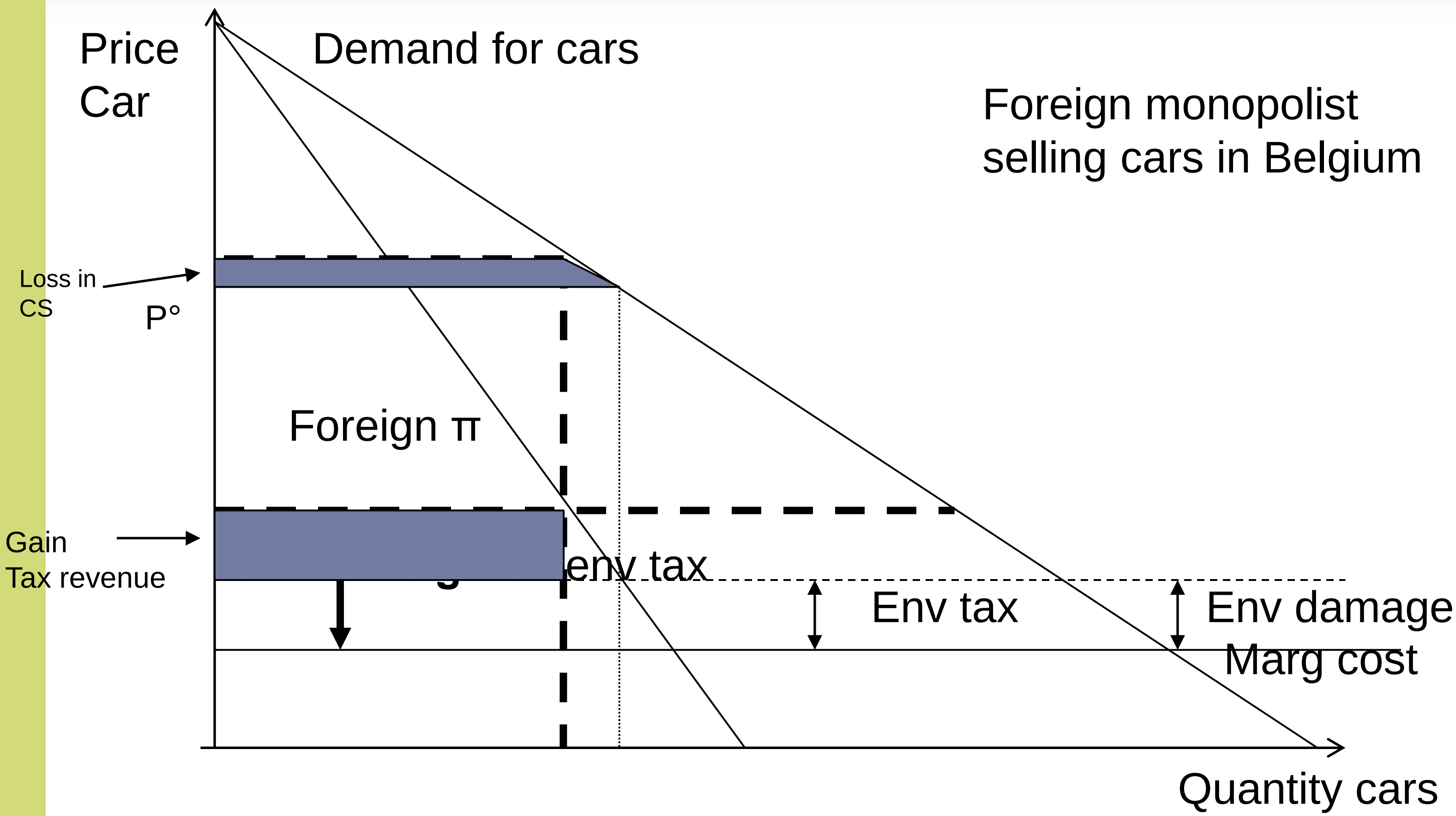
Strategic behavior



Intuitive examples

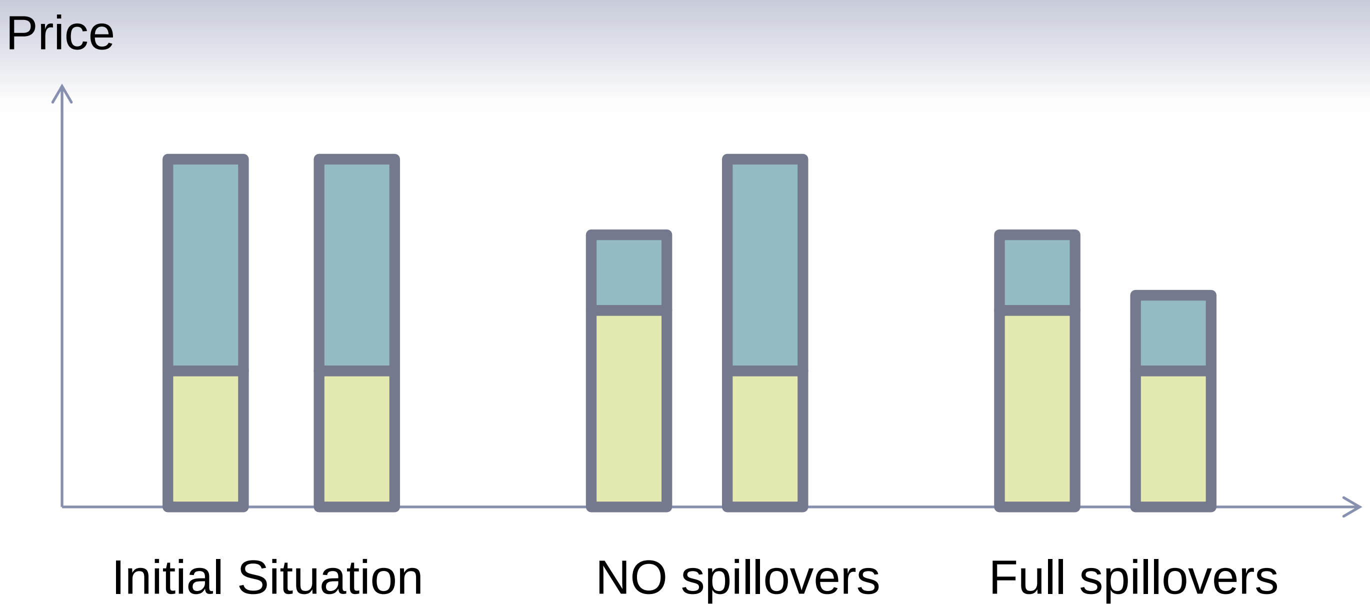
Strategic behavior

- Introduction
- **Examples**
- Model
- Theoretical Analysis
- Numerical example
- Conclusions



INTUITIVE EXAMPLES

R&D Spillovers



R&D investments should be supported by an R&D subsidy: both the price for the car is lowered and the total emissions decrease.

Intuitive examples

Lobbying

- Assume that fuel efficiency level depends on fuel taxes in two countries: $x(t_1,t_2)$ and $dx/dt_i > 0$
- If country 2 is not interested in the environment, then country 1 increases its tax until the desired efficiency level.
  - Benefit for country 2: ‘Free’ fuel efficient cars
  - Cost for country 1: car prices increases through both fuel efficiency and tax level

→ Leakage! Caring about environment decreases welfare more than just by adding technology costs

Intuitive examples

Lobbying | R&D Spillovers | Strategic behavior

- If we allow for other influences, the lobby effect can be completely turned around!
  - R&D subsidies become an instrument to strategically return tax income.
  - Strategic behavior creates competitive advantages within both the domestic and foreign market.
  - If country 1 is the only country to set high taxes, it can benefit through market effects.

  → Caring about environment now creates a competitive advantage…

INTRODUCTION

Research focus

Introduction

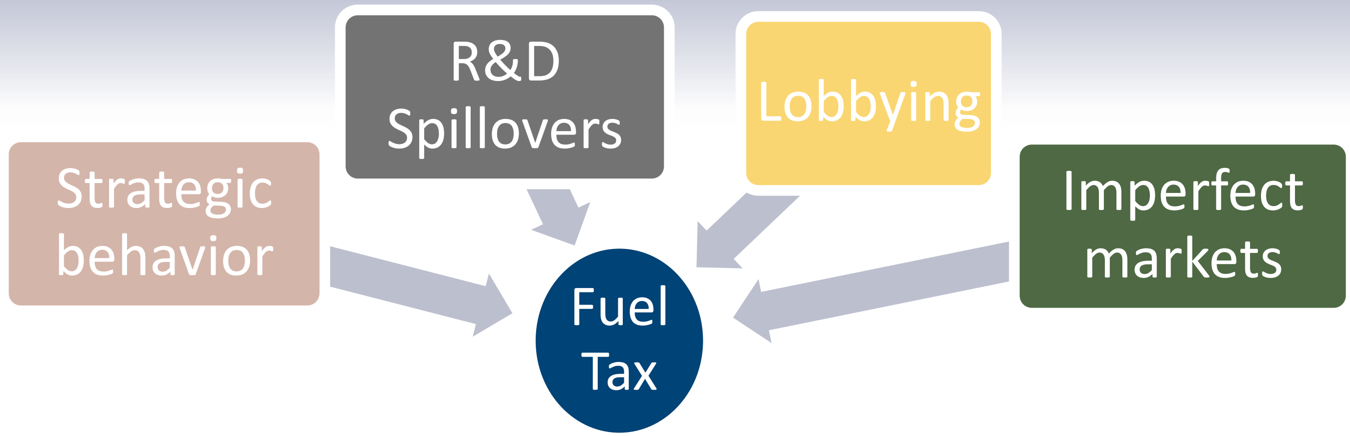
Examples

Model

Theoretical Analysis

Numerical example

Conclusions



- What is the *aggregate* effect on the optimal government policy?
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→ Within the car market

Model

Building blocks

- We start from a simple "strategic model" (Ulph and Ulph, 2007) where 2 governments and 2 monopolistic firms take decisions.
- Governments set a tax on fuel (and a subsidy for R&D), and can do this cooperatively or strategically.
- Each company decides on the number of cars and how fuel efficient they are.
- We can easily add:
  - Spillovers in R&D
  - Differences in valuation of environmental damage

Model

Approach

Introduction

Examples

Model

Theoretical Analysis

Numerical example

Conclusions

Stage 1: Each government decides on optimal tax and subsidy level by maximizing welfare

Stage 2: Companies decide on abatement level. They take into account:

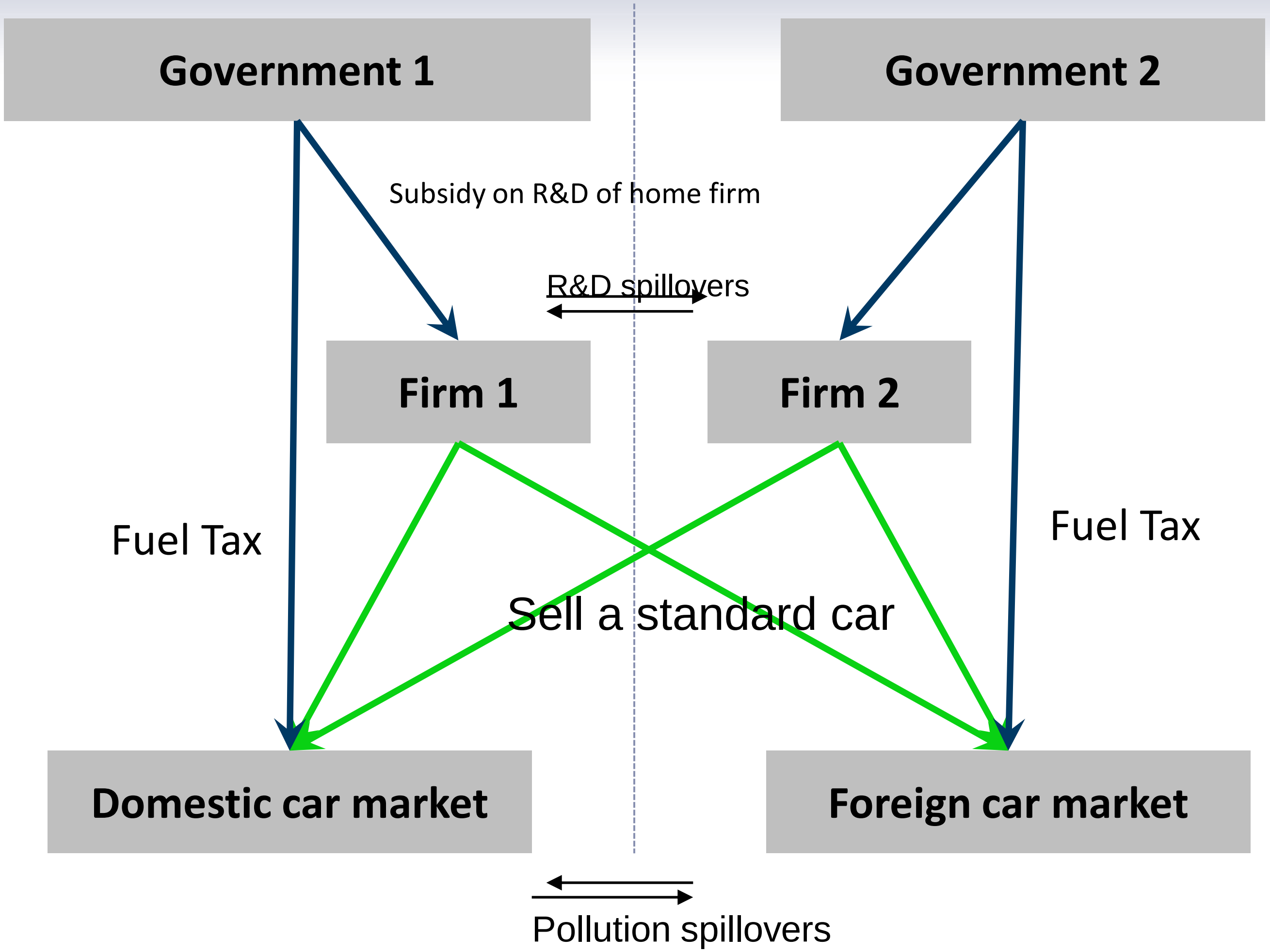
- Existing tax and subsidies of governments
- Abatement by the competitors

Stage 3: Firms decide on output levels in both countries, taking the output of the other as given

→ Solving backwards to find an optimal tax

Model

Setup



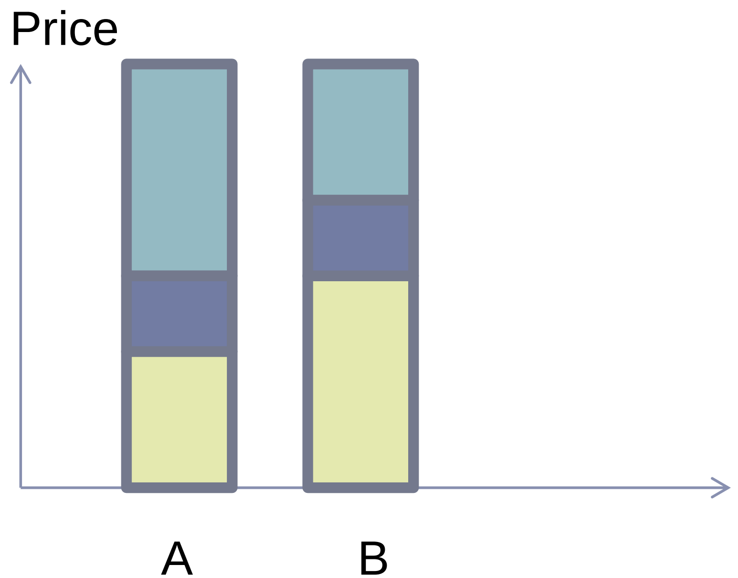
Government 1
Government 2
Subsidy on R&D of home firm
R&D spillovers
Firm 1
Firm 2
Fuel Tax
Fuel Tax
Sell a standard car
Domestic car market
Foreign car market
Pollution spillovers

Model

Assumptions

- Both firms sell only 1 (homogeneous) car, that can **differ only** in the pollution level e per unit of production –
- Fixed mileage per vehicle.
- Market:
  - Linear demand:
  - 1 price for both gasoline and car!

$$p = a - b(y_1 + y_2)$$



ANALYSIS

Stage 3

Output Decision y_{ij}

- Each firm sets an optimal output by maximizing profits.

$$y_{11} = \frac{a + c_{12} - 2c_{11}}{3b}, \qquad where\ c_{ij}\ (t_i, x_1, x_2)$$

- The number of cars sold in each country depends on
  - The fuel tax in that country
  - The efficiency level of the car and the car of their competitor

ANALYSIS

Stage 2

Choosing fuel efficiency x_i

$$2\beta x_1 = \left(1 + \frac{1}{3} - \frac{2\delta}{3}\right) g[y_{11}t_1 + y_{21}t_2]$$

- Imperfect competition causes OVER-investments in fuel efficiencies
- Spillovers in R&D create UNDER-investments in fuel efficiencies
  - AND positive externalities are not taken into account!!

Analysis

Stage 1: governments set fuel taxes

- Governments take into account their influence on the firm's decisions
- With a COOPERATIVE equilibrium, we maximize:

$$\max_{t_1,t_2} \frac{b}{2}(y_{11}+y_{12})^2+(p-d_1)y_{11}+(p-d_2)y_{12}-\frac{b}{2}(y_{21}+y_{22})^2+(p-d_1)y_{21}+(p-d_2)y_{22}$$
$$-\beta x_1^2-\beta x_2^2-g\,D\{e_1(y_{11}+y_{21})+e_2(y_{12}+y_{22})\}$$

  - Consumer surplus
  - Profits by the firms
  - Abatement costs
  - Total pollution cost of emissions

Analysis

Result

$$(t_1 - D')\left\{-\sum_{i,j}\frac{dE_{i,j}}{dt_1}\right\} = \delta\left[t_1 g(y_{11}+y_{21})\frac{dx_2}{dt_1} + t_1 g(y_{12}+y_{22})\frac{dx_1}{dt_1}\right] + \left[\sum_{i,j} b y_{i,j}\frac{dy_{i,j}}{dt_1}\right] + \left[\frac{(t_1 y_{11}+t_2 y_{21})g(2\delta-1)}{3}\frac{dx_1}{dt_1} + \frac{(t_1 y_{12}+t_2 y_{22})g(2\delta-1)}{3}\frac{dx_2}{dt_1}\right]$$

- Left hand side: A government sets a tax equal to marginal damage without any strategic effects or other imperfections.
- Right hand side: 3 effects, resulting from
  - Imperfect competition
  - Positive R&D spillovers

(Note: no strategic behavior and no different damage valuation)

ANALYSIS

Result

$$(t_1 - D')\left\{-\sum_{i,j}\frac{dE_{i,j}}{dt_1}\right\}$$

$$= \delta\left[t_1 g(y_{11} + y_{21})\frac{dx_2}{dt_1} + t_1 g(y_{12} + y_{22})\frac{dx_1}{dt_1}\right] + \left[\sum_{i,j} by_{i,j}\frac{dy_{i,j}}{dt_1}\right]$$

$$+ \left[\frac{(t_1 y_{11} + t_2 y_{21})g(2\delta - 1)}{3}\frac{dx_1}{dt_1} + \frac{(t_1 y_{12} + t_2 y_{22})g(2\delta - 1)}{3}\frac{dx_2}{dt_1}\right]$$

- Direct spillover effect: companies do not account for positive externalities of R&D efforts
  - -> Positive incentive
- Output effect: with imperfect competition, output is already heavily reduced
  - -> Negative incentive
- Correcting for second stage imperfections
  - -> Positive OR negative incentive!

Numerical illustration

- Numerical example as an exploratory exercise
  - We start from the cooperative equilibrium
  - Comparison with a non cooperative equilibrium
  - Look at lobbying effects, degree of competition, R&D spillover intensity
  - What is the effect of R&D subsidies?

Numerical illustration

- selected parameters:
  - Each car uses 5l of gasoline to drive 100km
  - In equilibrium, both firms sell 4000 cars in each market at a price of 16000 € .
  - Production cost equals 12000 €
  - Cost of pollution
    - Local pollution : 0.20 €/l
    - Global pollution: 0.20€/l
  - Abatement cost: 3 200 000€ * x^2

Numerical illustration

Benchmark equilibrium – only fuel taxes, no subsidies

	Cooperative	Non-cooperative
Welfare	$6.76 * 10^7$	$4.56 * 10^7$
Tax rate t_i (€/l)	0.18	0.46
Output y_{ii}	3460	2829
Abatement x_j (l/100km)	0.47	0.98

Table 4.1. Optimal solution for a cooperative and non-cooperative equilibrium. R&D spillovers are equal to 0.2

- Market imperfections lead to low taxation in a cooperative equilibrium
  - Market surplusses decrease partially compensate environmental damage
  - Making cars more fuel efficient through fuel taxes is costly!
- Strategic governments tend to overinvest in fuel efficiency

Numerical illustration

Benchmark equilibrium – only fuel taxes, no subsidies

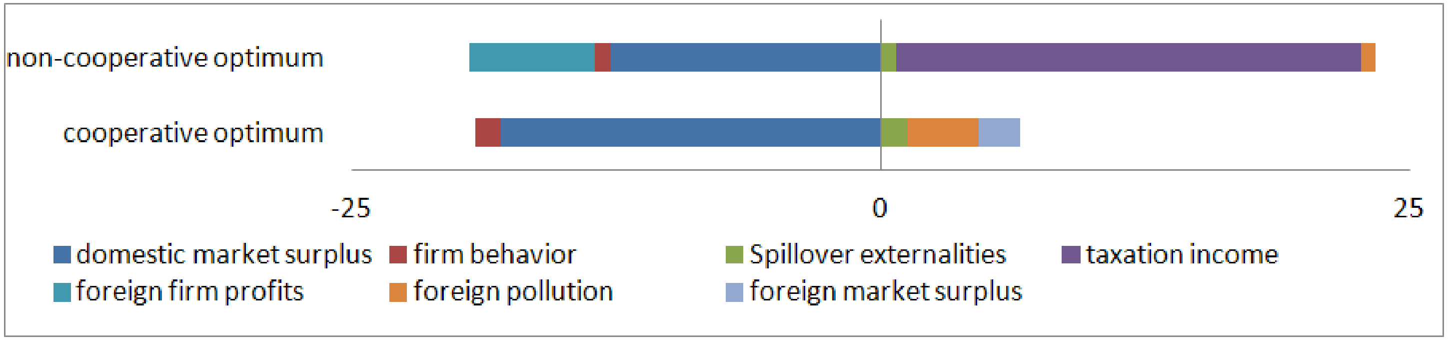


Figure 4.1. The relative importance of different strategic incentives on the optimal tax level of governments

- incentives for high non-cooperative fuel tax
  - Tax income from non-domestic firms
  - No interest in the foreign consumers
  - Giving the domestic firm a competitive advantage

Numerical illustration

relative spillovers and assessment of pollution damage – only tax no subsidies

	Domestic fuel tax	Foreign fuel tax
Benchmark	0.42	0.42
Only foreign firm has R&D spillovers	0.51	0.35
Foreign government values only local pollution	0.44	0.18
2 domestic firms, 1 foreign firm	0.28	0.5

Table 4.3. optimal fuel taxes in a non-cooperative equilibrium with asymmetric structure

- Not valuing global pollution does not affect foreign countries significantly (no subsidy policy)
- Having domestic car companies drives down the fuel tax

NUMERICAL ILLUSTRATION

Sensitivity study – with and without subsidy instrument

	No subsidy policy		Subsidy	
	Cooperative	Non-cooperative	Cooperative	Non-cooperative
Fuel Tax	0.21	0.39	0.16	0.38
Subsidy rate			0.34	0.12
Total welfare	$6.71 * 10^7$	$4.06 * 10^7$	$6.74 * 10^7$	$4.03 * 10^7$

Table 4.4.Welfare and tax comparison if a subsidy policy is used by governments (2 companies in each country)

- An R&D subsidy better targets investement imperfections in fuel efficiency
- With strategic governments however, subsidies are just another instrument to maximize profits…

General Conclusions

- Fuel (environmental) tax is mainly used as a disguised trade policy instrument
- Multiple policy instruments decrease overall welfare as trade incentives are more significant
- The optimal fuel tax depends heavily on
  - Degree of competition
  - Tax income
  - Differences in R&D spillovers between countries
- Differences in country characteristics can lead to very distinct policy measures

Further research

- Introduction
- Examples
- Model
- Theoretical Analysis
- Numerical example
- **Conclusions**

- From theory to application: Are we able to explain real world differences?
    - Extension of numerical example (EU, VS, Asia)
    - Adding oil costs
    - Fuel efficiency standards
- Better connection to other models
    - Existing car models (Verboven, 2002)