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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

## Comparison of fuel taxes and subsidies worldwide

Introduction

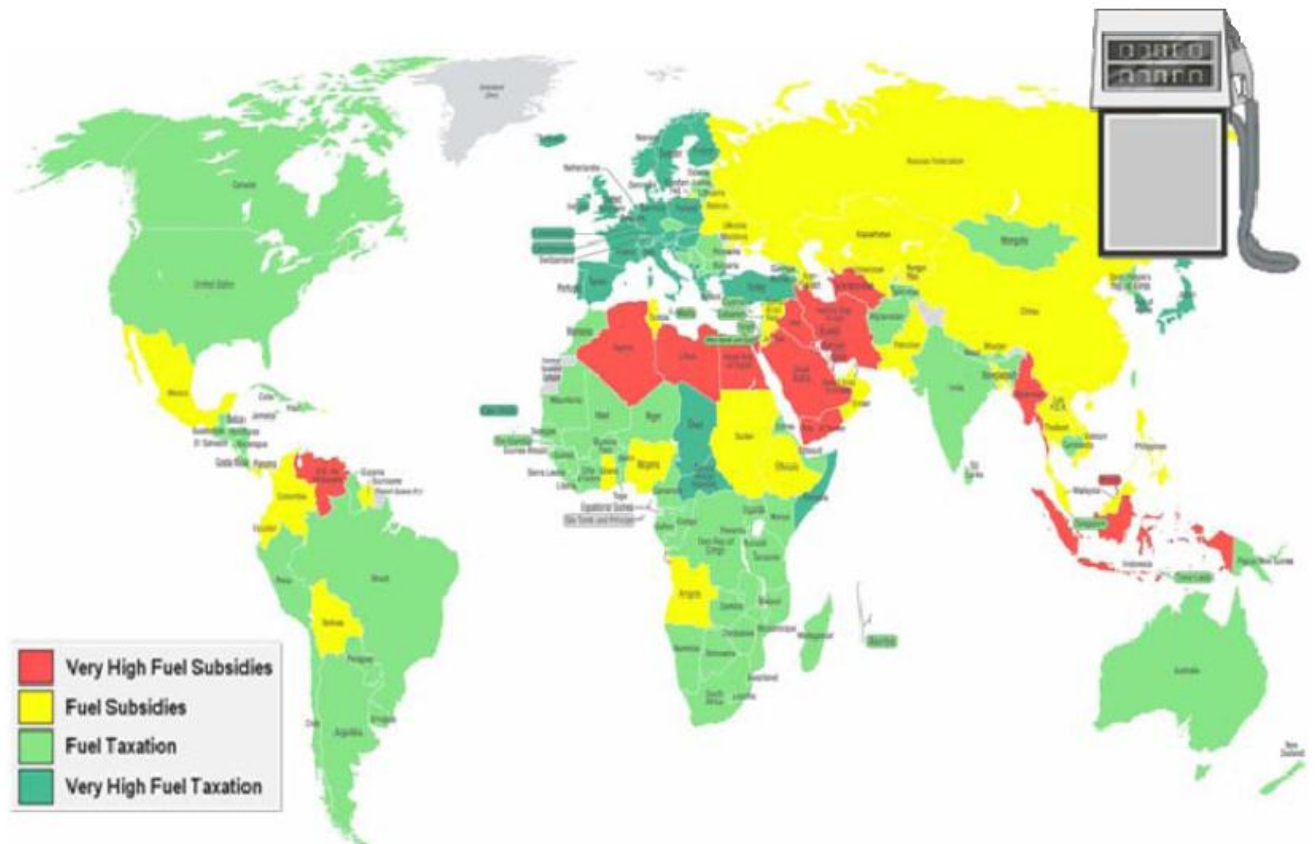
Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions

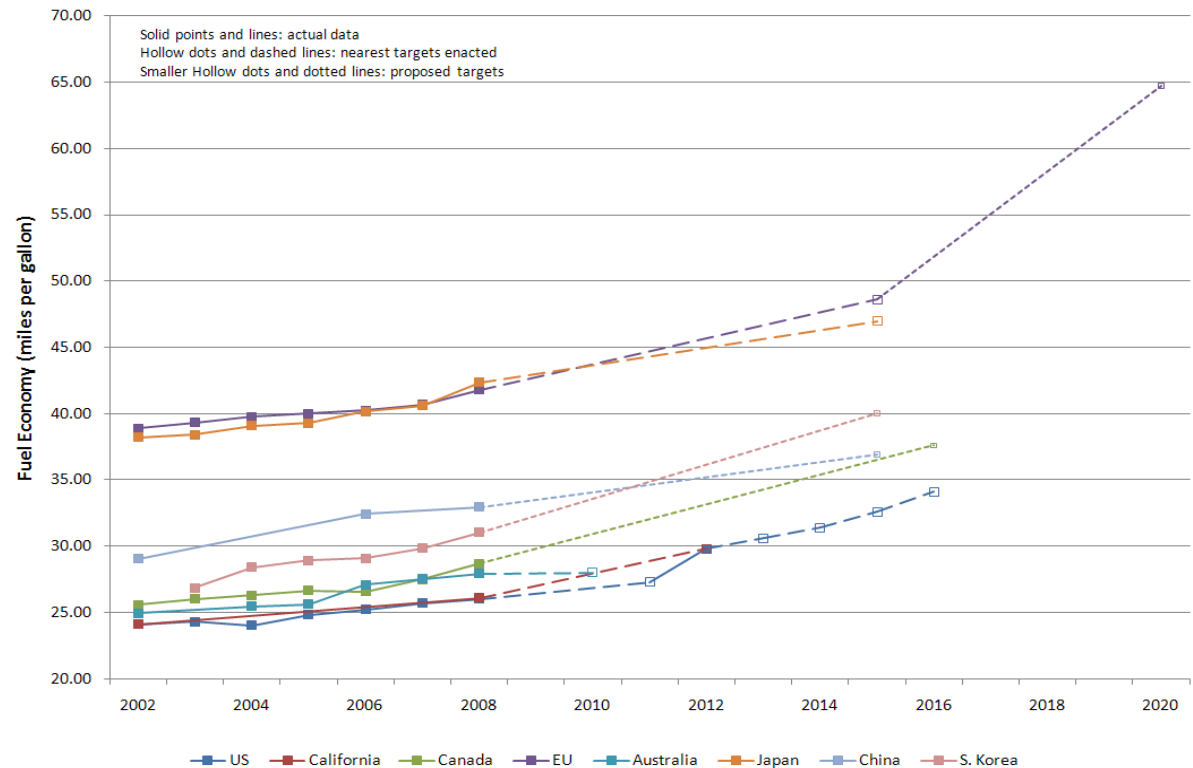


Source: International Fuel Prices 2005, Dr Gerhard P. Metschies. Deutsche Gesellschaft für Technische Zusammenarbeit GTZ GmbH. ([www.gtz.de/fuelprices](http://www.gtz.de/fuelprices))

# INTRODUCTION

## diverging fuel standards

### 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](http://www.pewclimate.org), July 2010.

Introduction

Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions

# INTRODUCTION

## Arguments for different policies

### Introduction

Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions

- ⊙ Significant differences in CO2 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

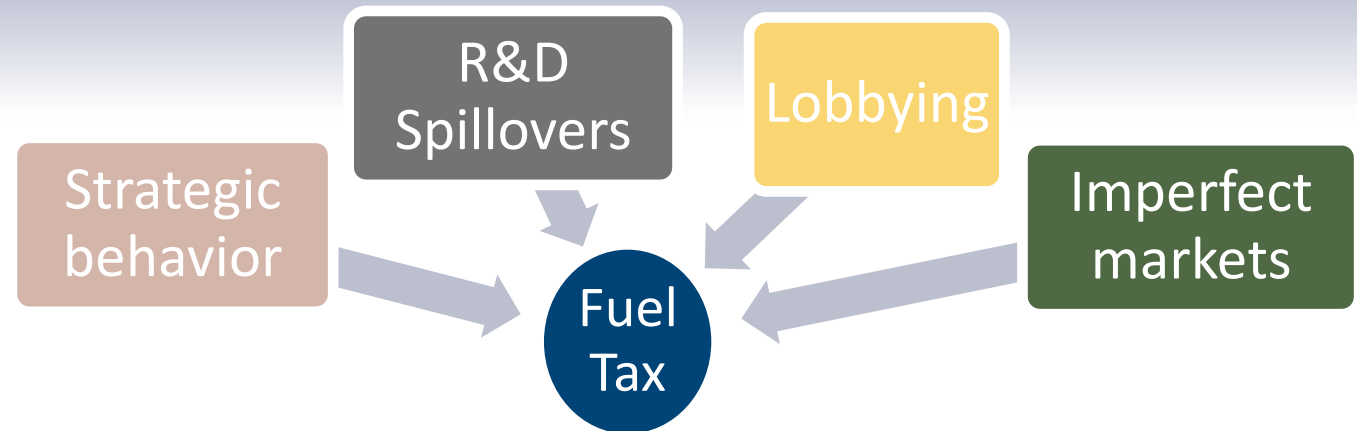
Examples

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

- ① Introduction
- ① Intuitive Examples
- ① Model
- ① Theoretical Analysis
- ① Numerical example
- ① Conclusions & Further Research

# INTUITIVE EXAMPLES

## Imperfect markets

Introduction

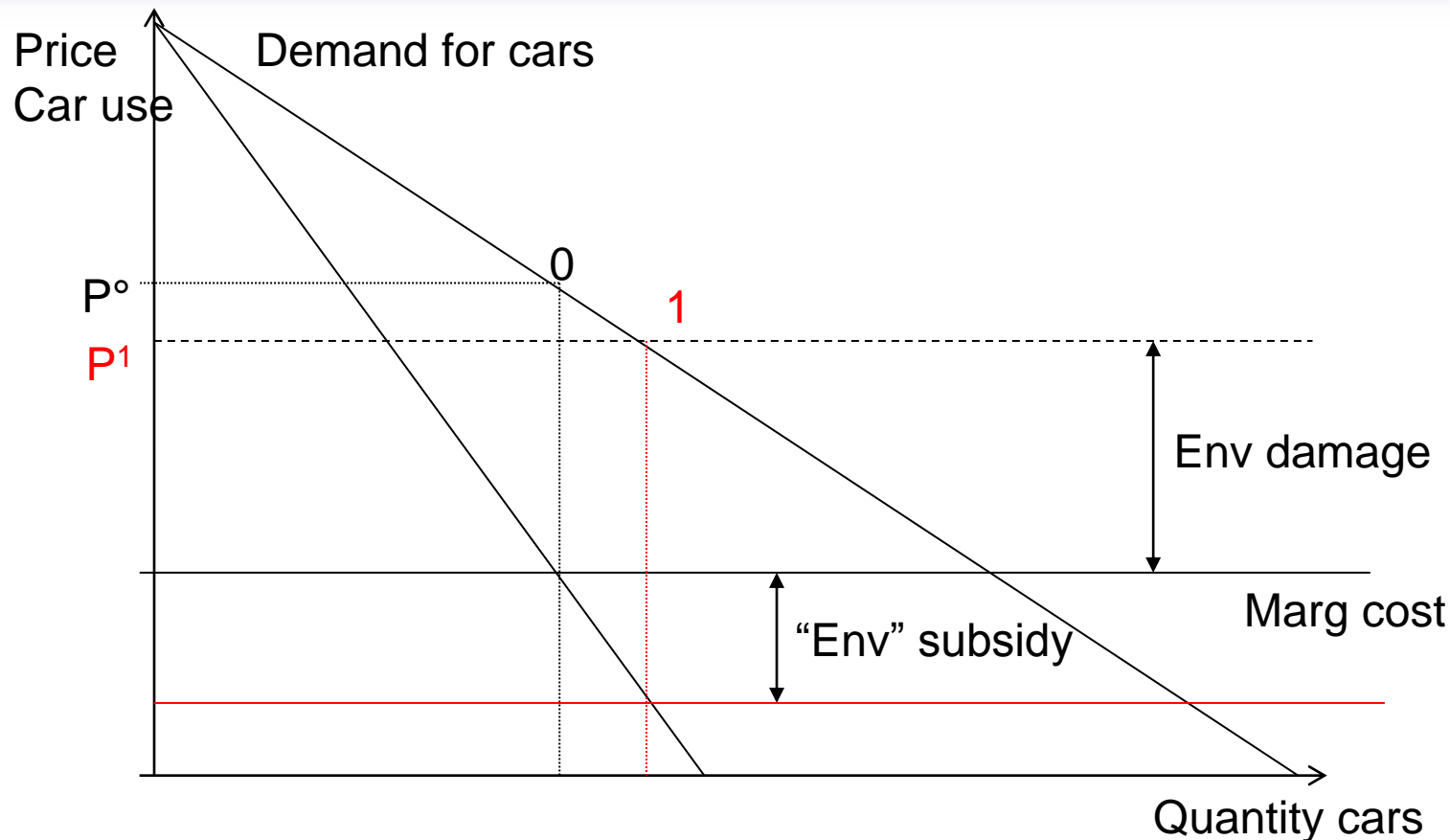
**Examples**

Model

Theoretical  
Analysis

Numerical  
example

Conclusions



# INTUITIVE EXAMPLES

Strategic behavior

Introduction

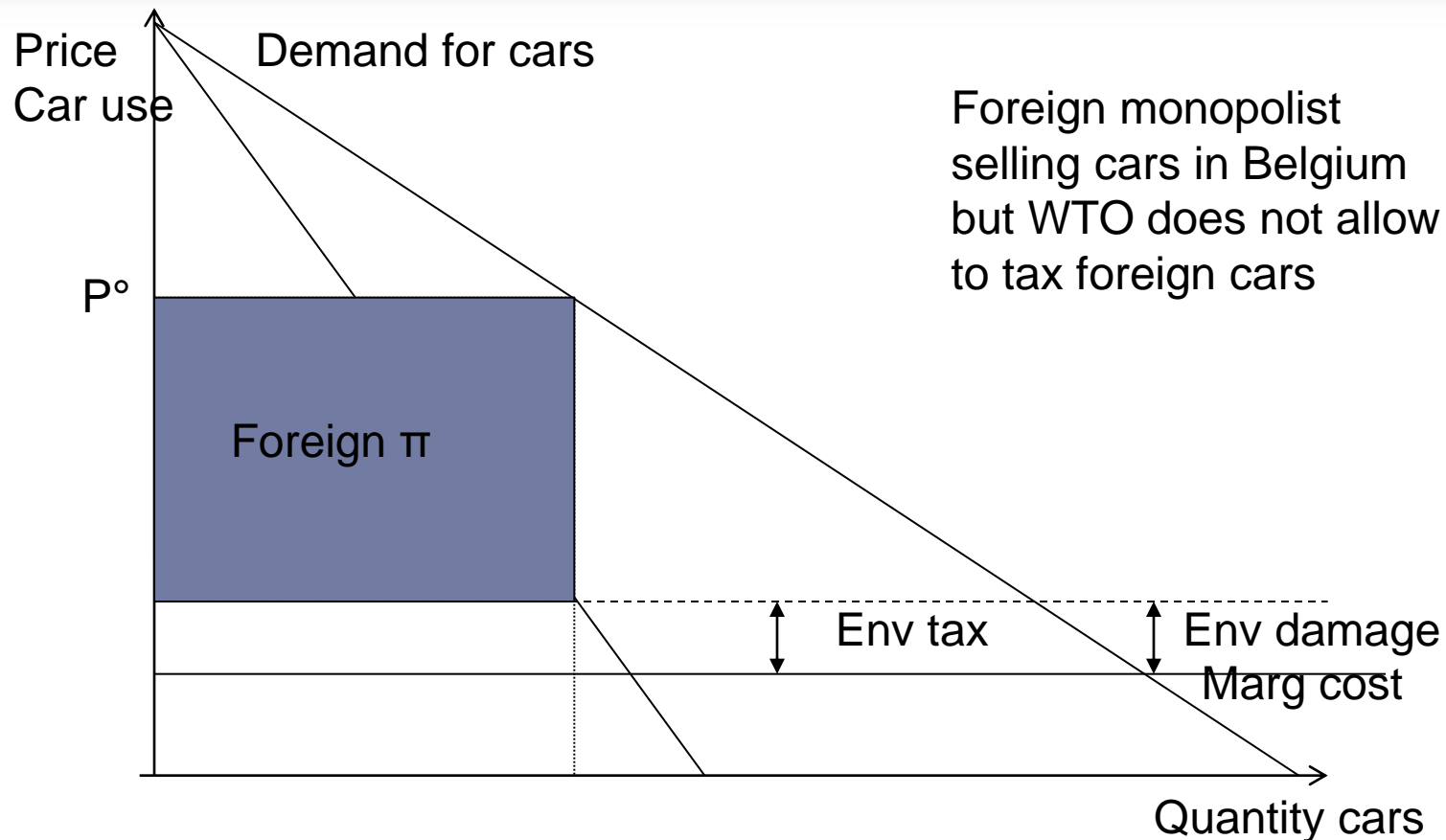
Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions



# INTUITIVE EXAMPLES

Strategic behavior

Introduction

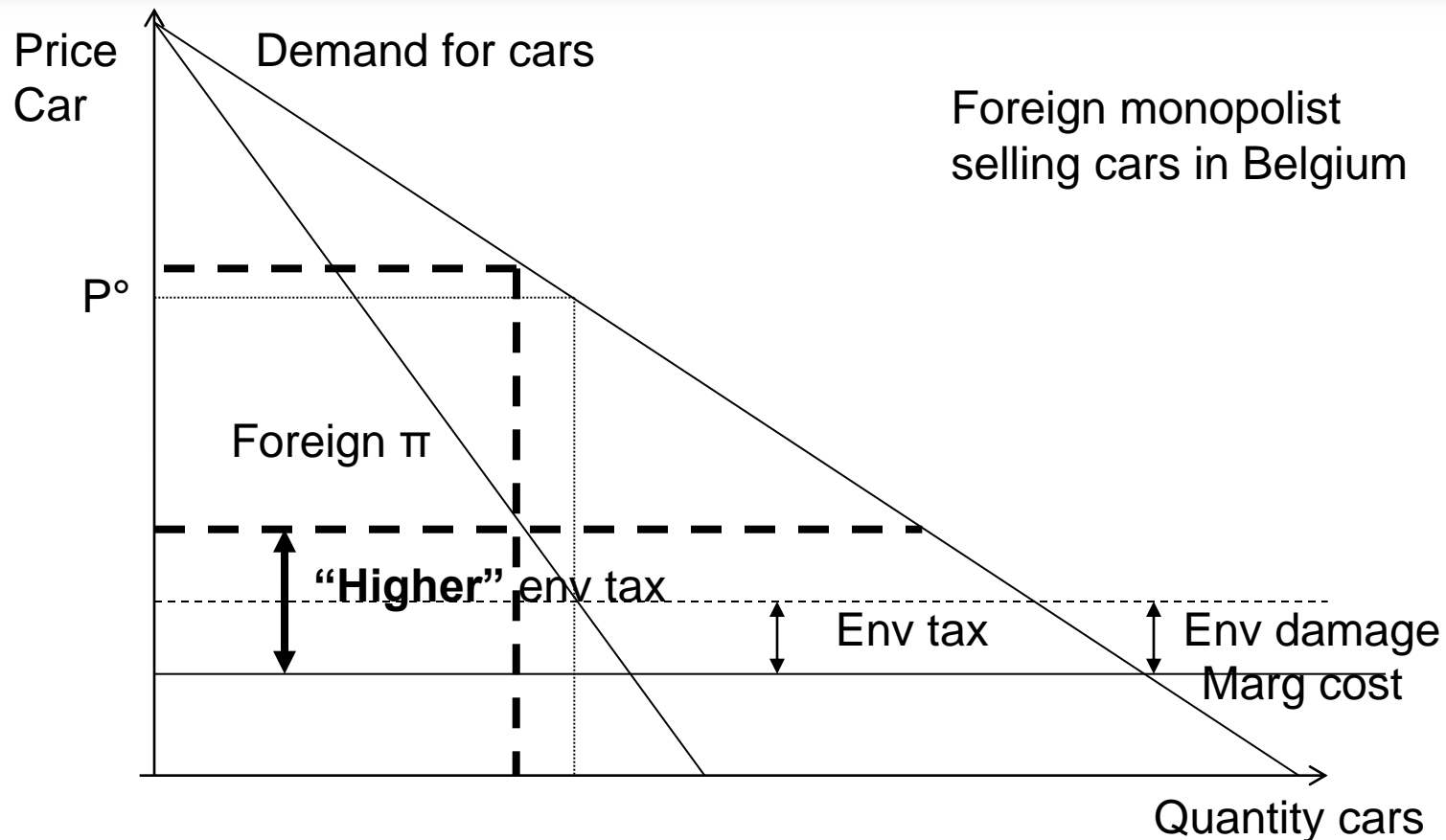
Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions



# INTUITIVE EXAMPLES

Strategic behavior

Introduction

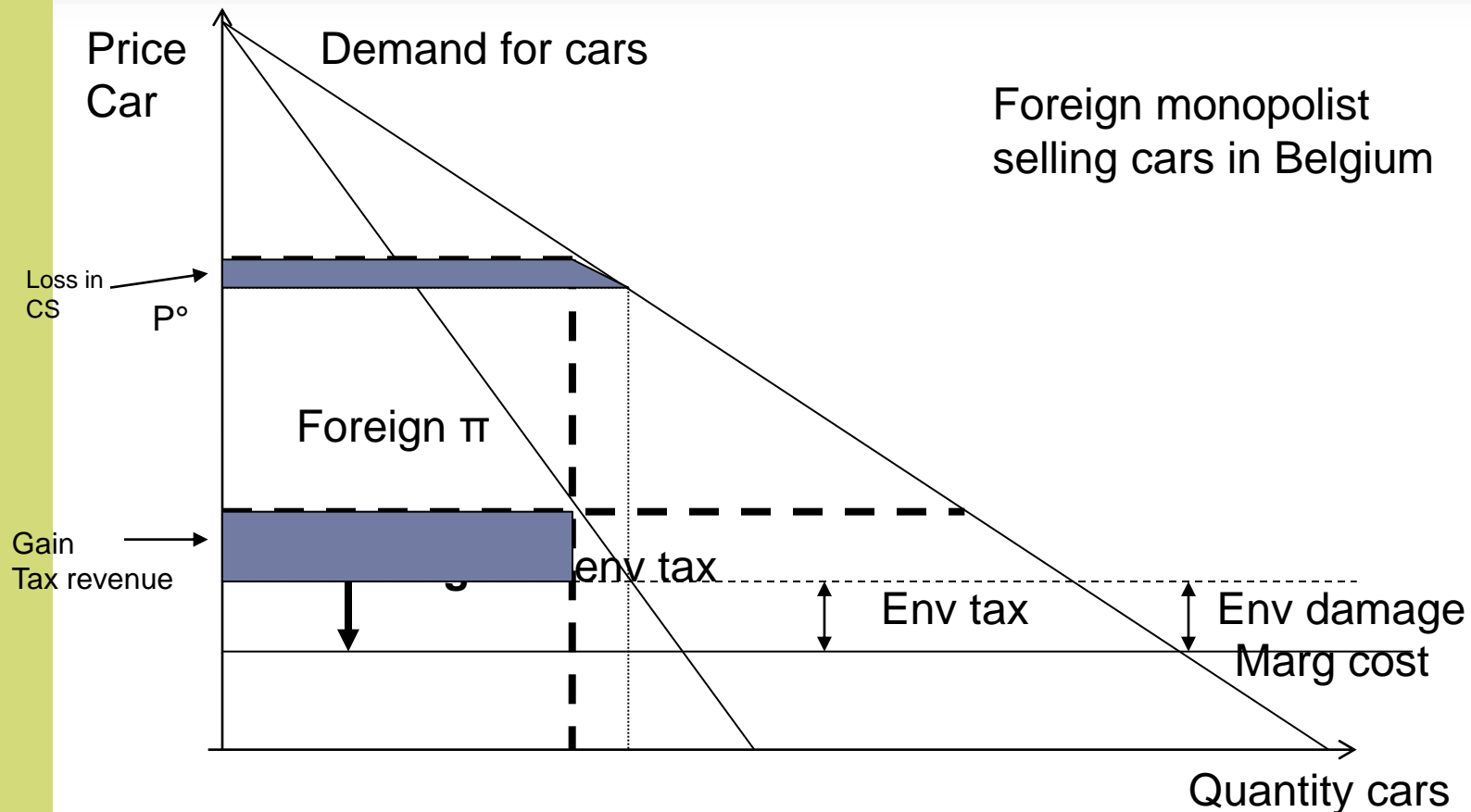
Examples

Model

Theoretical  
Analysis

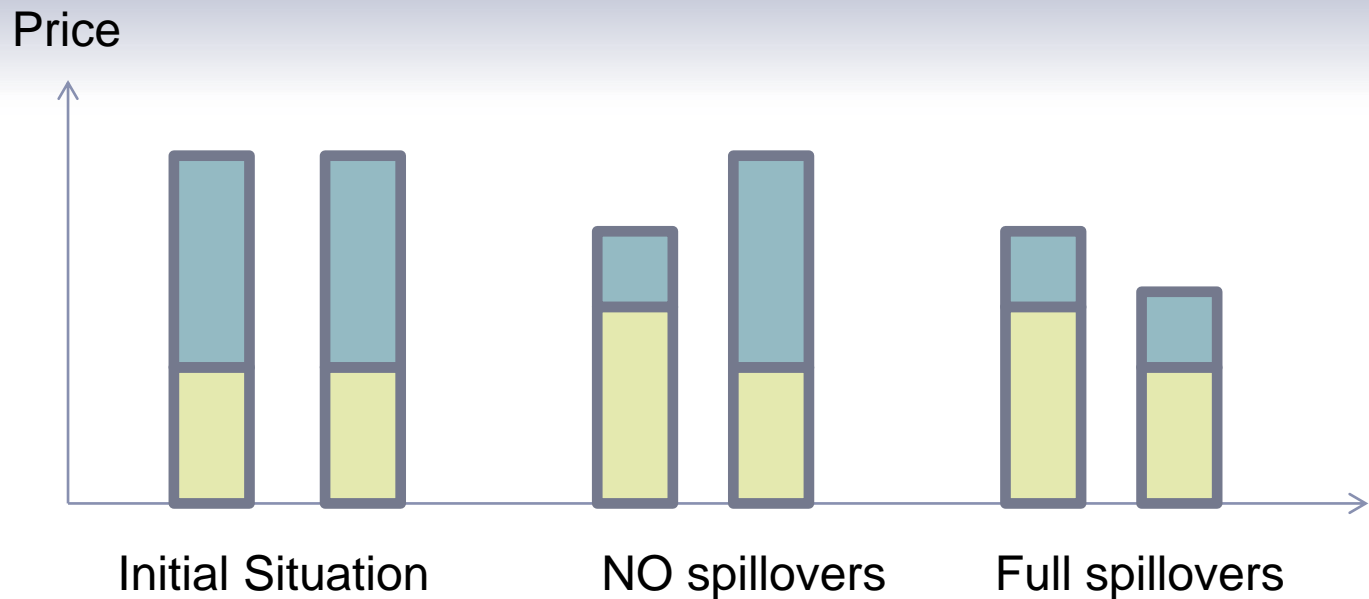
Numerical  
example

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.

Introduction

**Examples**

Model

Theoretical  
Analysis

Numerical  
example

Conclusions

# INTUITIVE EXAMPLES

## Lobbying

Introduction

Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions

- ⊙ 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

Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions

# INTRODUCTION

Research focus

Introduction

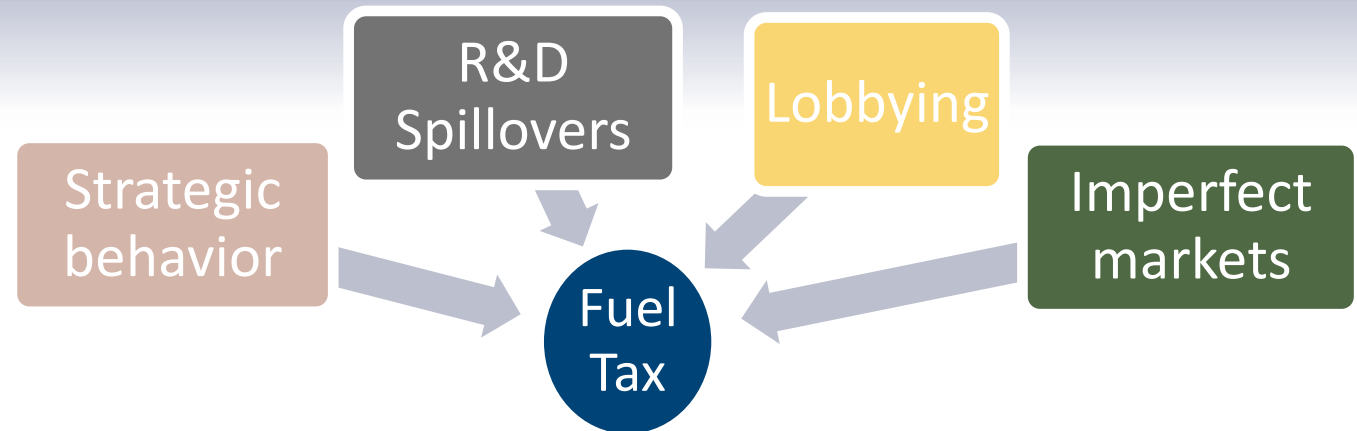
Examples

Model

Theoretical  
Analysis

Numerical  
example

Conclusions



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→ Within the car market

# MODEL

## Building blocks

Introduction

Examples

**Model**

Theoretical  
Analysis

Numerical  
example

Conclusions

- ⊙ 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

Introduction

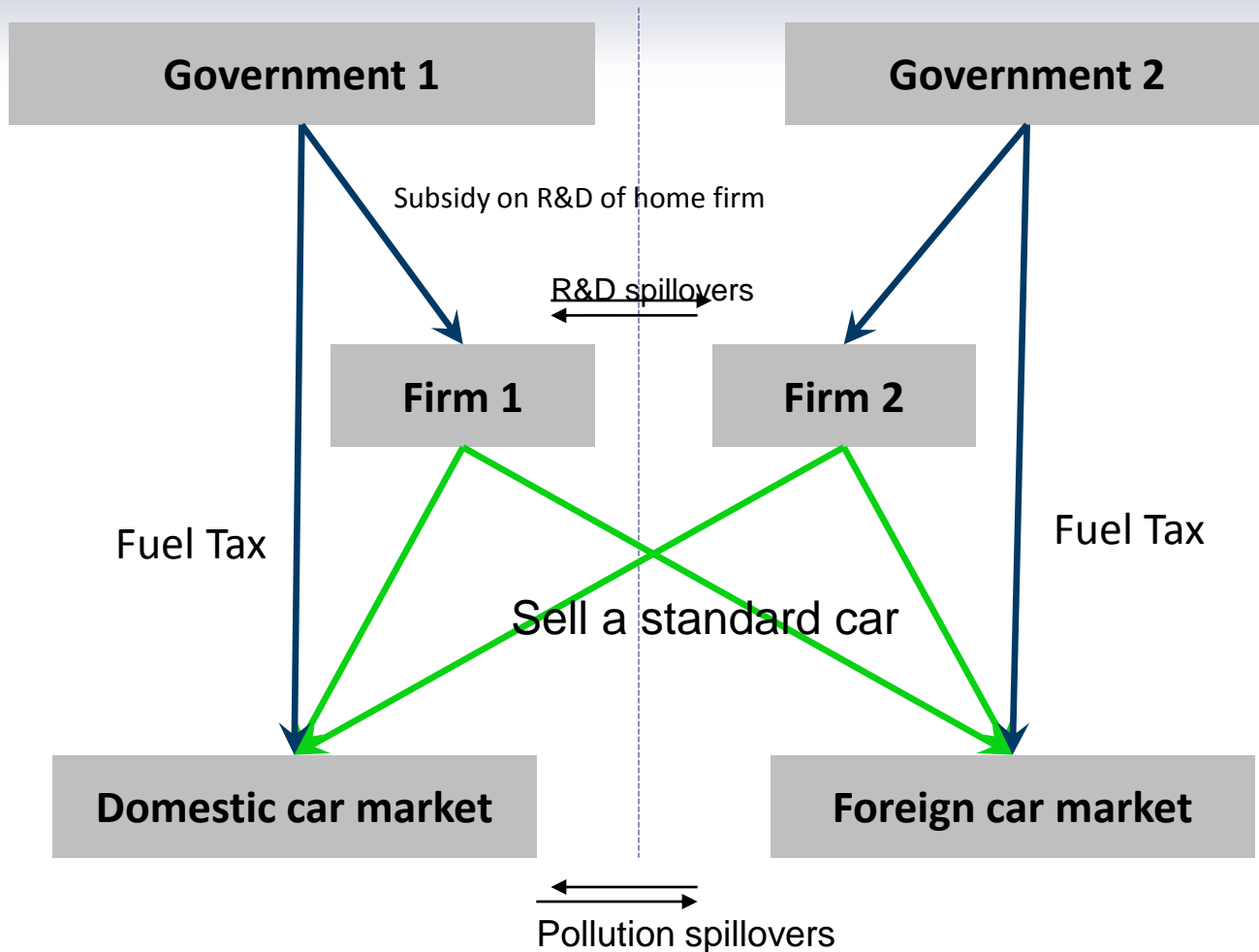
Examples

**Model**

Theoretical  
Analysis

Numerical  
example

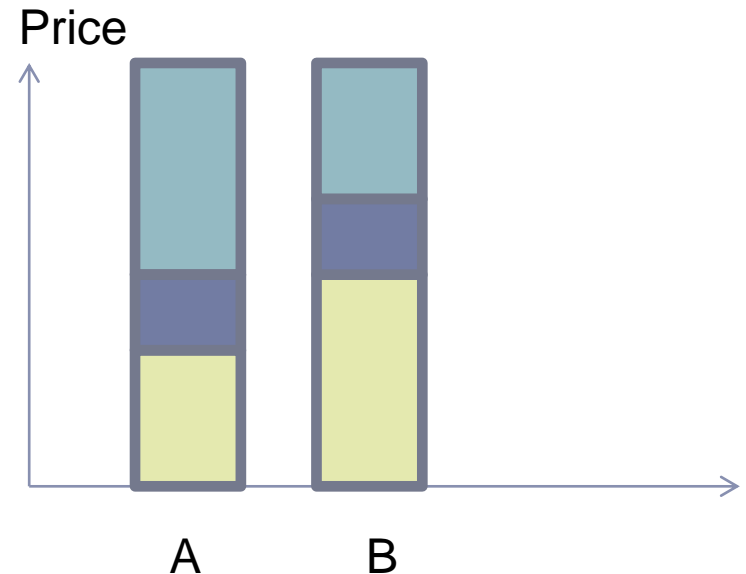
Conclusions



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



Introduction

Examples

**Model**

Theoretical  
Analysis

Numerical  
example

Conclusions

# ANALYSIS

Stage 3

## Output Decision $y_{ij}$

- ⊙ Each firm sets an optimal output by maximizing profits.

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

- ⊙ 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

Introduction

Examples

Model

**Theoretical  
Analysis**

Numerical  
example

Conclusions

### 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!!

Introduction

Examples

Model

**Theoretical  
Analysis**

Numerical  
example

Conclusions

# ANALYSIS

## Stage 1: governments set fuel taxes

Introduction

Examples

Model

**Theoretical  
Analysis**

Numerical  
example

Conclusions

- ⊙ 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

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

- ⊙ 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)*

Introduction

Examples

Model

**Theoretical  
Analysis**

Numerical  
example

Conclusions

# ANALYSIS

Result

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

- ⊙ 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!

Introduction

Examples

Model

**Theoretical  
Analysis**

Numerical  
example

Conclusions



# 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?

Introduction

Examples

Model

Theoretical  
Analysis

**Numerical  
example**

Conclusions

# NUMERICAL ILLUSTRATION

Introduction

Examples

Model

Theoretical  
Analysis

**Numerical  
example**

Conclusions

- ⊙ 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:  $3\,200\,000\text{€} * x^2$

# NUMERICAL ILLUSTRATION

Benchmark equilibrium – only fuel taxes, no subsidies

Introduction

Examples

Model

Theoretical  
Analysis

**Numerical  
example**

Conclusions

	Cooperative	Non-cooperative
Welfare	$6.76 * 10^7$	$4.56 * 10^7$
Tax rate $t_i$ (€/l)	0.18	0.46
Output $y_{ij}$	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 surpluses 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

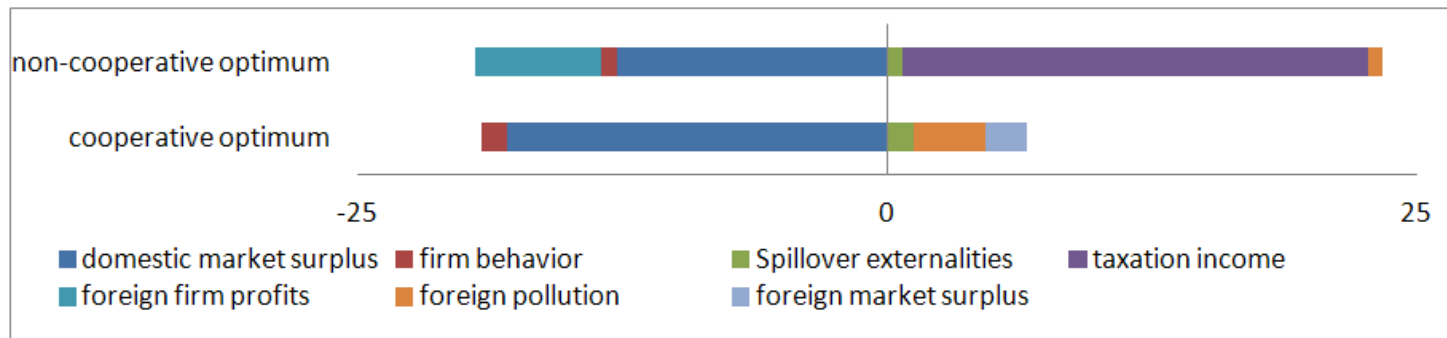


Figure 4.1. The relative importance of different strategic incentives on the optimal tax level of governments

- ① 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

Introduction

Examples

Model

Theoretical  
Analysis

**Numerical  
example**

Conclusions

# 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

Introduction

Examples

Model

Theoretical  
Analysis

**Numerical  
example**

Conclusions

# NUMERICAL ILLUSTRATION

Sensitivity study – with and without subsidy instrument

Introduction

Examples

Model

Theoretical  
Analysis

**Numerical  
example**

Conclusions

	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 investment imperfections in fuel efficiency
- ⊙ With strategic governments however, subsidies are just another instrument to maximize profits...

# GENERAL CONCLUSIONS

Introduction

Examples

Model

Theoretical  
Analysis

Numerical  
example

**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**

- ③ 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
  
- ③ Better connection to other models
  - Existing car models (Verboven, 2002)