

THE COFIRING PROBLEM OF A POWER PLANT UNDER POLICY REGULATIONS

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IFORS 2008

Sandton, South Africa

18 July 2008

FA-17: Energy: Policy and planning

BACKGROUND (1): MOTIVATION

- Coal is a dominant fuel in electricity production
 - 40 % of world's electricity production
 - 1 % unit decrease leads to 60 Mt decrease in CO₂
- Climate change mitigation
 - pressure to decrease coal use
- Cofiring of fossil fuel and biomass
 - can contribute to reaching tightening climate and renewable energy goals cost-efficiently

BACKGROUND (2): LITERATURE

- **Motivation:**
- Baxter, L. 2005.

- **Econometric analysis of cofiring:**
- Brännlund, R., Lundgren, T. 2004.

- **Policy analysis:**
- Fischer, C. & Newell, R. 2008.
- Menanteu, P., Finon, D. & Lamy, M. 2003.

BACKGROUND (3): TECHNOLOGY

- **Pulverized fuel (PF) combustion**
 - The share of biomass is small,
 - but PF is dominant technology, so the global potential in decreasing CO₂ emission is considerable

- **Fluidized bed combustion (FBC)**
 - Larger biomass share is possible,
 - but the capacities are smaller
 - Northern countries such as Finland cofire also peat and biomass in FBC boilers

POLICY ANALYSIS

■ **Climate Policy**

- Focus on emission trading
- Emission credit prices are exogenously passed through to electricity price, impact from
 - 1) Emission credit price
 - 2) The carbon intensity of the marginal technology
 - 3) Pass-through share of carbon costs

■ **Renewable energy promoting policies**

- Focus on feed-in laws
 - 1) Feed-in tariff (FIT) – fixed minimum price
 - 2) Feed-in premium (FIP) – fixed premium

THE MODEL (1)

- Short-run profit maximization with endogenous effective price and fuel choice
- Linear conversion of energy
 - Fuel lower-heating value → electric and thermal energy
- Non-linear average costs containing
 - Direct fuel costs (price and transportation)
 - Capacity costs
 - Cofiring costs

→ Non-linear programming problem

THE MODEL (2)

$$\Pi = (p_{th}\eta_{th} + p_e^{eff}\eta_e)(x_1 + x_2) - C^{dir}(x_1, x_2) - C^{cap}(x_1, x_2) - C^{co}(x_1, x_2) - p_{ec}\varepsilon_2x_2$$

$$p_e^{eff} = p_e + p_{ec}IL + [I_{FIT}I(p_{FIT} > p_e + p_{ec}IL)(p_{FIT} - p_e - p_{ec}IL) + I_{FIP}p_{FIP}] \frac{x_1}{x_1 + x_2}$$

$$C^{dir}(x_1, x_2) = \sum_i (p_i + t_i x_i^{1/2}) x_i$$

$$C^{cap}(x_1, x_2; X_{max}) = \kappa \left\{ \left(1 - \frac{x_1 + x_2}{X_{max}} \right) \frac{1}{a} \left[1 - \left(1 - \frac{x_1 + x_2}{X_{max}} \right)^{-a} \right] + \frac{x_1 + x_2}{X_{max}} \right\}$$

$$C^{co}(x_1, x_2) = a_0 \left(1 + a_1 \left(\frac{x_1}{x_1 + x_2} - \sigma_1 \right)^2 \right) (x_1 + x_2)$$

SIMULATION STUDY (1)

1) Representative power plants:

Condensing PF plant

- Location: Central Europe
- Fuels: coal and wood
- Fuel capacity: 1300 MW
- Power capacity: 585 MW

CHP FPC plant

- Location: Scandinavia
- Fuels: peat and wood
- Fuel capacity: 200 MW
- Power capacity: 60 MW
- Heat capacity: 120 MW

2) Marginal fuels: coal and natural gas

SIMULATION STUDY (2)

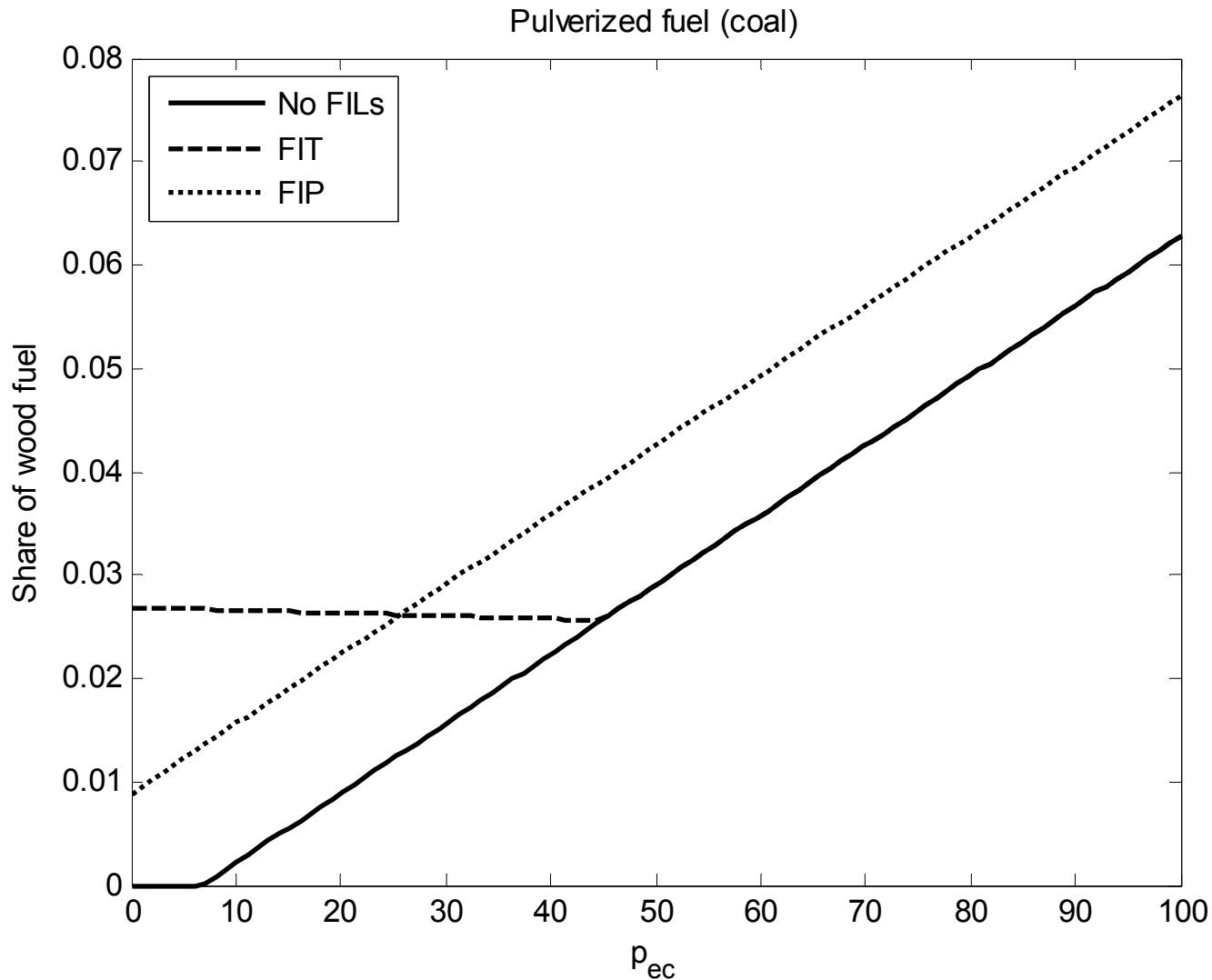
3) Policy scenarios:

- i) Only emission trading, prices 0-100 €/tCO₂
- ii) Feed-in tariff and emission trading
- iii) Feed-in premium and emission trading

SOLVING THE MODEL

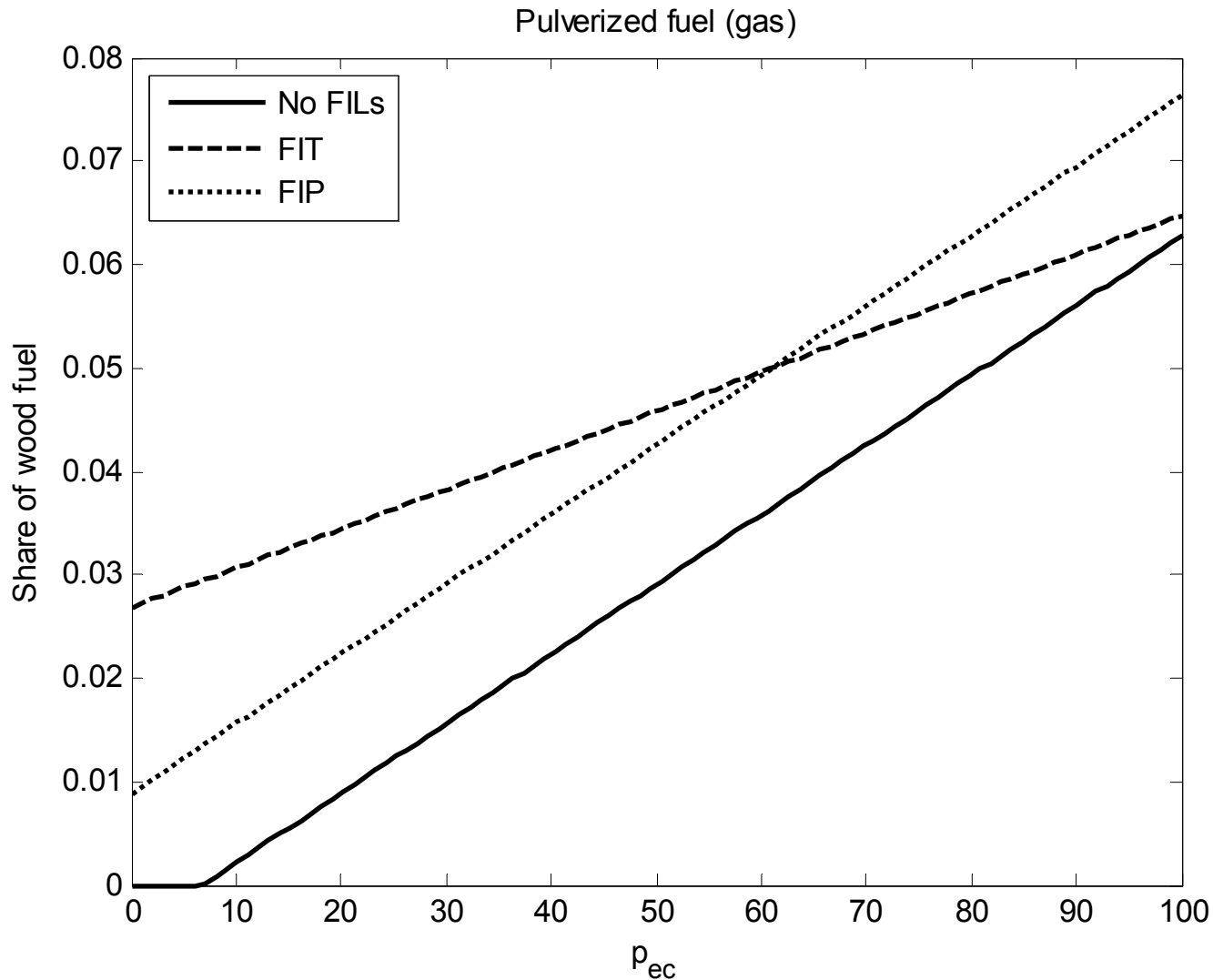
- Programs: GAMS and MATLAB
(linking tool provided by Michael C. Ferris)
- Non-linear programming: GAMS
 - Solver: Conopt3
- Figures: MATLAB

THE RESULTS (1)



PF plant
FIT = 100
FIP = 15
 $\sigma_1 = 0$
 $p_e = 65$
MF: coal

THE RESULTS (2)



PF plant

FIT = 100

FIP = 15

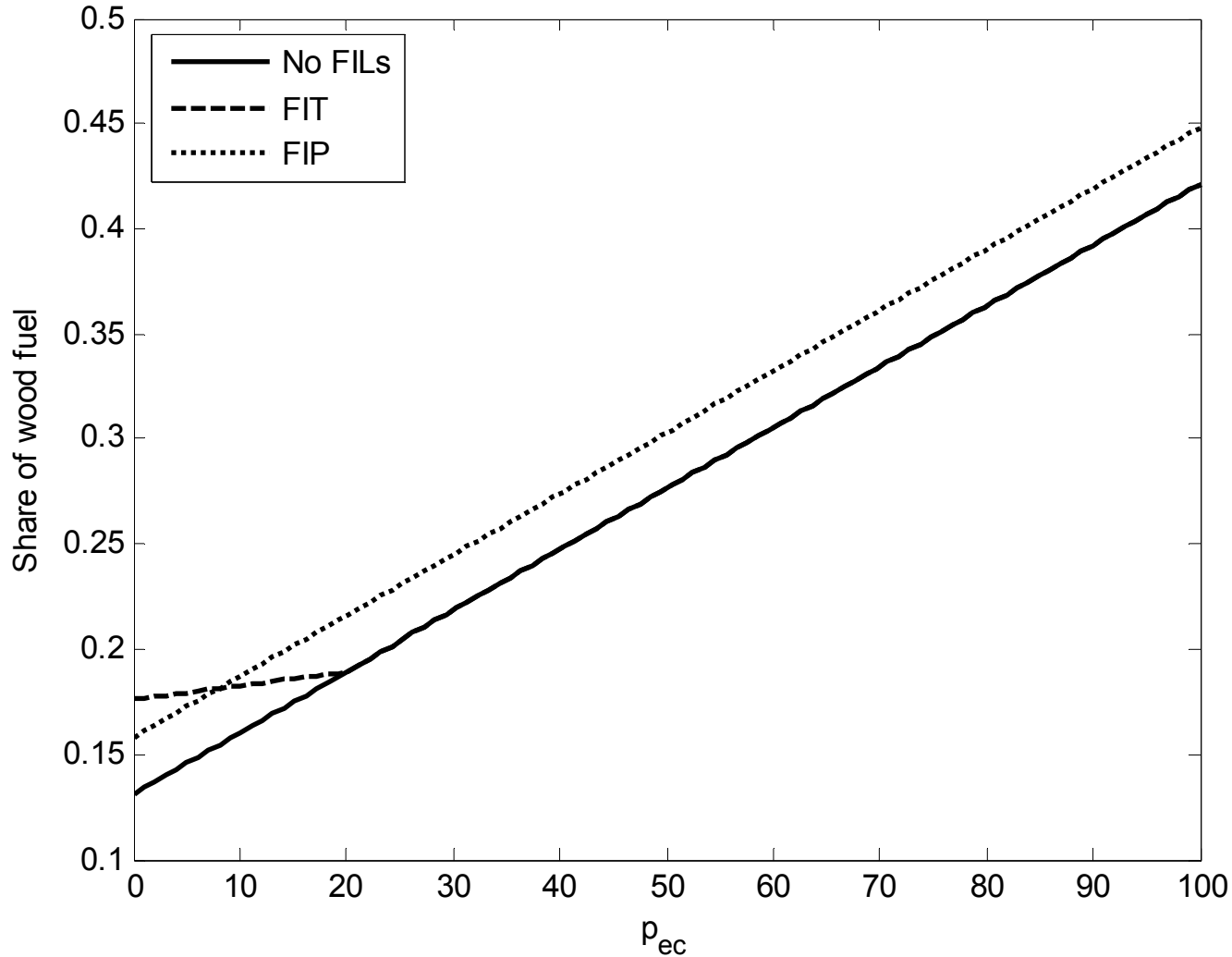
$\sigma_1 = 0$

$p_e = 65$

MF: gas

THE RESULTS (3)

Fluidized bed combustion



FBC plant

FIT = 60

FIP = 12

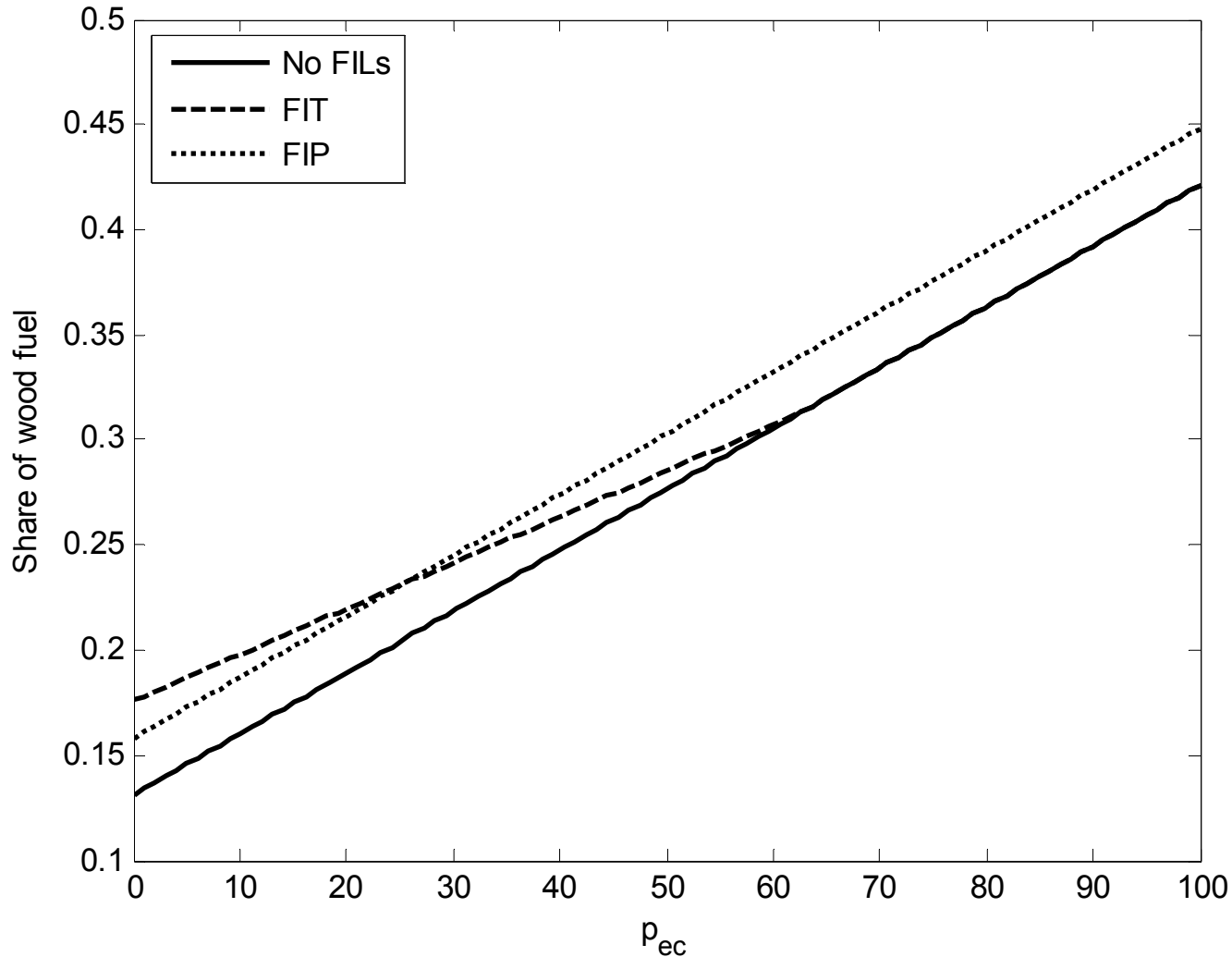
$\sigma_1 = 0.14$

$p_e = 40$

MF: coal

THE RESULTS (4)

Fluidized bed combustion (gas)



FBC plant

FIT = 60

FIP = 12

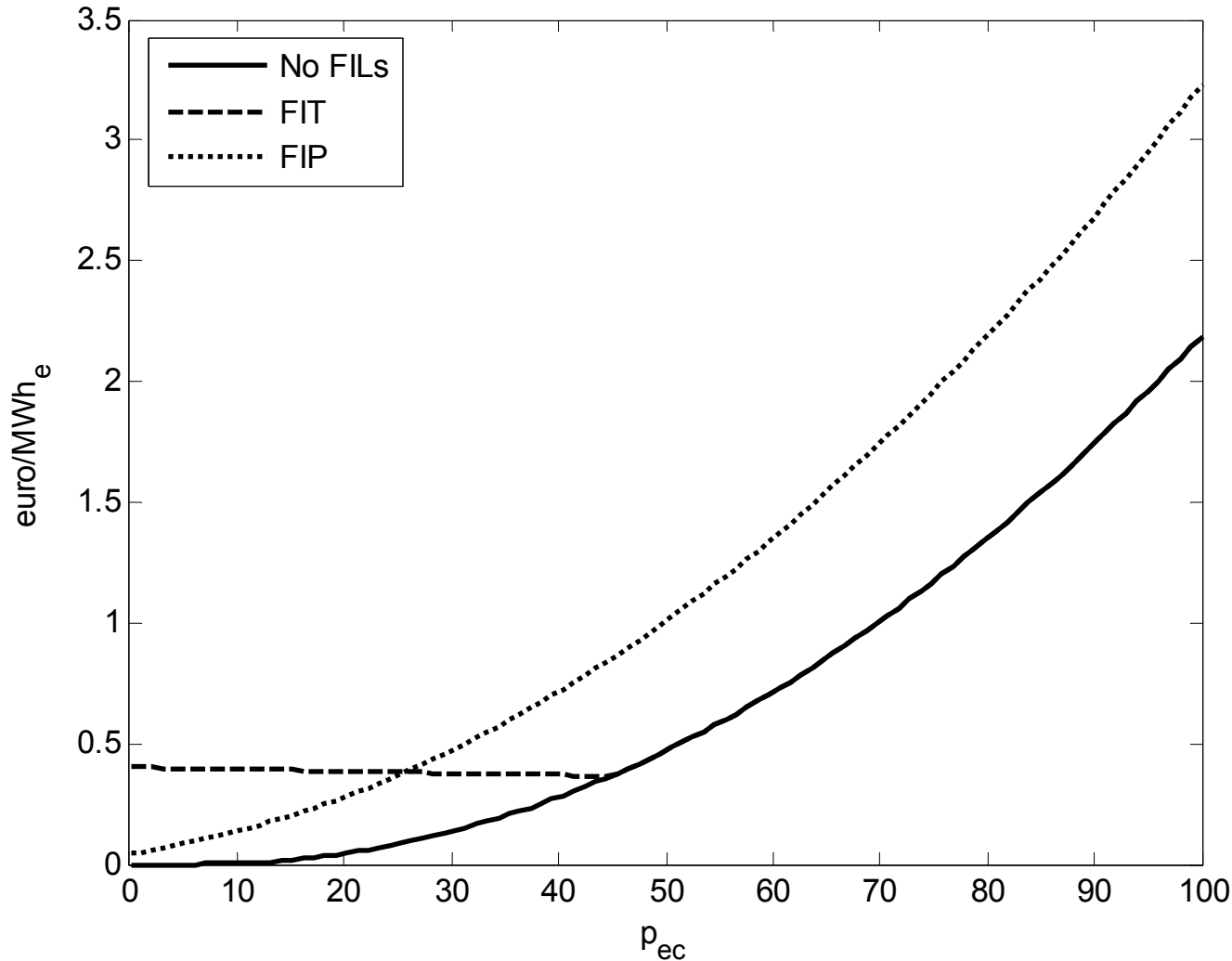
$\sigma_1 = 0.14$

$p_e = 40$

MF: gas

THE RESULTS (5)

Increase of unit profits due to the cofiring (coal)



PF plant

FIT = 60

FIP = 12

$\sigma_1 = 0$

$p_e = 65$

MF: coal

CONCLUSIONS

- The effect of FIT on wood share decreases as emission credit prices increase while effect of FIP remains constant
- Emission credit price increase may decrease wood use in the case of FIT
 - Power plant is efficient enough compared to the marginal plant
 - FIT together with emission trading may be a problematic policy

ONGOING WORK

Model extensions:

- Dynamic model 1 (medium term)
 - Controls: fuel use
 - State: boiler temperature (hot, warm and cold)
 - Price process (stochastic)
- Dynamic model 2 (long term)
 - Time structure of feed-in laws
 - Investment decisions

THANK YOU!



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- **Fiscer, C. & Newell, R. 2008.** Environmental and technology policies for climate mitigation. *Journal of environmental economics and management*. 55: 142-162.
- **Menanteu, P., Finon, D. & Lamy, M. 2003.** Prices versus quantities: choosing policies for promoting the development of renewable energy. *Energy Policy*. 31: 799-812.
- **Baxter, L. 2005.** Biomass-coal co-combustion: opportunity for affordable renewable energy. *Fuel*. 84: 1295-1302.
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- **Sijm, J., Bakker, J., Chen, Y., Harmsen, H. & Lise, W. 2005.** *CO2 price dynamics: The implications of EU emissions trading for the price of electricity*. ECN-C--05-081.