# "GEEM: A policy model for assessing climate-energy reforms for Italy"

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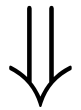
# GEEM: A Comprehensive C&E Policy Simulation Tool

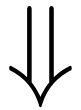
- The ***General Equilibrium Environmental Model*** (GEEM) is a large-scale DGE model aiming to serve as a policy simulation tool
- It focuses on simulating the **macroeconomic impact** of the introduction of climate-energy policies oriented to reduce GHG emissions
- It can be also used to evaluate the **interaction** between climate-energy policies and other structural policies as well as exogenous supply shocks

# Motivations

- 2030 EU Climate Change and Energy policy framework
- Paris COP21



A growing effort toward a **low carbon economy**



Endowing public authorities with a **quantitative instrument** to assess the macroeconomic impact of environmental policies

# Reducing Emissions

- Three main actions:
  1. Lowering the amount of emission permits
  2. Increasing the share of RES in electricity generation
  3. Fostering efficiency in production

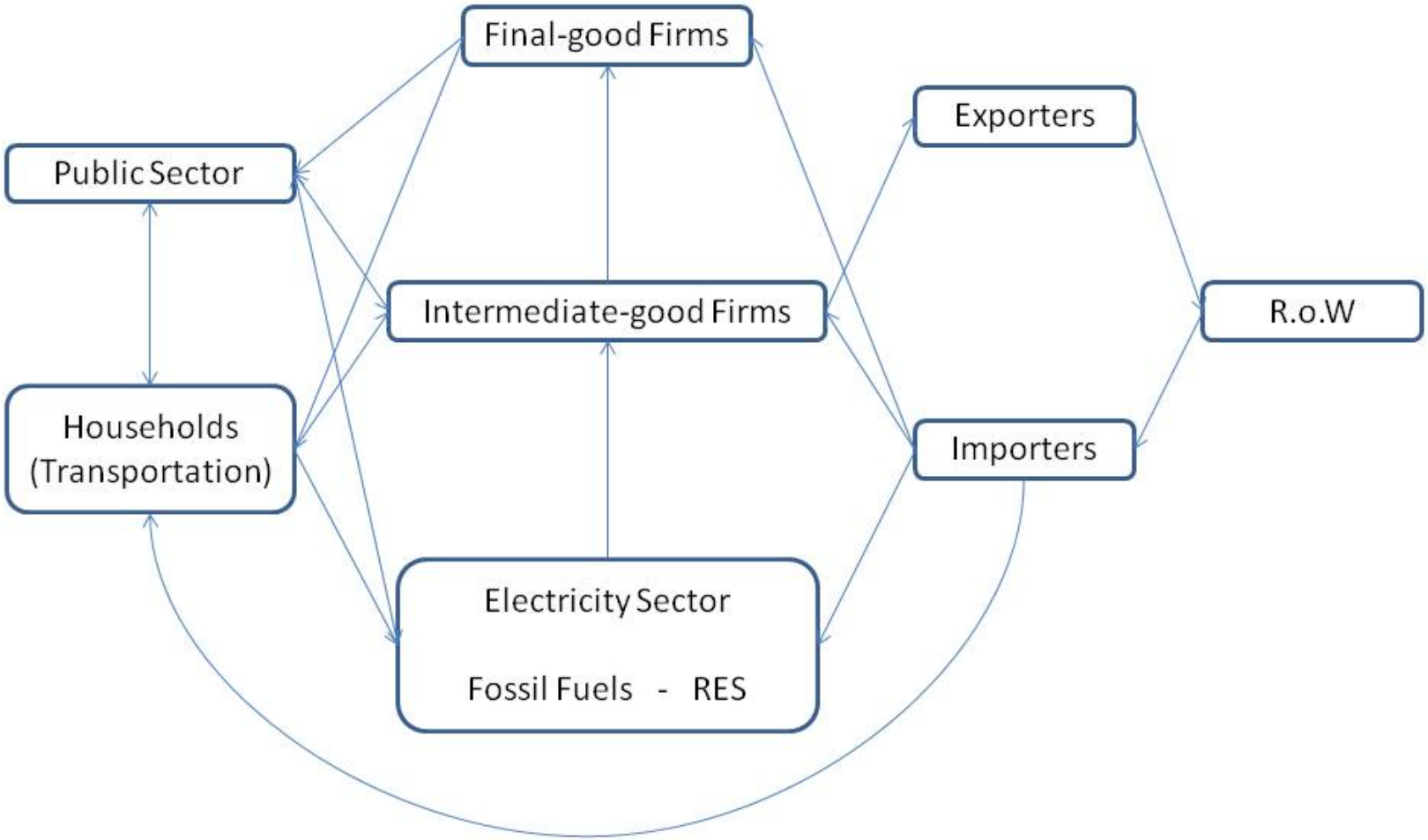
# Not Only C&E Policies

- The strength of GEEM:
  1. Emission reduction policies **along with**:
     - Fiscal policies
     - Liberalization measures
     - Economic efficiency policies
     - Energy-price shocks
  2. Performance analysis of **structural policies** in presence of environmental constraints

# Modeling Innovations

- GEEM presents three main **modeling innovations**:
  1. Simultaneous presence of:
     - Environmental constraints and externalities
     - Distortionary taxation
     - Market imperfections
  2. An **electricity sector** accounting for generation from:
     - Fossil fuel sources
     - Renewable sources (RES)
  3. A **transportation sector** $\Rightarrow$ fuel consumption on the household side

# The Structure of the Model



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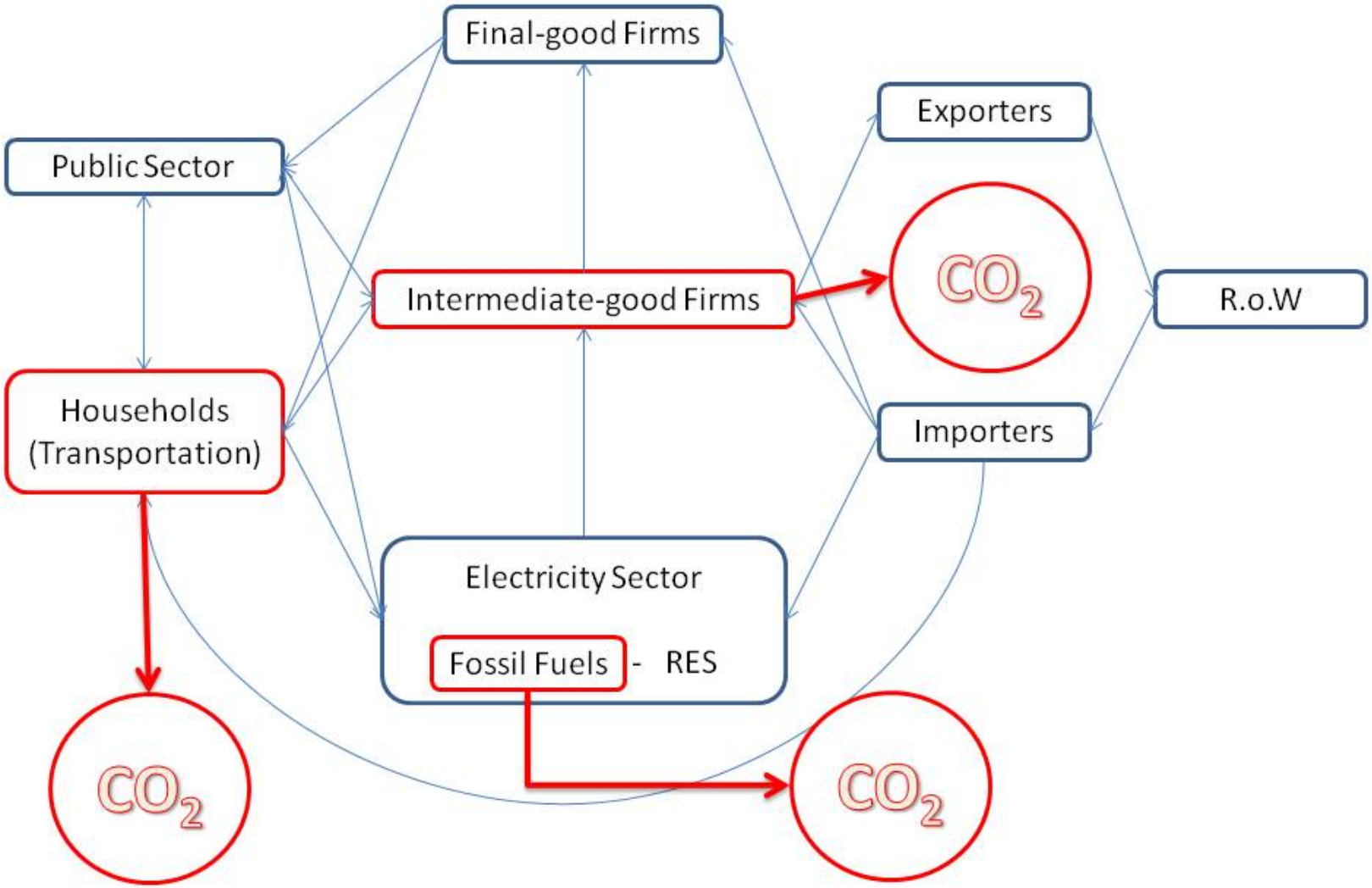

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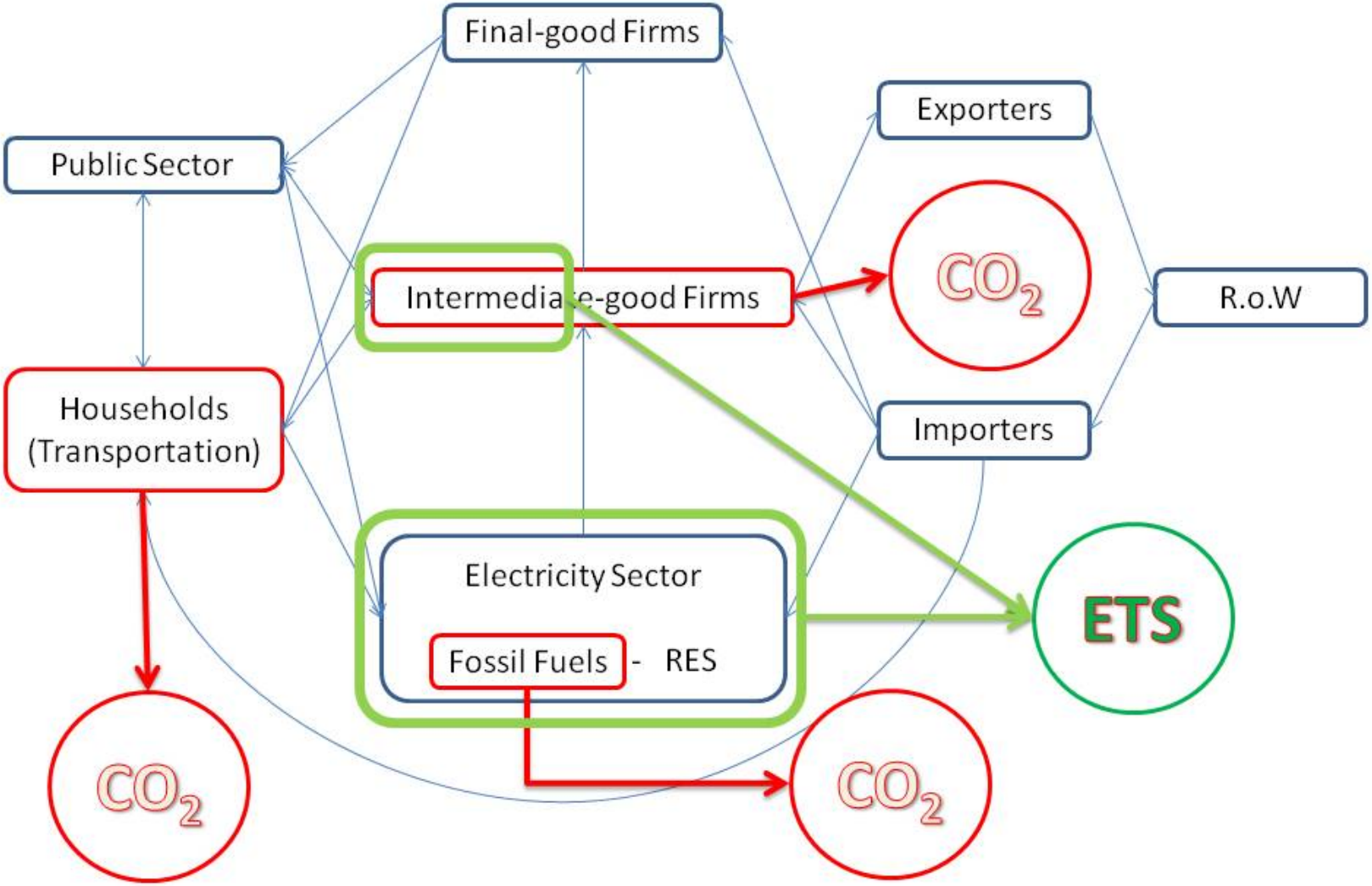

# Emissions Trading System

- The ETS is a Cap&Trade scheme structured as a financial market:
  - Primary market $\Rightarrow$ Government sells a fixed amount of emission permits (auction)
  - Secondary market $\Rightarrow$ Firms subject to the ETS engage in sales and purchases of the permits
- The ETS involves:
  - The electricity sector
  - Energy intensive industries, e. g.:
    - Cement
    - Paper
    - Ceramic
    - Refinery
    - Still

# The Core of the Model (1/5)

- Production of intermediate-goods:

$$Y_t = A_t d(M_t)\left\{\rho^{1-\sigma}[f(K_t, L_t)]^{\sigma} + (1-\rho)^{1-\sigma}(EL_t)^{\sigma}\right\}^{\frac{1}{\sigma}}$$

- Production of electricity:

$$EL_t = \left\{\rho_{EL}^{1-\sigma_{EL}}(EL_{FOS,t})^{\sigma_{EL}} + (1-\rho_{EL})^{1-\sigma_{EL}}(EL_{RES,t})^{\sigma_{EL}}\right\}^{\frac{1}{\sigma_{EL}}}$$

- Monopolistic competition in the electricity market:

$$P_{EL,t} = \underbrace{\mu}_{\text{markup}} \times MC_t$$

# The Core of the Model (2/5)

- Three sources of emissions ($CO_2$) generation:
  1. Good production: $Z_{Y,t} = (1 - U_t)\varphi_Y(Y_t)^{\mu_Y}$
  2. Electricity generation: $Z_{EL,t} = (1 - U_{EL,t})\varphi_{EL}(EL_{FOS,t})^{\mu_{EL}}$
  3. Transportation: $Z_{T,t} = \varphi_T(F_t)^{\mu_T}$
- Emissions from ETS sectors:

$$Z_t^{ETS} = s_{ETS} Z_{Y,t} + Z_{EL,t}$$

- Total emissions:

$$Z_t^{TOT} = Z_t^{ETS} + (1 - s_{ETS})Z_{Y,t} + Z_{T,t}$$

# The Core of the Model (3/5)

- Households maximize utility subject to the budget constraint:

$$C_t + I_t + I_t^{RES} + \cdots = (1-\tau_L) W_t L_t + (1-\tau_K) r_{K,t} K_t + (1-\tau_K^{RES}) r_{K,t}^{RES} K_t^{RES} + \ldots$$

- Households' consumption includes goods and fuel for transportation:

$$C_t = g(C_{Y,t}, C_{F,t})$$

- The demand of fuel is negatively related to the price (and excise taxes):

$$C_{F,t} = h(P_{F,t}(1+\tau_F))$$

# The Core of the Model (4/5)

- The long-run resource constraint of the economy is:

$$Y = C + I + G + EX - IM + C_U$$

- Import ($IM$) includes:
  1. Foreign goods
  2. Fossil fuels used for electricity generation (coal, gas and oil) and fuel used for transportation (refined oil and biofuel)
  3. Investment goods for the RES sector $I^{RES}$ (i.e. solar cells, windmill blades)

- The emission abatement cost $C_U$ accounts for the resources used for emission abatement efforts

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# The Core of the Model (5/5)

- The budget constraint of the government is:

$$B_t = R_{t-1} B_{t-1} + G_t - TAX_t - p_Z Z_t^{ETS}$$

- Taxation ($TAX_t$) includes:
  1. Labor taxes: $\tau_L W_t L_t$
  2. Taxes/Subsidies on capital: $\tau_K r_{K,t} K_t + \tau_K^{RES} r_{K,t}^{RES} K_t^{RES}$
  3. Excise taxes on consumption of fuel for transportation: $\tau_F C_{F,t}$

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# What GEEM Can Do

- GEEM is built to simulate several different scenarios, e. g.:

| | | |
|---|---|---|
| **Emission reduction policies** | 1 | Emission reduction in ETS sectors |
| | 2 | 1 + carbon market revenues earmarked for reducing labor taxes |
| **Fiscal policies** | 3 | Tax shift from labor to fuel for transportation |
| | 4 | Tax shift from RES to fuel for transportation |
| | 5 | Public spending increase |
| **Liberalization policies** | 6 | Decrease in electricity sector price markup |
| **Energy Price Shock** | 7 | Shock on oil and gas price |

# Emission Reduction Policies (1/2)

- $Z_t^{ETS} = s_{ETS} Z_{Y,t} + Z_{EL,t}$
- $\Delta Z^{ETS} = -20\%$

Table 1: Scenario 1 - ETS emissions reduction

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| GDP | -0.17 | -0.15 | -0.19 | -0.08 | -0.01 |
| Consumption | -0.14 | -0.16 | -0.17 | -0.14 | -0.13 |
| Investments | -0.25 | -0.25 | -0.19 | -0.15 | -0.13 |
| RES Investments | 0.28 | 0.24 | 0.25 | 0.21 | 0.15 |
| Labor | -0.19 | -0.14 | -0.21 | -0.05 | 0.00 |
| Total Emissions | -3.35 | -6.93 | -10.51 | -10.77 | -10.77 |
| Electricity - Total | -0.35 | -0.42 | -0.50 | -0.34 | -0.24 |
| *Electricity - Fossil* | -0.75 | -0.84 | -0.93 | -0.67 | -0.49 |
| *Electricity - Res* | 0.40 | 0.35 | 0.30 | 0.27 | 0.21 |

# Emission Reduction Policies (2/2)

- $Z^{ETS} \downarrow + \tau_L \downarrow$
- $\Delta(p_Z Z^{ETS}) = -\Delta(\tau_L WL) = 0.4\%$ of GDP

Table 2: Scenario 2 - ETS emissions + Reducing labor taxes

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| GDP | 0.07 | 0.23 | 0.23 | 0.37 | 0.45 |
| Consumption | 0.10 | 0.12 | 0.12 | 0.16 | 0.17 |
| Investments | -0.14 | -0.10 | -0.01 | 0.05 | 0.10 |
| RES Investments | 0.31 | 0.30 | 0.34 | 0.32 | 0.29 |
| Labor | 0.17 | 0.43 | 0.42 | 0.58 | 0.64 |
| Total Emissions | -3.28 | -6.85 | -10.43 | -10.69 | -10.68 |
| Electricity - Total | -0.27 | -0.26 | -0.29 | -0.11 | -0.01 |
| *Electricity - Fossil* | -0.60 | -0.59 | -0.62 | -0.35 | -0.18 |
| *Electricity - Res* | 0.34 | 0.33 | 0.32 | 0.32 | 0.31 |

# A Focus on Consumption

- Total consumption = consumption of Ricardian + consumption of Non-Ricardian households

Table 3: Scenario 2 - Consumption

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| Consumption | 0.10 | 0.12 | 0.12 | 0.16 | 0.17 |
| *Consumption - Ricardian* | 0.04 | 0.05 | 0.06 | 0.06 | 0.09 |
| *Consumption - Non Ricardian* | 1.63 | 1.67 | 1.55 | 2.31 | 2.16 |

# Fiscal Policies and Taxation (1/3)

- $\Delta Z^{TOT} = 0$, $\tau_F \uparrow + \tau_L \downarrow$
- $\Delta(\tau_F C_F) = -\Delta(\tau_L WL) = 1\%$ of GDP

Table 4: Scenario 3 - Tax shift from labor to fuel (transportation)

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| GDP | 0.48 | 0.79 | 0.86 | 0.84 | 0.85 |
| Consumption | 0.55 | 0.33 | 0.34 | 0.45 | 0.45 |
| Investments | 0.24 | 0.33 | 0.39 | 0.43 | 0.49 |
| RES Investments | 0.06 | 0.12 | 0.17 | 0.21 | 0.29 |
| Labor | 0.74 | 1.19 | 1.24 | 1.16 | 1.10 |
| Total Emissions | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Electricity - Total | 0.18 | 0.33 | 0.41 | 0.45 | 0.47 |
| *Electricity - Fossil* | 0.34 | 0.53 | 0.62 | 0.64 | 0.62 |
| *Electricity - Res* | -0.13 | -0.04 | 0.03 | 0.10 | 0.20 |

# Fiscal Policies and Taxation (2/3)

- $\Delta Z^{TOT} = 0$, $\tau_F \uparrow + \tau_K^{RES} \downarrow$
- $\Delta(\tau_F C_F) = -\Delta(\tau_K r_K K)^{RES} = 0.1\%$ of GDP

Table 5: Scenario 4 - Tax shift from RES taxes to fuel (transportation)

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| GDP | 0.19 | 0.17 | 0.14 | 0.12 | 0.09 |
| Consumption | 0.09 | 0.07 | 0.06 | 0.07 | 0.05 |
| Investments | 0.30 | 0.25 | 0.21 | 0.18 | 0.14 |
| RES Investments | 8.22 | 8.04 | 7.91 | 7.81 | 7.68 |
| Labor | -0.03 | -0.02 | -0.04 | -0.06 | -0.07 |
| Total Emissions | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Electricity - Total | 0.80 | 1.36 | 1.72 | 1.98 | 2.34 |
| *Electricity - Fossil* | -3.20 | -2.26 | -1.62 | -1.14 | -0.49 |
| *Electricity - Res* | 8.90 | 8.59 | 8.34 | 8.15 | 7.88 |

# Fiscal Policies and Taxation (3/3)

- $\Delta Z^{TOT} = 0$
- $\Delta G = 1\%$ of GDP

Table 6: Scenario 5 - Public spending increase

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| GDP | 0.51 | 0.62 | 0.68 | 0.72 | 0.78 |
| Consumption | -0.59 | -0.72 | -0.74 | -0.74 | -0.74 |
| Investments | 0.64 | 0.65 | 0.66 | 0.67 | 0.68 |
| RES Investments | 7.04 | 6.42 | 5.89 | 5.43 | 4.66 |
| Labor | 0.39 | 0.57 | 0.66 | 0.72 | 0.82 |
| Total Emissions | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Electricity - Total | 0.96 | 1.52 | 1.82 | 2.00 | 2.15 |
| *Electricity - Fossil* | -2.90 | -1.71 | -0.93 | -0.38 | 0.36 |
| *Electricity - Res* | 8.74 | 7.94 | 7.22 | 6.60 | 5.56 |

# Liberalization Measures

- $\Delta Z^{TOT} = 0$
- $P_{EL,t} = \mu MC_t \rightarrow \Delta\mu = -10\%$

Table 7: Scenario 6 - Markup reduction in the electricity sector

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| GDP | 0.15 | 0.15 | 0.14 | 0.14 | 0.13 |
| Consumption | 0.07 | 0.09 | 0.08 | 0.08 | 0.07 |
| Investments | 0.22 | 0.19 | 0.17 | 0.15 | 0.12 |
| RES Investments | 5.99 | 5.76 | 5.57 | 5.43 | 5.23 |
| Labor | -0.02 | -0.01 | -0.01 | -0.01 | -0.01 |
| Total Emissions | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Electricity - Total | 1.03 | 1.88 | 2.52 | 3.01 | 3.69 |
| *Electricity - Fossil* | -1.97 | -0.50 | 0.61 | 1.48 | 2.71 |
| *Electricity - Res* | 6.95 | 6.52 | 6.18 | 5.91 | 5.52 |

# Energy Price Shock

- $\Delta Z^{TOT} = 0$
- $\Delta P_{OIL,t} = \Delta P_{GAS,t} = -20\%$

Table 8: Scenario 7 - Shock on Oil and Gas Price

| | Years | | | | |
|---|---|---|---|---|---|
| | 5 | 10 | 15 | 20 | 30 |
| GDP | 0.20 | 0.21 | 0.21 | 0.21 | 0.20 |
| Consumption | 0.17 | 0.19 | 0.19 | 0.19 | 0.18 |
| Investments | 0.34 | 0.30 | 0.27 | 0.25 | 0.22 |
| RES Investments | 6.01 | 5.28 | 4.70 | 4.23 | 3.56 |
| Labor | -0.05 | -0.03 | -0.03 | -0.03 | -0.03 |
| Total Emissions | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Electricity - Total | 1.36 | 2.57 | 3.58 | 4.43 | 5.74 |
| *Electricity - Fossil* | -2.04 | 0.23 | 2.16 | 3.83 | 6.45 |
| *Electricity - Res* | 8.12 | 7.12 | 6.27 | 5.54 | 4.45 |

# Conclusions

- Extensions:
  1. Directed Technical Change and endogenous efficiency improvements
  2. Open economy $\Rightarrow$ Multi-country framework
- Environmental CGE $\Rightarrow$ MEF-MATTM joint research project