Energy Mix Transition Model
: Vintage model and Renewable energy

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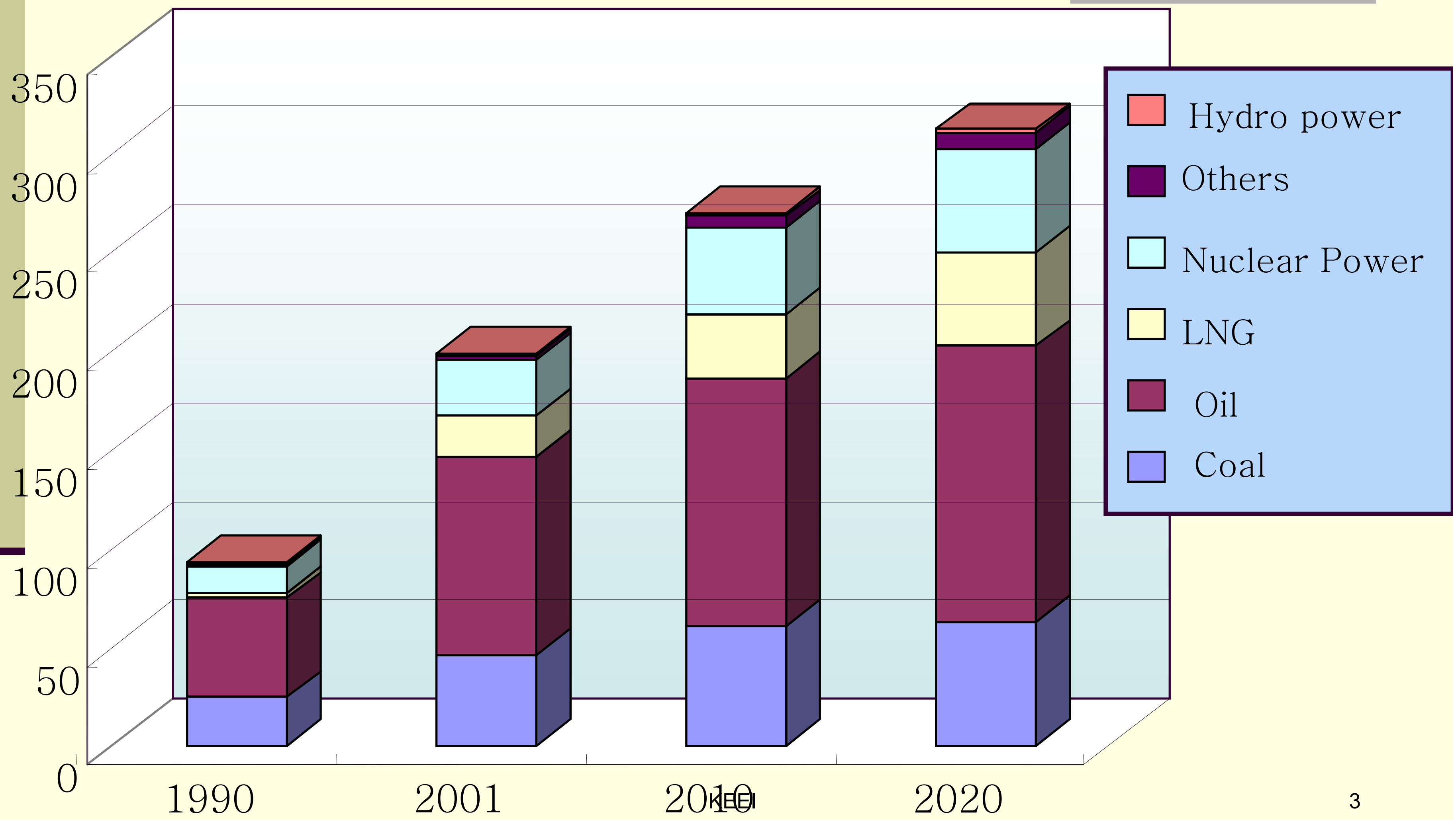
Energy sources and mix in Korea

- ❖ Main energy source
  - 1960s – fire wood and coal
  - 1970s – coal and oil
  - 1980s – coal, oil, nuclear
  - 1990s – oil, nuclear, LNG
- ❖ highly dependent on the imported fossil fuel
- ❖ less demand for oil and more for natural gas
- ❖ share of alternative energy : 1.4% in 2002

Present and Future energy mix



Needs for alternative energy

- Diversification of Energy source
- Energy security and stabilization of energy price
- Environmental concern to mitigate greenhouse effect
- Alternative to the fossil fuel exhaustion
- Public demand for clean energy source

Introduction of alternative energy

- ❖ Low profitability
- ❖ Lack of investment for R&D
  - Irreversibility of the investment
  - Technological spillover effect
  - Learning by using
  - Vested interests of current technologies
  - Complementary effect or economies of diversity

Theoretical Model

- Economic structure :

  Final goods production + energy production
- Production function : Dixit and Stiglitz(1977)
- Dynamic model
- Imperfect competitive model
- Monopoly profit

Model Structure (1)

❖ Energy Production

- Energy vintage $E_{\tau,t} = L^{e}_{\tau,t}$
- Profit maximization for energy producer

$$\pi_{\tau,t} = P_{E_{\tau,t}} E_{\tau,t} - (L_{E_{\tau,t}} + L_f)W$$

❖ Final goods

- Final consumption good $Y_t = E_t^{\alpha} L_{Y_t}^{1-\alpha}$
- Energy composite good $E_t = [\int_{t-T}^{t} (A_{\tau,t} E_{\tau,t})^{\frac{\varepsilon-1}{\varepsilon}} dt]^{\frac{\varepsilon}{\varepsilon-1}}$

  (by Dixit and Stiglitz (1977))
- productivity of vintage

$$A_{\eta,t} = A_0 e^{gr} + [1-(1+\alpha B_{\tau,t})^{\lambda-1}](A_{\tau}^{\max} - A_0 e^{gr})$$

Model Structure (2)

- Objective Function

max
$$\int_{t-T}^{t}[(A_{\tau,t}E_{\tau,t})^{\frac{\varepsilon-1}{\varepsilon}}d\tau]^{\frac{\varepsilon}{\varepsilon-1}}$$

s.t
$$\int_{t-T}^{t}(P_{K_\tau}\psi_\tau+P_E)E_\tau d\tau \le P_K K+P_E E$$

- Demand for energy vintage

$$E_\tau=E_S\left[\frac{A_\tau}{A_S}\right]^{\varepsilon-1}\left[\frac{P_{K_\tau}\psi_\tau+P_{E_\tau}}{P_{K_S}\psi_S+P_S}\right]$$

Results of the theoretical model

- Energy tax discourages energy consumption and the introduction of alternative energy (under constant energy-capital ratio)
- Complementarity of energy decreases demand for alternative energy
- Bigger complementarity among energy sources, less minimum demand for the particular energy
- Learning-by-using (LBU) delays the introduction of alternative energy or lowers the growth rate of alternative energy market

Empirical model

- ❖ Global CGE based on GREEN
- ❖ Data : Green data from OECD
- ❖ Period : 1985 – 2100
- ❖ Base year : 1985
- ❖ Dynamic model based on Ramsey model

Empirical model structure (1)

❖ Assumption

- Balanced growth of economy
- Energy vintage as time in use
- N monopolistically competitive companies produce the differentiated energy vintage
- A company stop producing energy if it can not operate profitably (market demand is not big enough to cover the fixed cost)
- LBU: More time in use, higher productivity

Empirical model structure (2)

❖ Energy production

- Energy vintage

$$E_i = \sum_{\tau=0}^{T} (E_{i,\tau,t}^{\alpha})^{1/\alpha}$$

- Energy demand

$$E_{i,\tau} = P_{i,\tau}^{-\sigma} e_i^{\sigma-1} M_{e_i} \quad e_i = \left(\sum P_{i,s}^{1-\sigma}\right)^{\frac{1}{\sigma-1}}$$

- Mark-up price

$$P_{i,\tau}(1-1/\sigma) = c(w,r)$$

- Zero profit condition

$$P_{i,r} = c(w,r) + \frac{F}{E_{i,\tau}} \qquad E_{i,\tau} = (\sigma-1)\frac{F}{c(w,r)}$$

Empirical model structure (3)

- Energy mix

$$E_t = \sum_{i}^{N} \left(A_{i,t} E_{i,\tau,t}^{\frac{\varepsilon-1}{\varepsilon}} \right)^{\frac{\varepsilon-1}{\varepsilon}}$$

i=coal, oil, LNG, sub

- Learning-by-using

$$A_{i,t} = E_{i,t}^{(1/(1-(aT-1))} - E_{i,t}$$

❖ Final consumption good

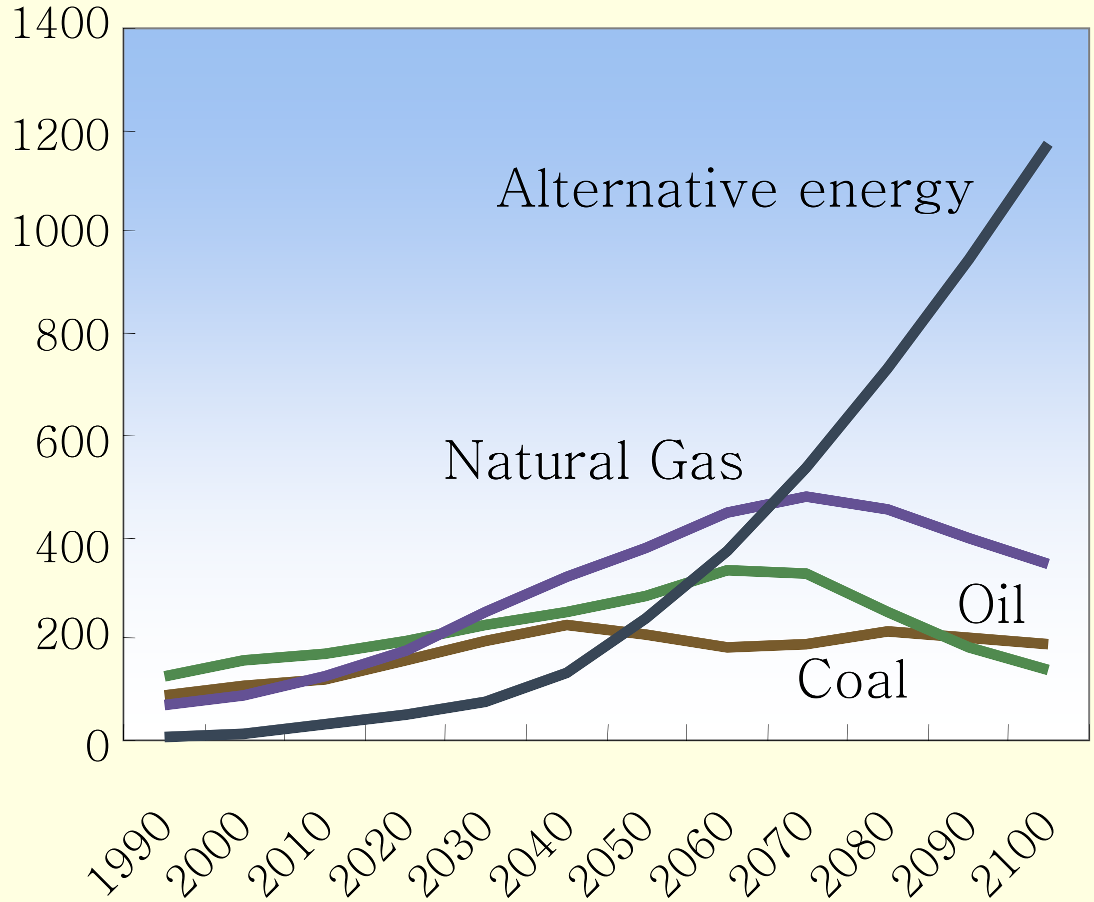
$$Y_t = (a_1 XA_t^{\rho} + a_2 EKL_t^{\rho})^{1/\rho}$$

$$EKL_t = (a_1 E_t^{\rho} + a_2 KL_t^{\rho})^{1/\rho}$$

$$KL_t = K_t^{\rho} L_t^{1-\rho} \qquad K_{t+1} = (1-\delta)K_t + I_t$$

Energy production profile

- Oil and gas : Hubbert's Bell curve
- Coal and alternative energy
  : MESSAGE model



Scenario

- Scenario1:

  Greenhouse gas abatement Abate 30% of BaU emission from 2008

- Scenario2:

  Subsidy recycle government revenue from carbon tax to support alternative energy development

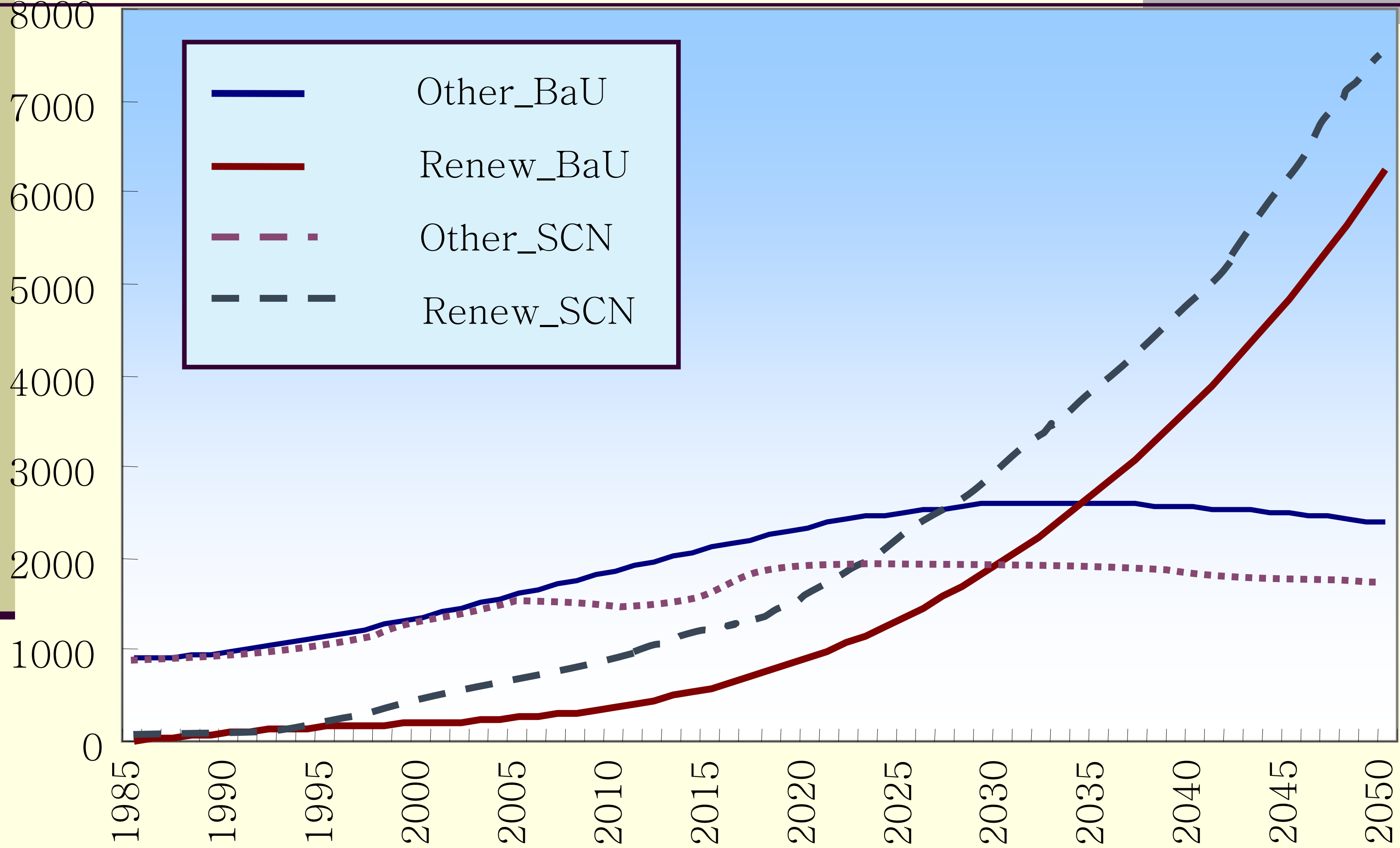
	Mark-up price	Zero profit price	Import rate of fixed factor	Monopoly profit	Vintage
Coal	1.27	1.30	-0.02	-772	0.88
Oil	1.27	1.41	-0.09	-5,302	0.92
Natural Gas	1.283	1.281	0.002	95	1.01
Alternative energy	1.31	1.06	0.24	106,509	1.20

(BaU = 1, 1985 million US$)

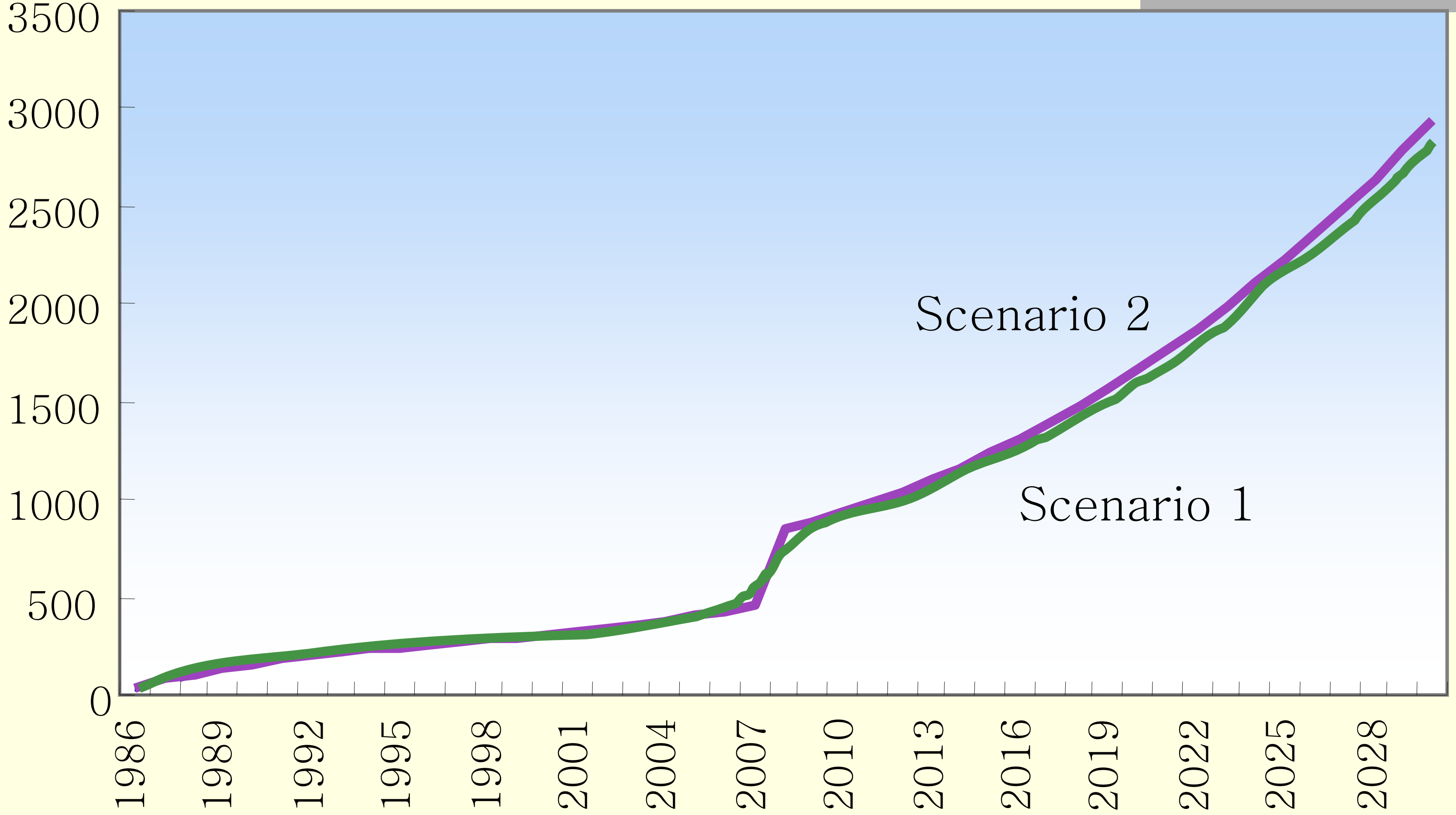
Energy vintage and welfare change

		Scenario1	Scenario2
Welfare change	%	-0.71	-0.68
	1985 million US$	-2118	-2031
Vintage (BaU=1)	Coal	0.88	0.88
	Oil	0.92	0.92
	Natural Gas	1.00	0.97
	Alternative energy	1.20	1.22

Energy mix under the Scenario 1



Demand of alternative energy



Results of empirical model

- Emission abatement through energy tax will increase the monopoly profit of natural gas and alternative energy
- Natural gas and alternative energy vintage increase in terms of their share and time in use
- Subsidy is helpful to increase the alternative energy vintage
- Scenario2 achieves higher welfare and less abatement cost than Scenario1