MODELING THE INTERDEPENDENCE OF ENERGY, AGRICULTURE AND ENVIRONMENT

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INTRODUCTION

- THE ROLE OF BIOFUELS MUST BE SEEN IN THE CONTEXT OF
- SCARCE ENERGY RESOURCES
- THE DEMAND FOR CLEAN ENERGY
- THE ALLOCATION OF LAND BETWEEN FOOD AND ENERGY PRODUCTION

- WE DEVELOP AN ECONOMIC FRAMEWORK TO STUDY THE
- ADOPTION OF BIOFUELS

- LAND IS USED FOR FOOD PRODUCTION

- ENERGY IS SUPPLIED BY SCARCE FOSSIL FUELS

- THE PRICE OF ENERGY RISES BECAUSE OF SCARCITY AND
- POLLUTION EXTERNALITIES

- OVER TIME THE RISE IN ENERGY PRICES MAKES IT ECONOMICAL
- FOR LAND TO BE MOVED OUT OF FARMING AND INTO ENERGY
- PRODUCTION

- AS LAND SHIFTS OUT OF FOOD INTO ENERGY PRODUCTION, THE
- PRICE OF FOOD ALSO RISES

- ULTIMATELY, FOSSIL FUELS ARE COMPLETELY EXHAUSTED AND
- ALL ENERGY IS SUPPLIED BY LAND

- LAND ALLOCATION REACHES A STEADY STATE

- THE DEMAND FOR A CLEAN ENVIRONMENT IS EXPRESSED IN
- TERMS OF A CAP ON THE STOCK OF CARBON

- WE EXPLORE HOW REGULATION OF POLLUTION MAY
- AFFECT THE TRANSITION TO BIOFUELS

- THE FACTORS THAT AFFECT THE SUBSTITUTION INTO BIOFUELS
- ARE

- SCARCITY OF LAND
- DEMAND FOR FOOD
- HOW STRICT IS REGULATION
- ABUNDANCE OF THE FOSSIL FUEL

- UTILITY IS GIVEN BY

$$U(x_f, x_y) = x_f^{\alpha} x_y^{1-\alpha}$$

- THE LAND CONSTRAINT CAN
- BE WRITTEN AS

$$\bar{L} - L_f - L_y \geq 0$$

- FOOD PRODUCTION IS 1:1
- WITH LAND

$$f(L_f) = L_f$$

ENERGY PRODUCTION IS MODELED SIMILARLY

$$y(t) = \quad _{y}$$

UNIT COSTS OF PRODUCTION ARE

$$c_i, i \in \{f, y\}$$

THE FOSSIL FUEL IS A NONRENEWABLE RESOURCE

$$\dot{X}(t) = -x(t)$$

TOTAL ENERGY CONSUMPTION IS

$$y(t) = +$$

POLLUTION FROM THE FOSSIL FUEL IS GIVEN BY

$$\dot{Z}(t) = x(t) - \alpha Z(t)$$

REGULATION IS IMPOSED AS A CAP ON THE POLLUTION STOCK

$$\bar{Z} - Z(t) \geq 0$$

- OBVIOUSLY THIS IS A VERY RESTRICTIVE MODEL, AND
- MANY THINGS ARE MISSING, SUCH AS

- MULTIPLE RESOURCES AND DEPOSITS

- LAND QUALITIES

- DEMAND SHIFTS

- EXPLICIT ENVIRONMENTAL DAMAGES

- E 85

THE EQUILIBRIUM CONDITIONS ARE

$$u'_{ff}(x_{ff}) = \pi$$

$$u'_{ex}(x_{ex}) + c = \pi$$

PRICE OF FOOD AND BIOFUEL = UNIT COST OF PRODUCTION

+ LAND RENT

$$u'_{ex}(x_{ex}) + c = \pi - \theta\mu$$

PRICE OF FOSSIL FUEL = EXTRACTION COST + SCARCITY RENT

+ EXTERNALITY COST

$$\pi = \theta(\bar{L} - L_{ff})$$

OIL HAS A SCARCITY RENT

$$\dot{\lambda} / \lambda = \rho$$

BECAUSE OF DISCOUNTING AND FREE DILUTION,
THE DAMAGE COST OF FOSSIL FUEL GOES UP

$$\dot{\mu} / \mu = \alpha (\mu + \nu)$$

THE FULL MARGINAL COSTS OF ENERGY ARE

FOOD: $c_f + \pi$

BIOFUEL: $c_y + \pi$

OIL: $c_x + \lambda - \theta\mu$

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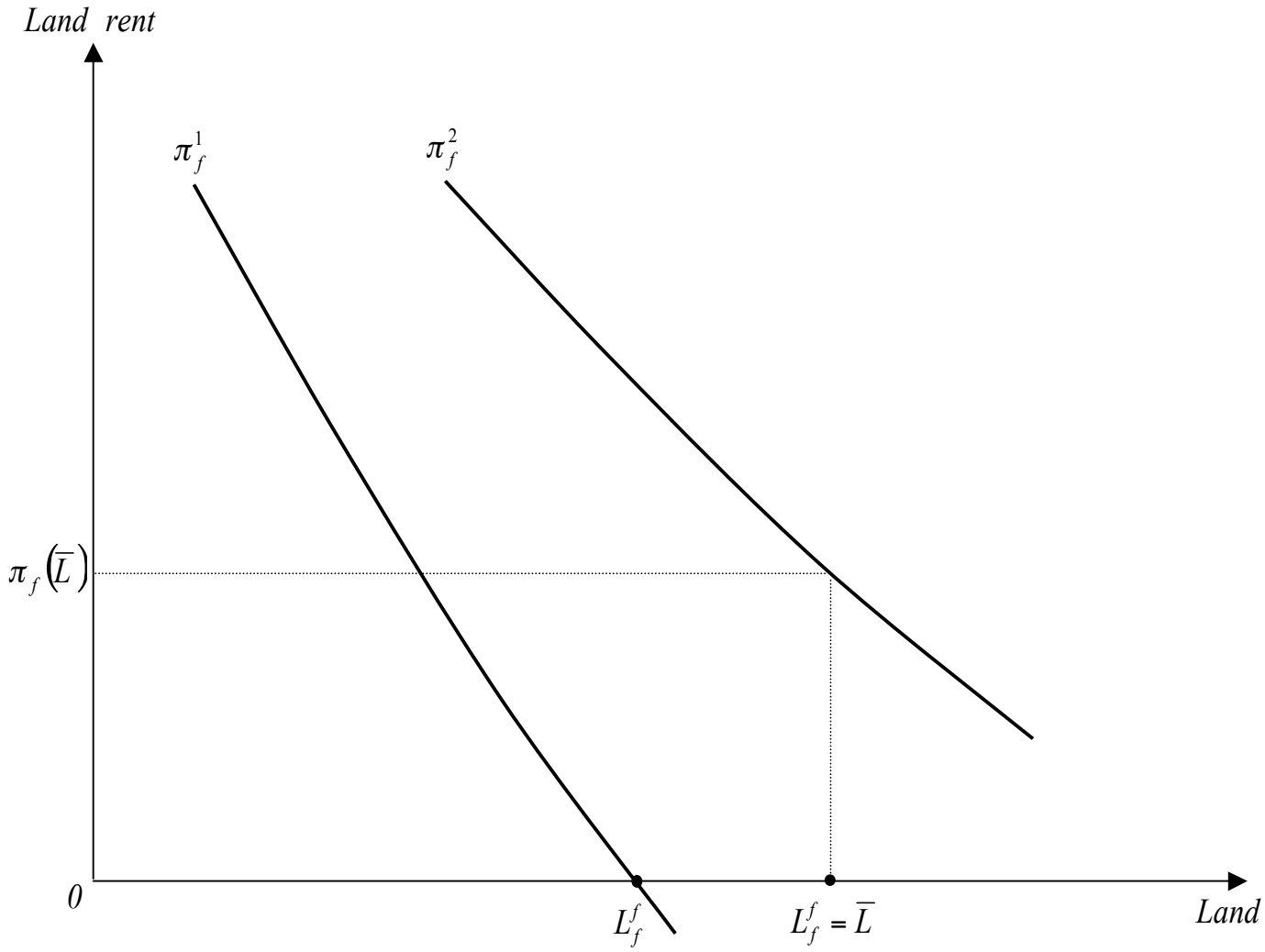

Fig 1. Land is used only for Food

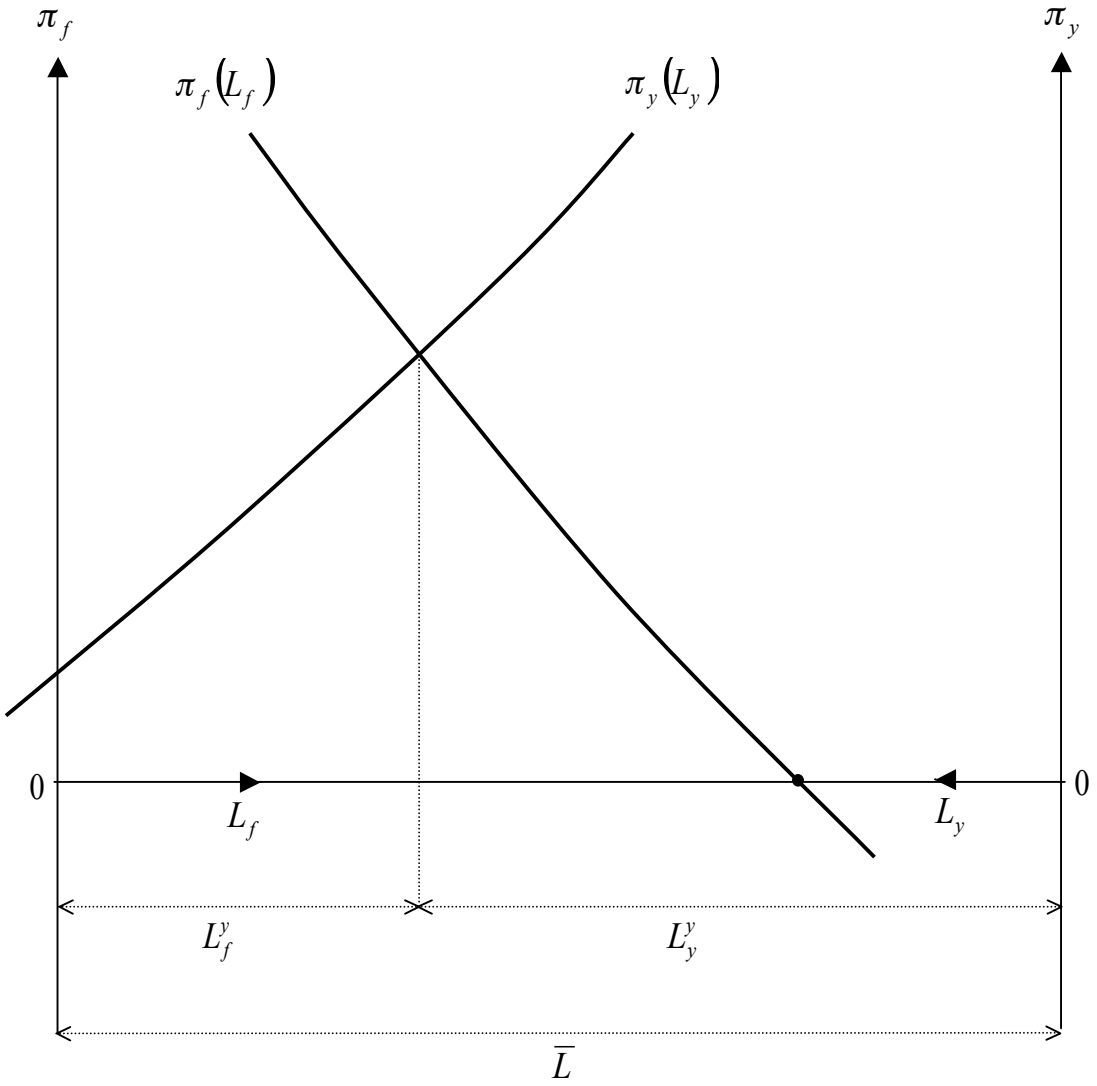

Fig 2. Land is used both for Food and Clean Energy

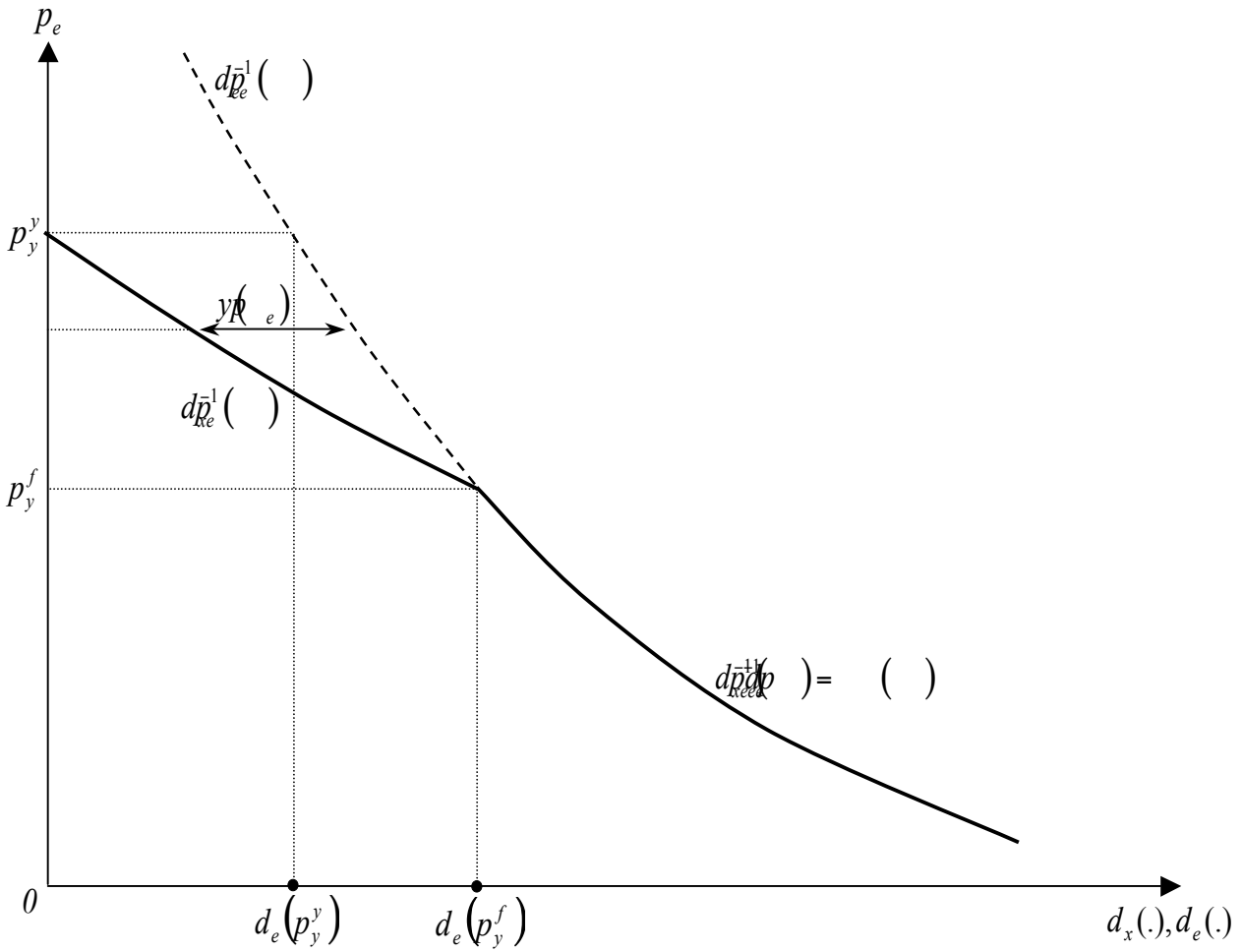

Fig 3. Energy Supply when Land is Scarce or Demand for Food is High

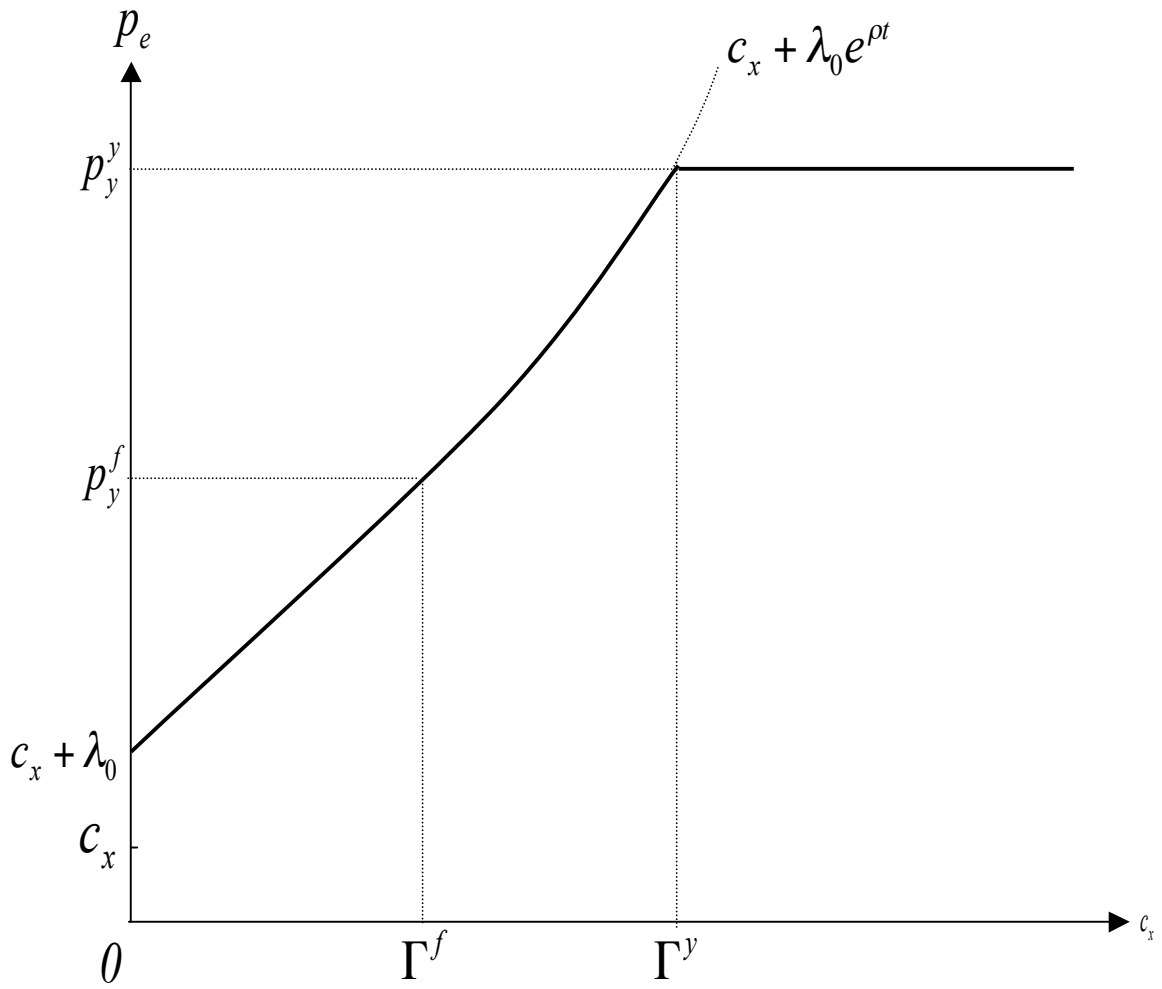

Fig 4. Energy Supply from Land increases monotonically

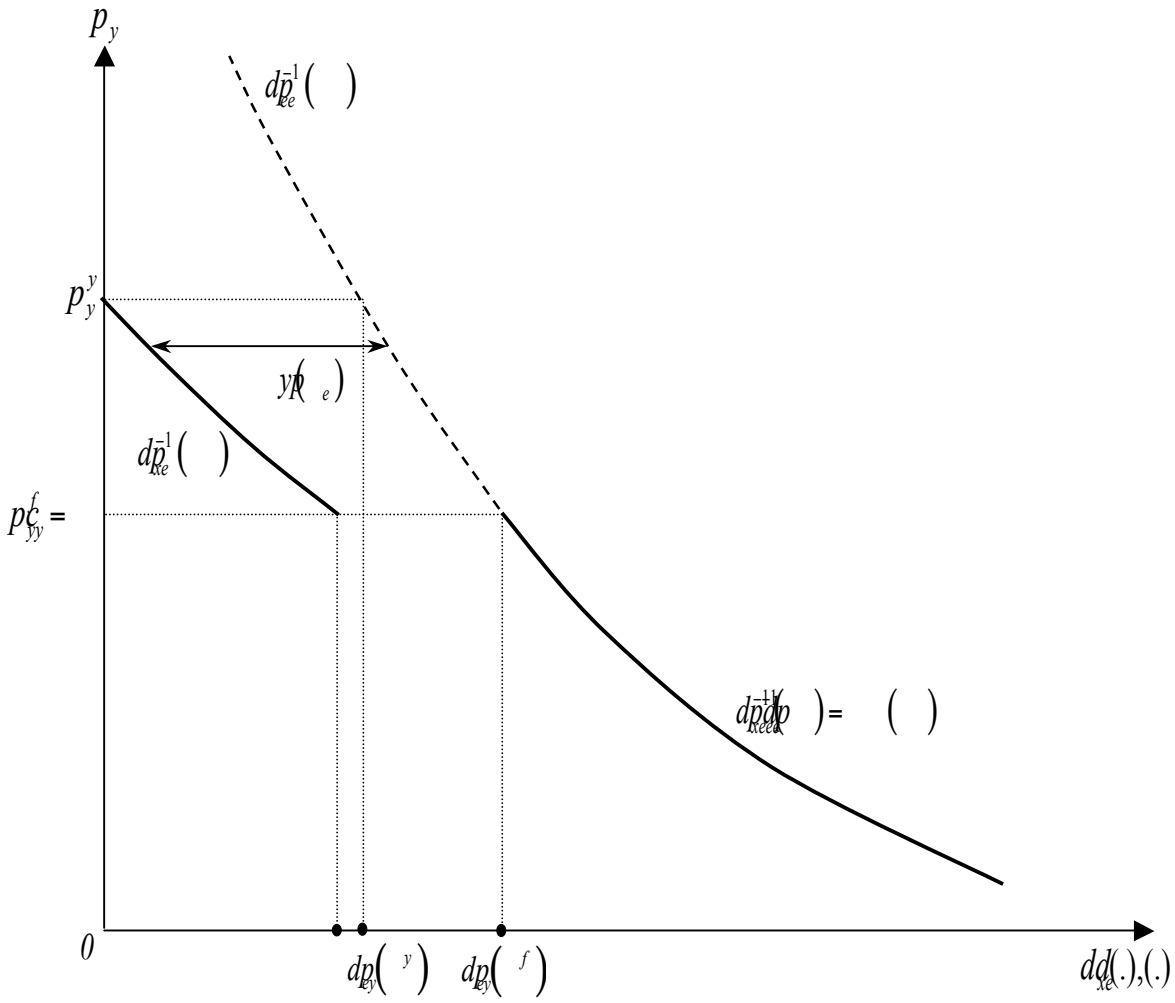

Fig 5. Energy Supply with Abundant Land or Low Demand for Food

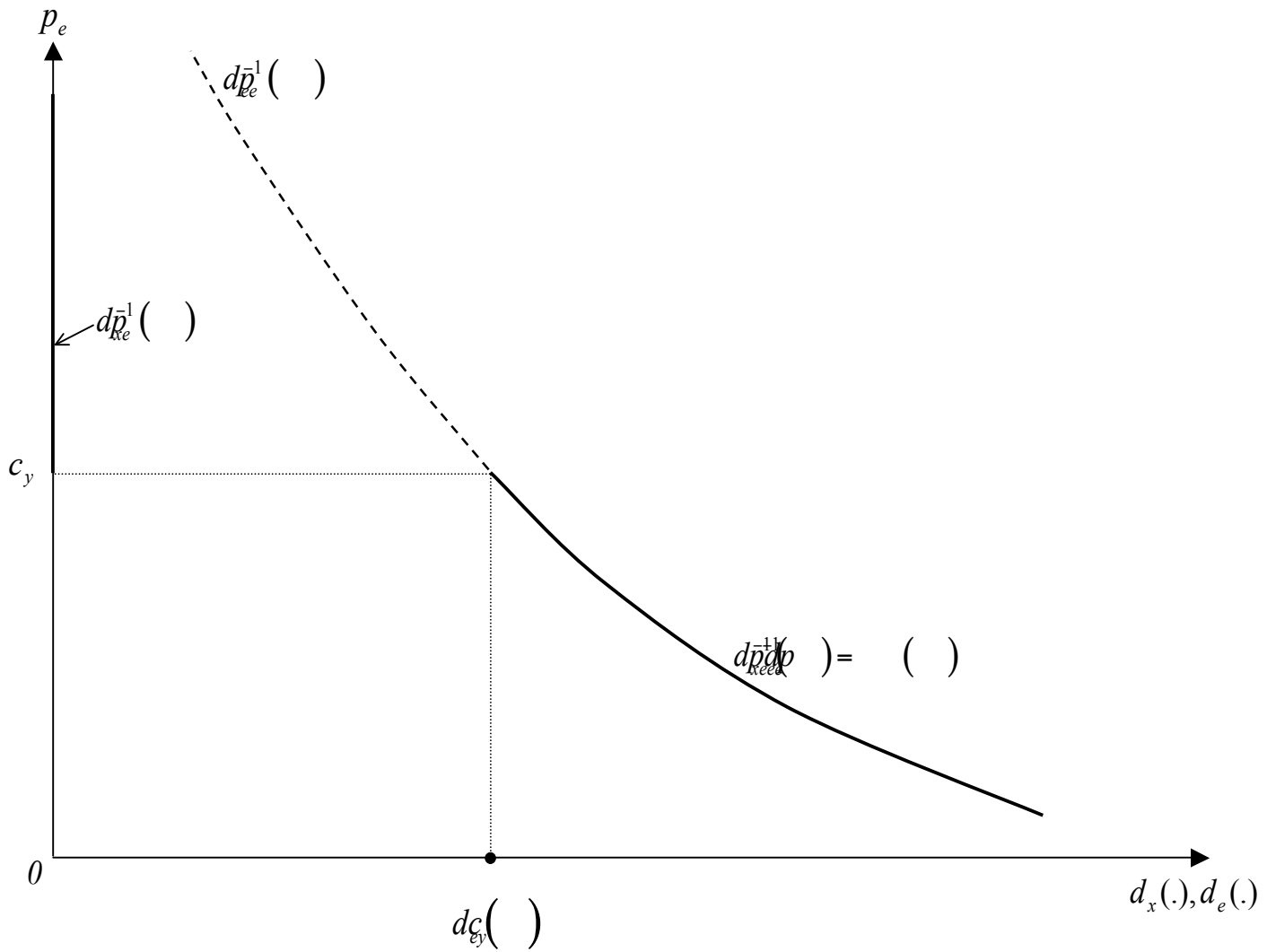

Fig 6. Oil Demand when Land is Abundant or the Demand for Energy is Low

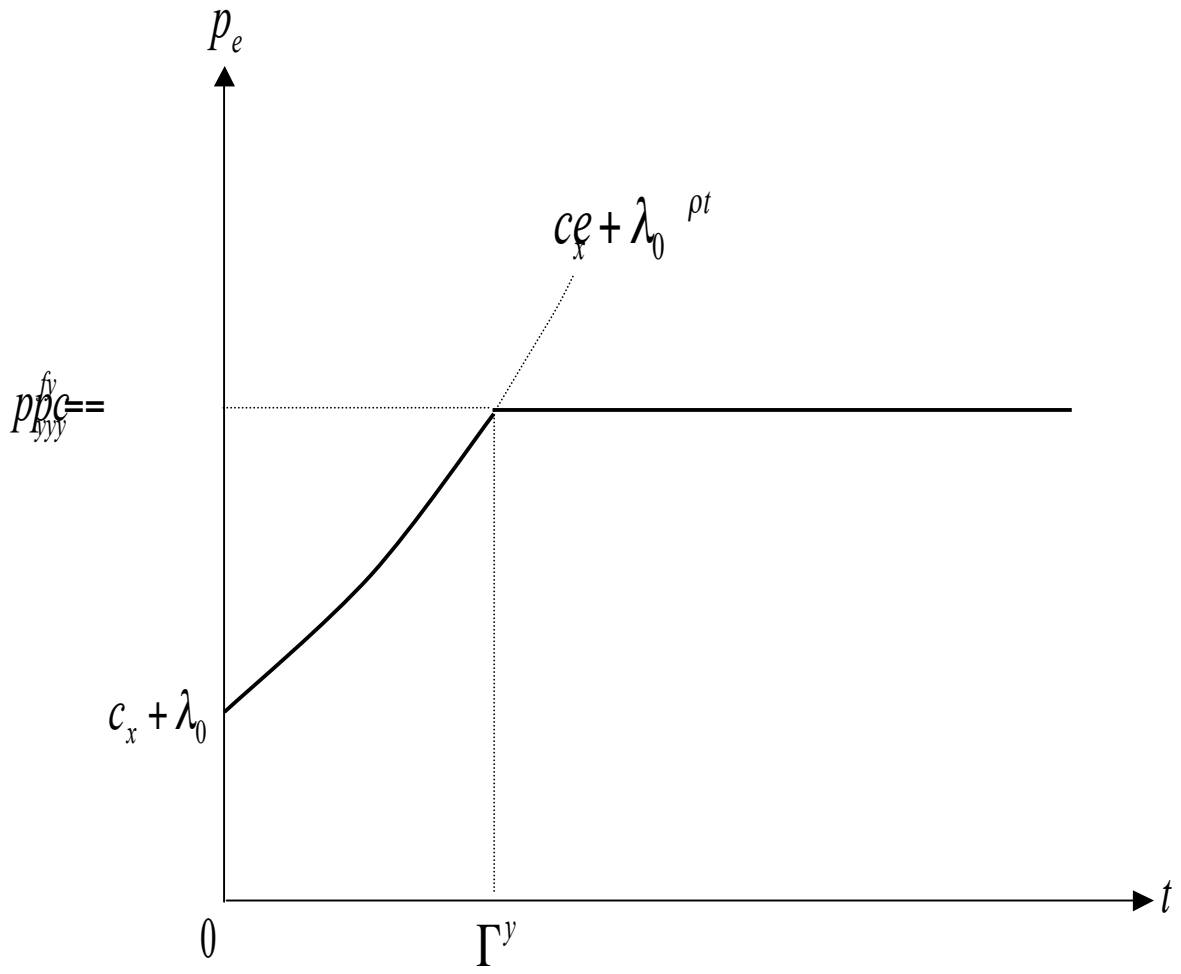

Fig 7. Energy from Land acts as a pure Backstop Resource

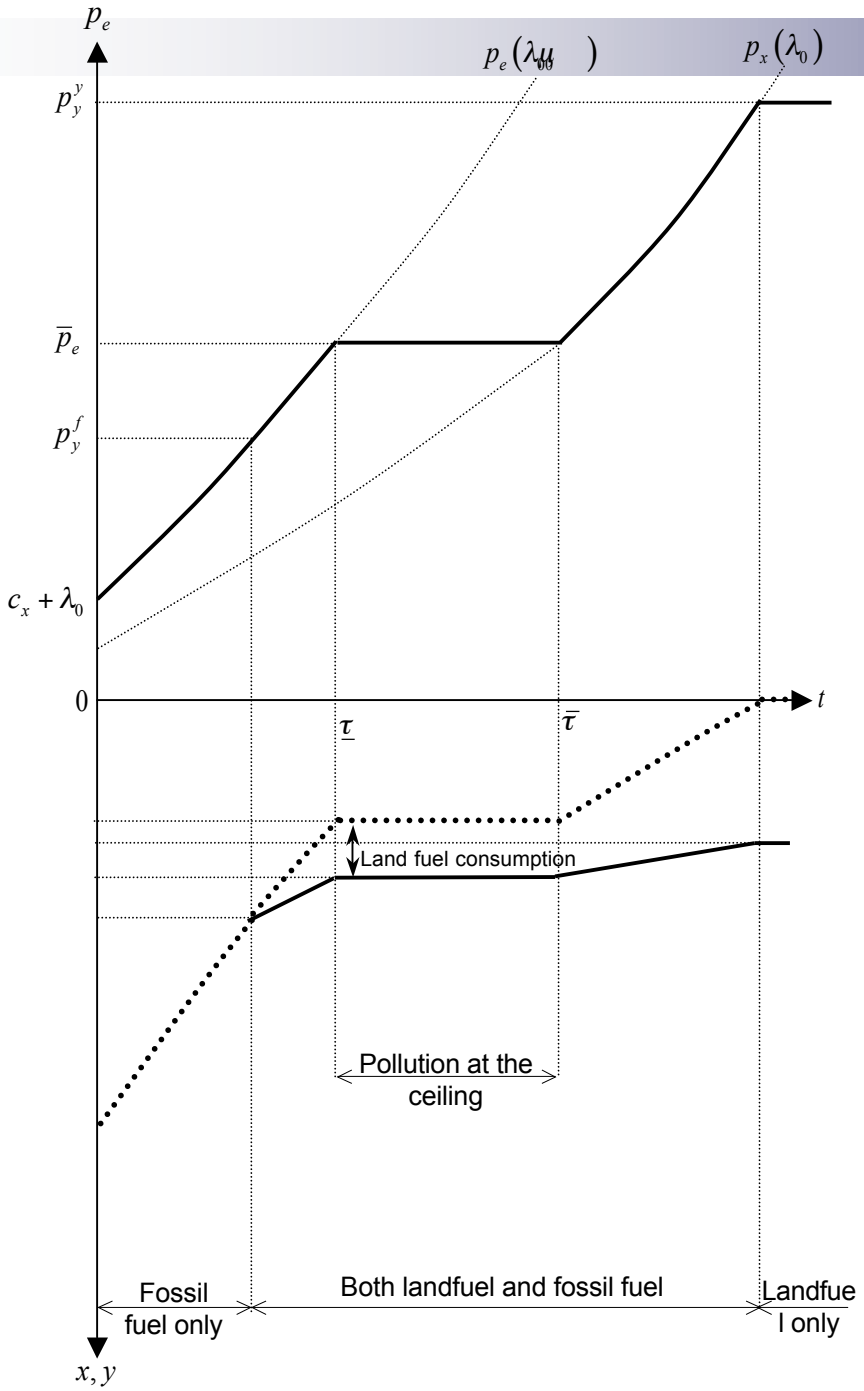

Fig 8. With Env Regulation, Land May Supply Energy before Regulation Binds

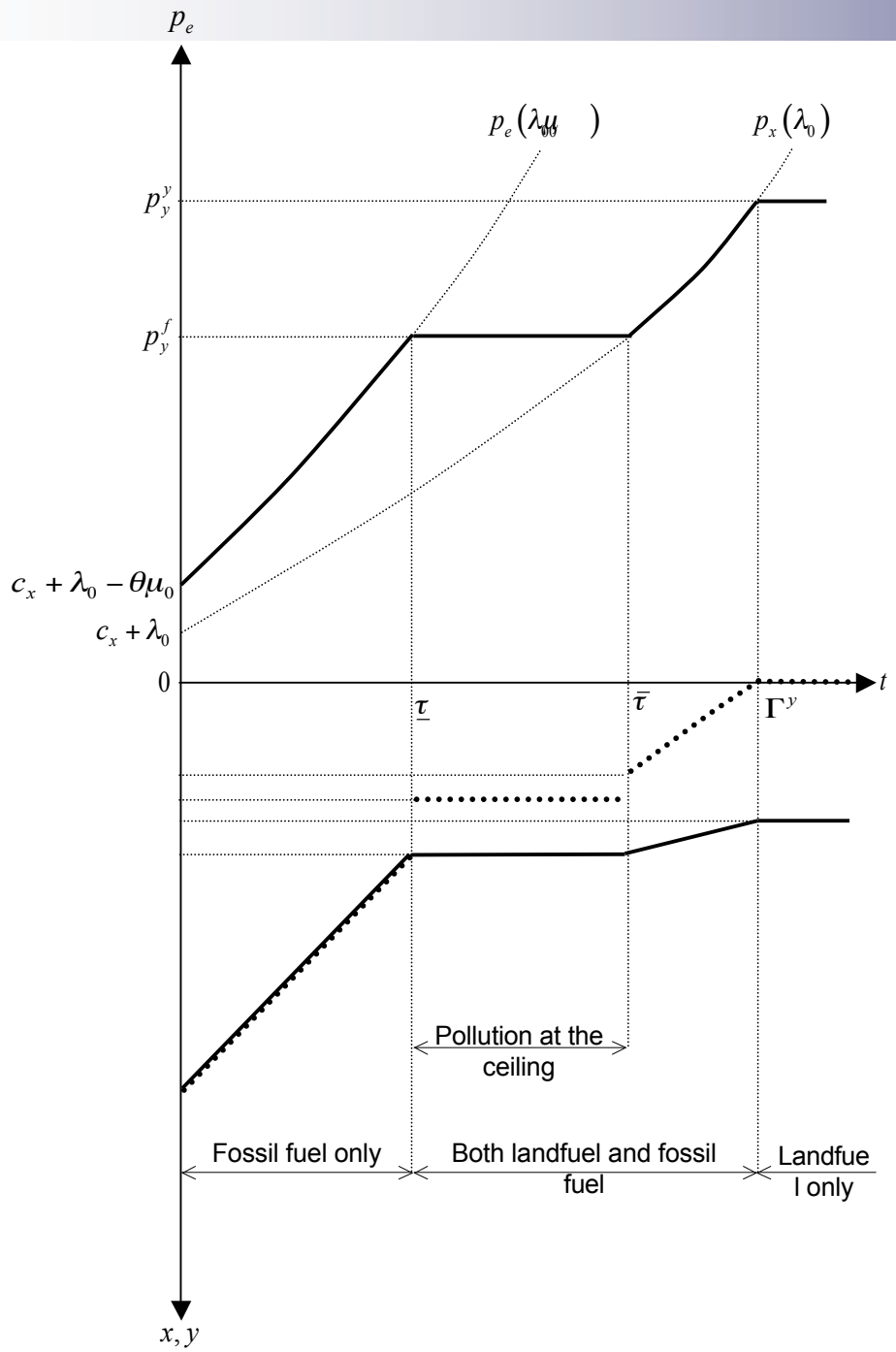

Fig 9. Multiple Discontinuities in the Supply of the Land Fuel when Land is Abundant

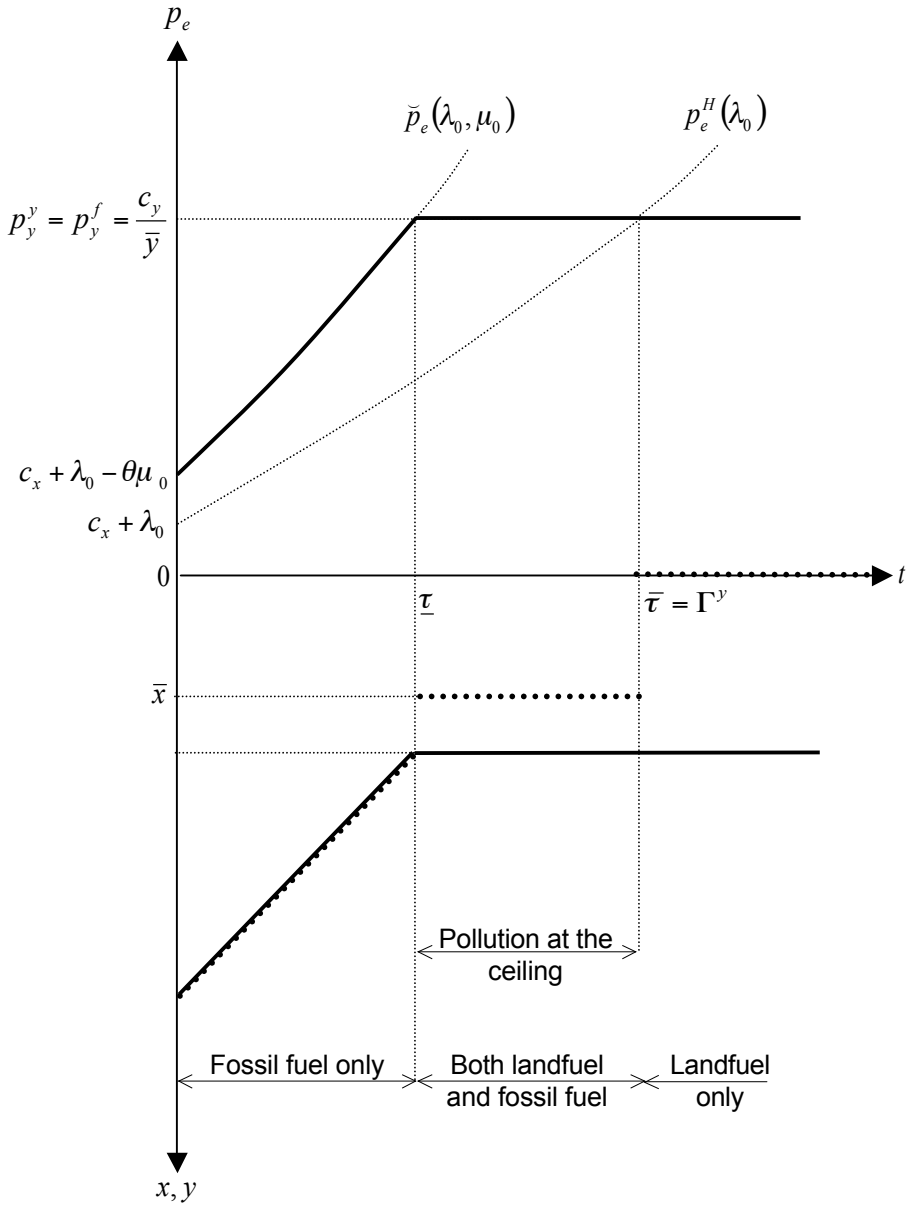

Fig 10. Oil is Exhausted exactly when Regulation ceases to Bind: Land Abundant both for Food and Energy

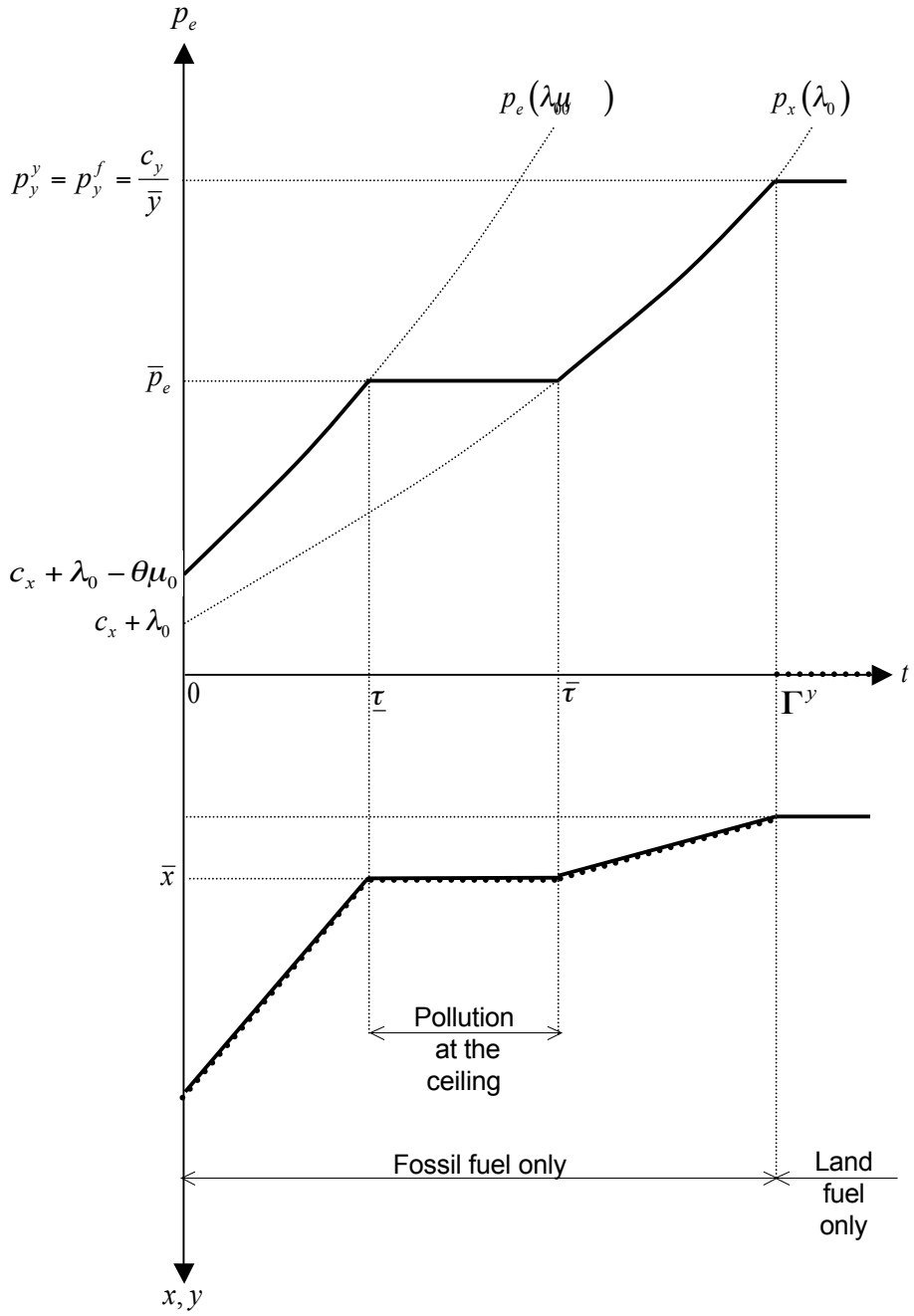

Fig 11. Fuel from Land is Expensive: Only Oil is used under Regulation

EXTENSIONS OF THE FRAMEWORK

- ABATEMENT TECHNOLOGIES
- IN THIS FRAMEWORK, ABATEMENT ONLY OCCURS WHEN THE POLLUTION CAP IS BINDING
- ABATEMENT IS ONLY DONE AT THE BEGINNING OF THE CEILING PERIOD
- ABATEMENT AND BIOFUELS ARE TWO CLEAN OPTIONS BUT OPERATE DIFFERENTLY –
- BIOFUELS MAY BE USED BEFORE REGULATION IS EFFECTIVE BUT NOT ABATEMENT

- INCREASING COST OF FOSSIL FUELS
- IF COSTS OF THE FOSSIL FUEL INCREASE WITH EXTRACTION, THEN THE TRANSITION TO THE BIOFUEL MAY OCCUR FASTER
- THE FOSSIL FUEL MAY BE USED FOR A LONGER PERIOD OF TIME

- LAND PARCELS OF DIFFERENT QUALITY
- LANDS MAY HAVE COMPARATIVE ADVANTAGE IN PRODUCING FOOD OR ENERGY CROPS
- OR THE COST OF PRODUCTION MAY BE DIFFERENT
- WHEN ENERGY PRICES ARE LOW, ENERGY PRODUCTION MAY BE DONE ON LOW QUALITY LANDS
- WITH INCREASE IN PRICES DRIVEN BY SCARCITY, FOOD PRODUCTION MAY BE SHIFTED OUT OF HIGH QUALITY LANDS
- MULTIPLE LAND QUALITIES MAY BE ASSIGNED TO FOOD OR ENERGY PRODUCTION AT THE SAME TIME

- A DAMAGE FUNCTION FOR POLLUTION THAT MAY BE A FUNCTION OF FLOW AND STOCK OF POLLUTION
- IF DAMAGES ARE HIGH, BIOFUELS MAY BE ADOPTED RIGHT AT THE BEGINNING
- REGULATING POLLUTION FLOWS INSTEAD OF STOCK
- FLOW REGULATION MAY ALSO CAUSE EARLIER ADOPTION
- BOTH LOCAL AND GLOBAL REGULATION

POLICY IMPLICATIONS AND CONCLUDING REMARKS

- WE HAVE PRESENTED AN ECONOMIC FRAMEWORK WHICH RECOGNIZES

- FOSSIL FUEL SCARCITY
- TRADEOFFS IN ALLOCATION OF LAND
- ENVIRONMNENTAL REGULATION

- SUPPLY OF THE BIO FUEL DEPENDS UPON MANY FACTORS

- AND THERE MAY BE DISCONTINUITIES

- FRAMEWORK CAN BE USED TO EXAMINE THE EFFECT OF AGRICULTURAL POLICIES SUCH AS

- EXPORT SUBSIDIES
- IMPORT TARIFFS
- TECHNOLOGICAL CHANGE IN FOOD PRODUCTION

- ON THE OTHER HAND, ENVIRONMENTAL POLICIES MAY ALSO IMPACT SUBSTITUTION BETWEEN FOOD AND CLEAN ENERGY

- E.G., STRICTER CARBON CONCENTRATION TARGETS

- MANY RESTRICTIVE ASSUMPTIONS
- DIFFERENT BIOFUEL TECHNOLOGIES
- DISTRIBUTION OF LAND QUALITIES
- ENERGY SECURITY
- NEED AN EMPIRICAL MODEL WITH REALISTIC NUMBERS AND PLAUSIBLE SCENARIOS