Impact of Biofuels on Planted Acreage in Market Equilibrium

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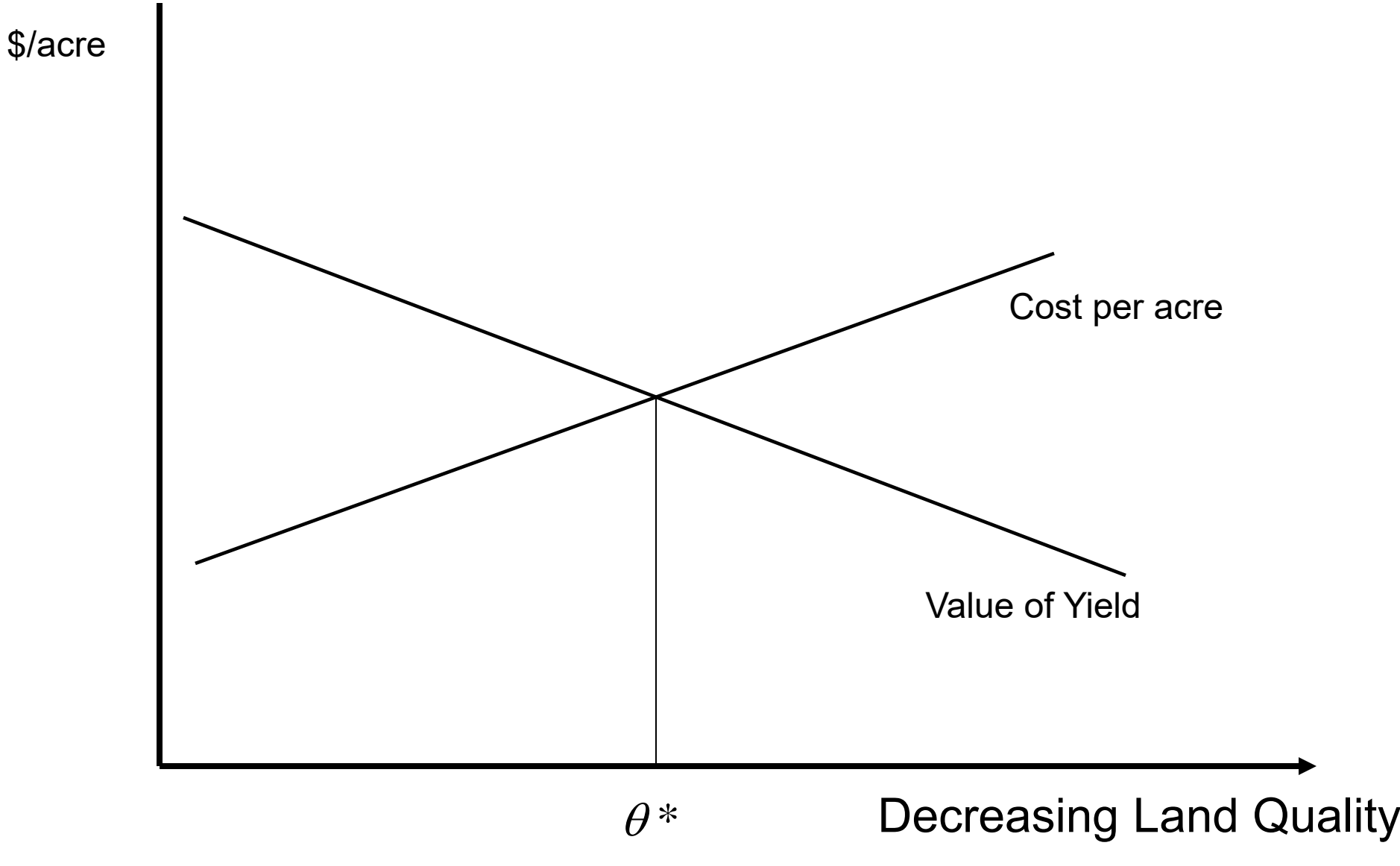
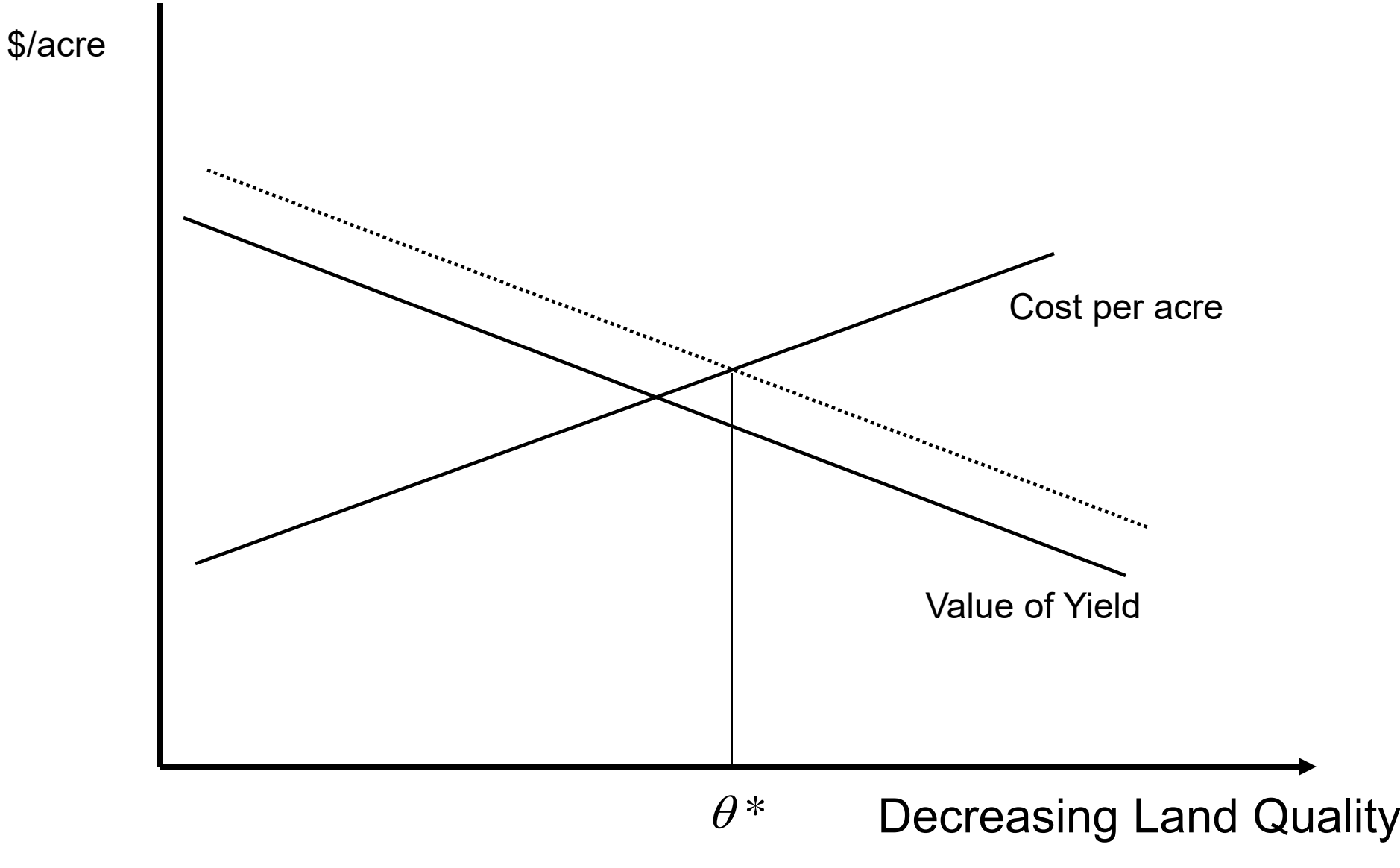
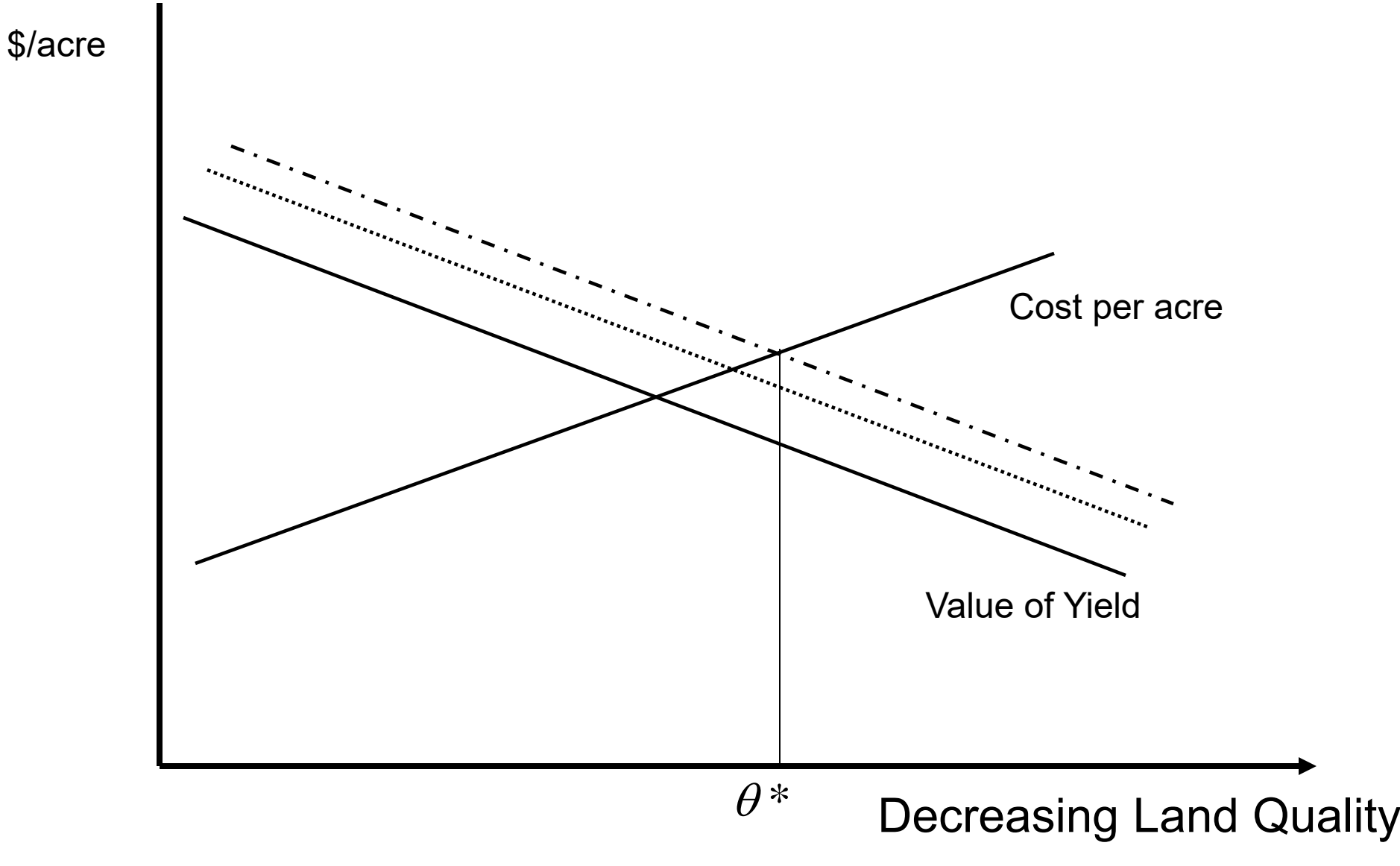
Land Market Equilibrium with Fixed Market Price



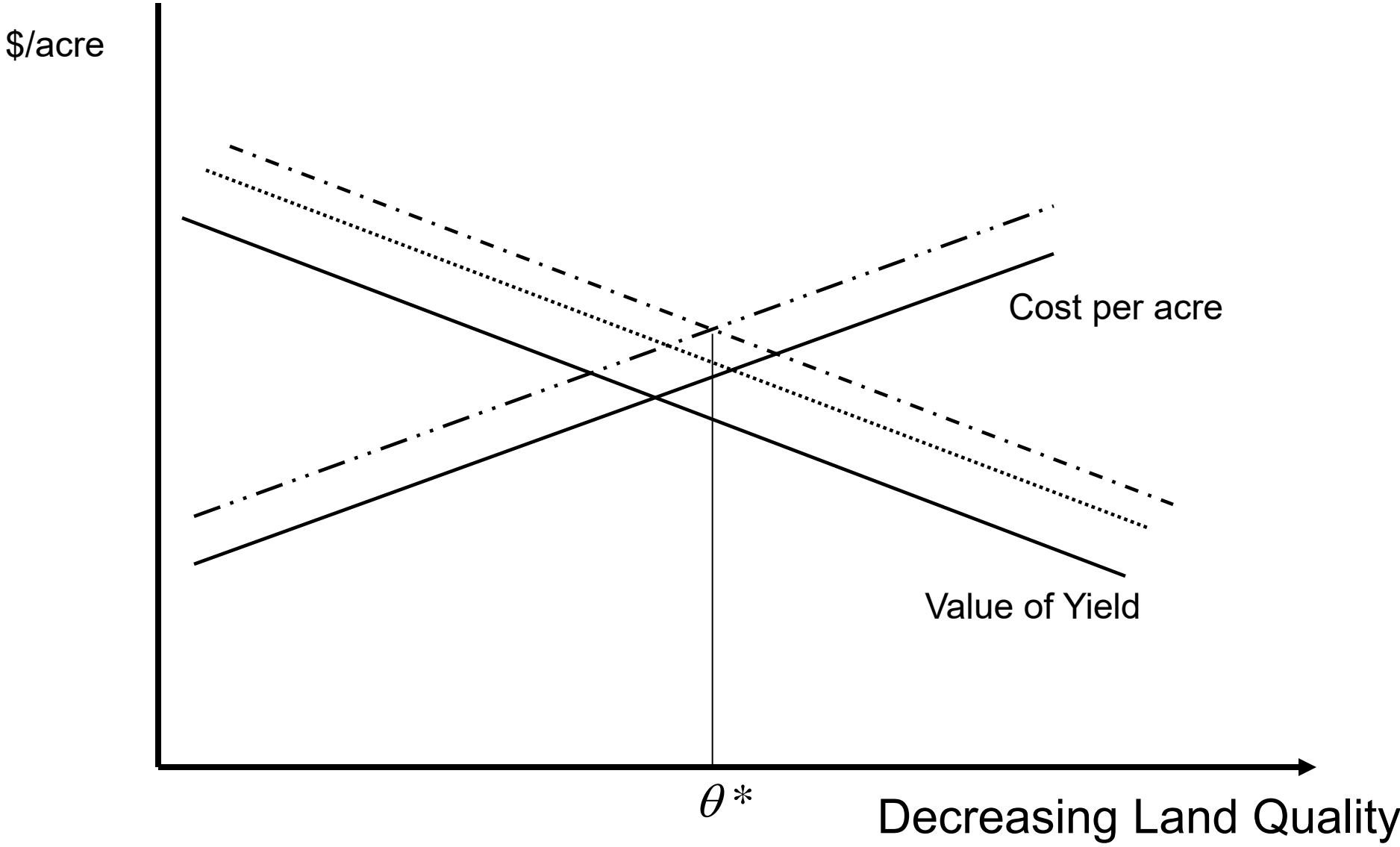
Impact of an increase in market price



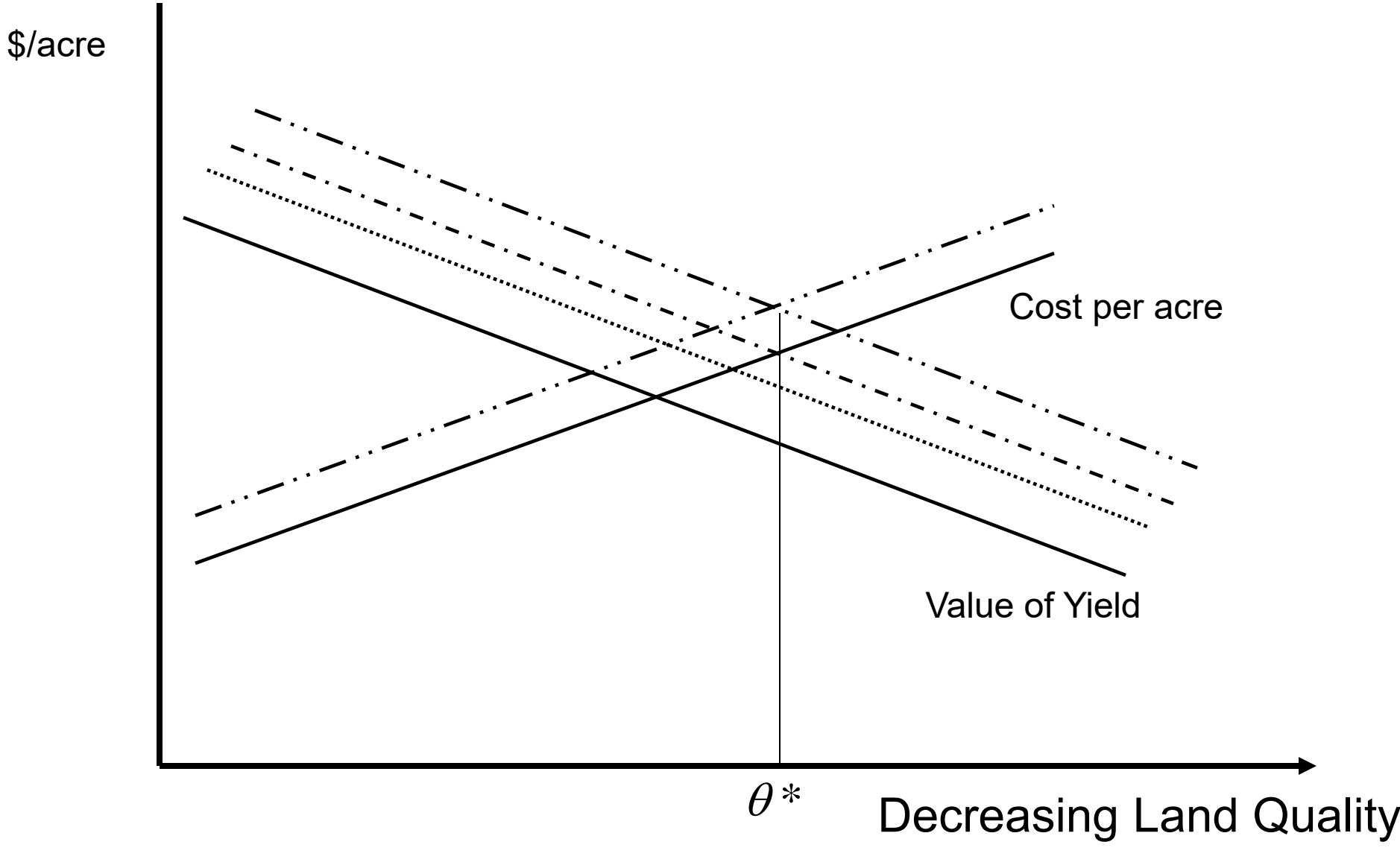
But input use will increase which increases yield



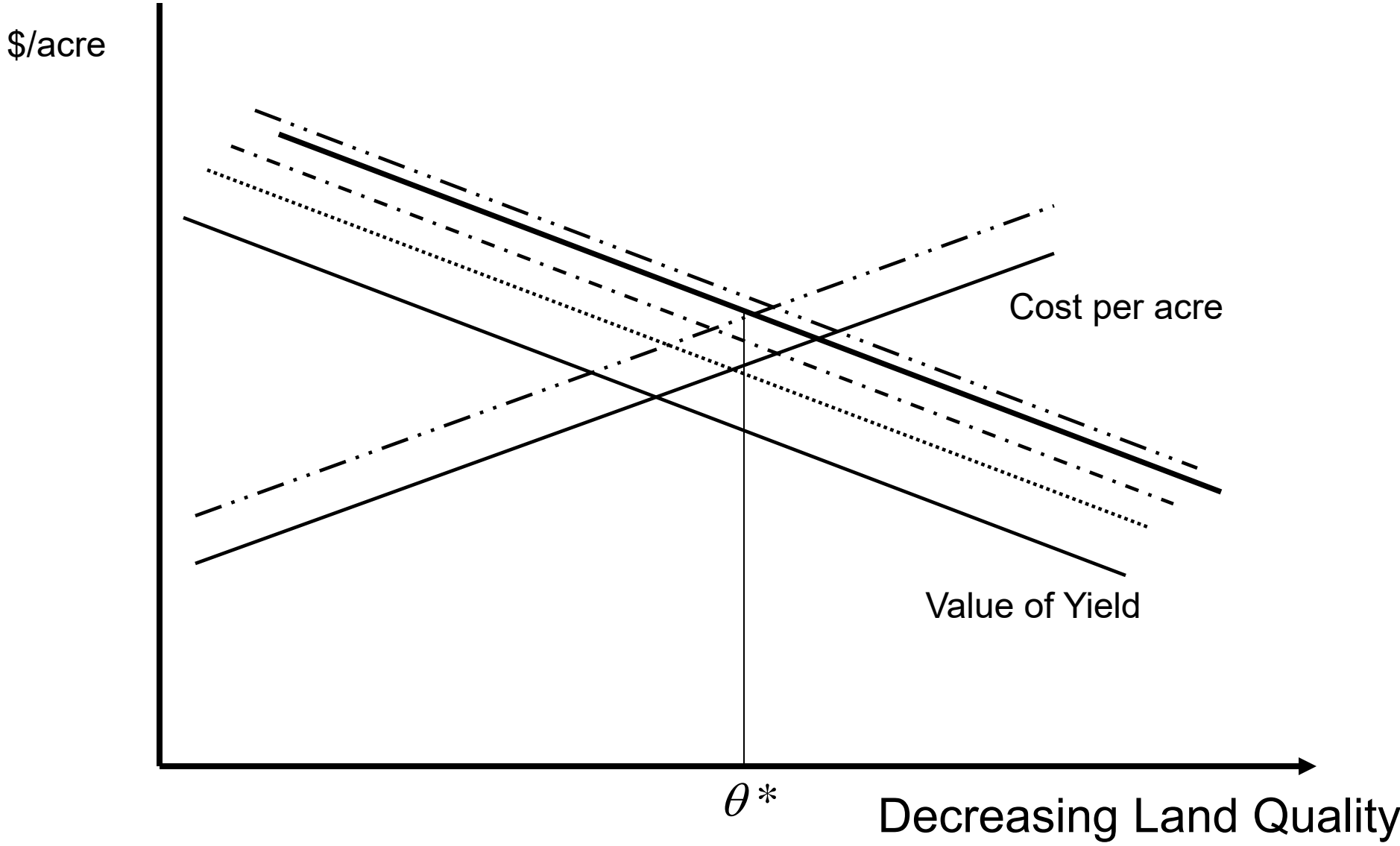
But increased input use increases cost



Will higher price induce yield increase?



If so then market price will drop



Our (draft) Paper

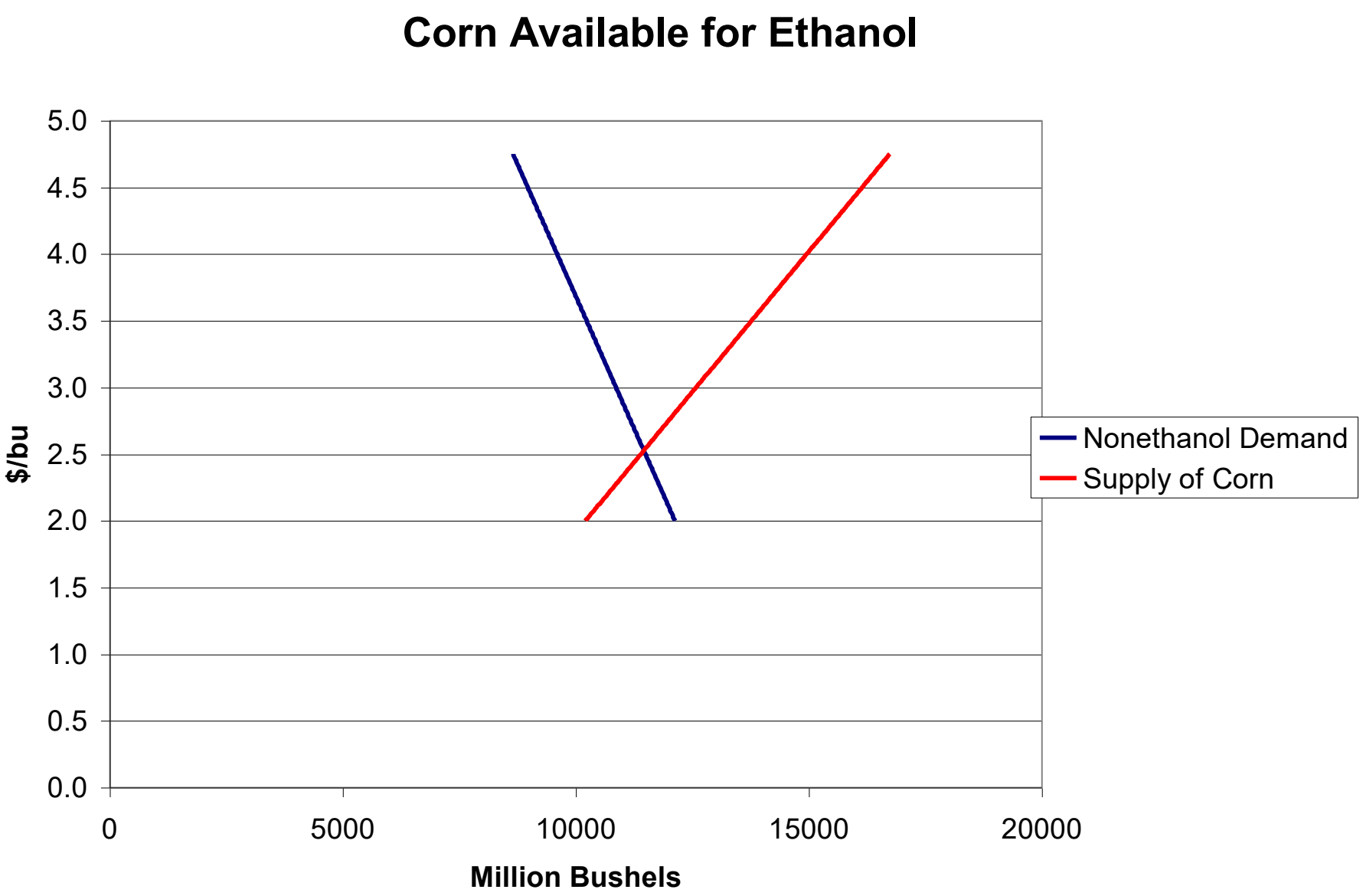
- Tries to disentangle the impacts of expanded biofuels production on land use given adjustments in
  - Allocation of land between crops
  - Input use
  - Output market price
  - Land markets
  - Induced innovation

Purpose

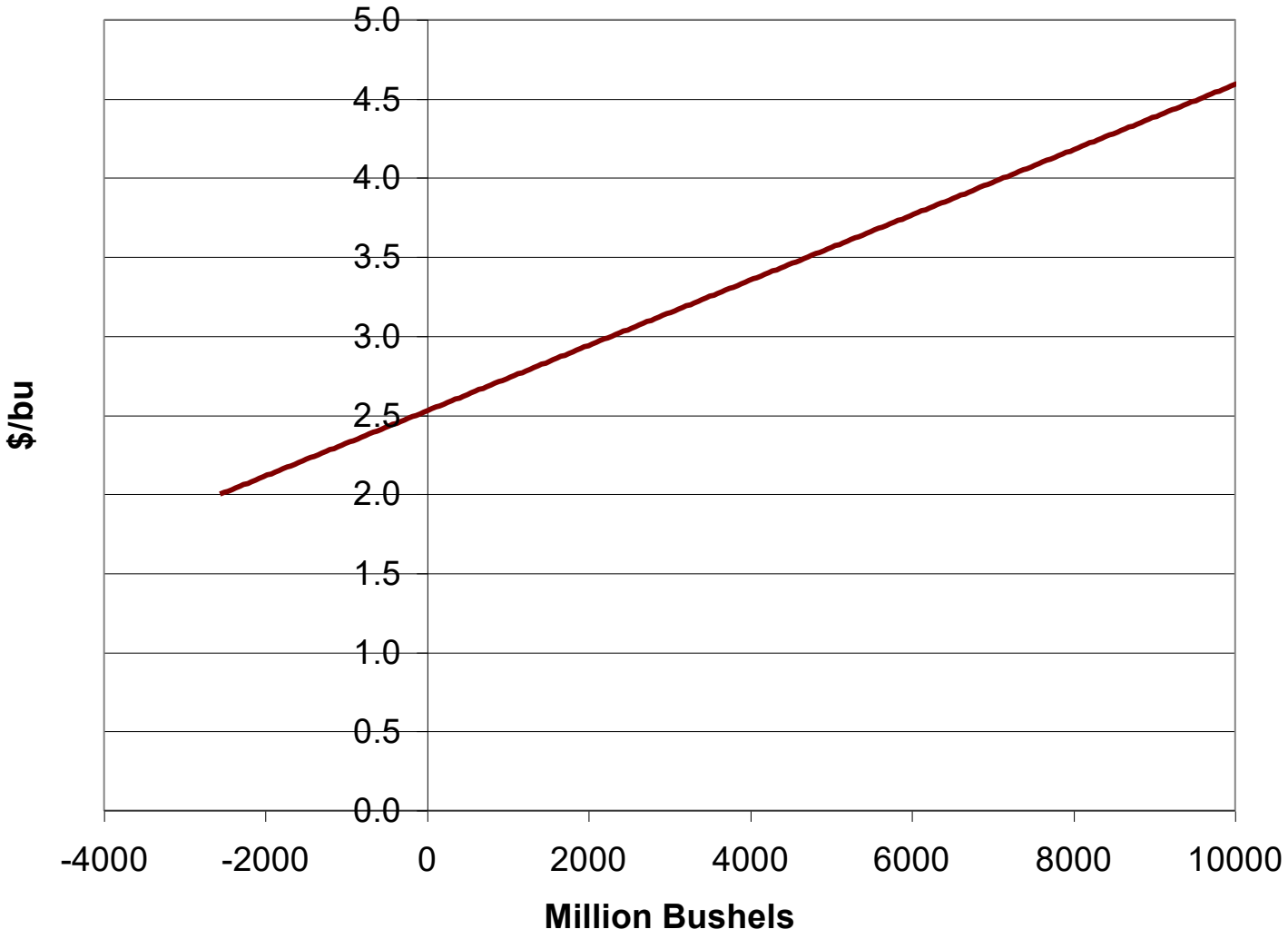
- How will land use change
  - From expanded biofuels production
  - From a technological development that increases yields
  - Under a consumption subsidy vs. a consumption mandate with a cap

Equilibrium Model of Land Use Changes

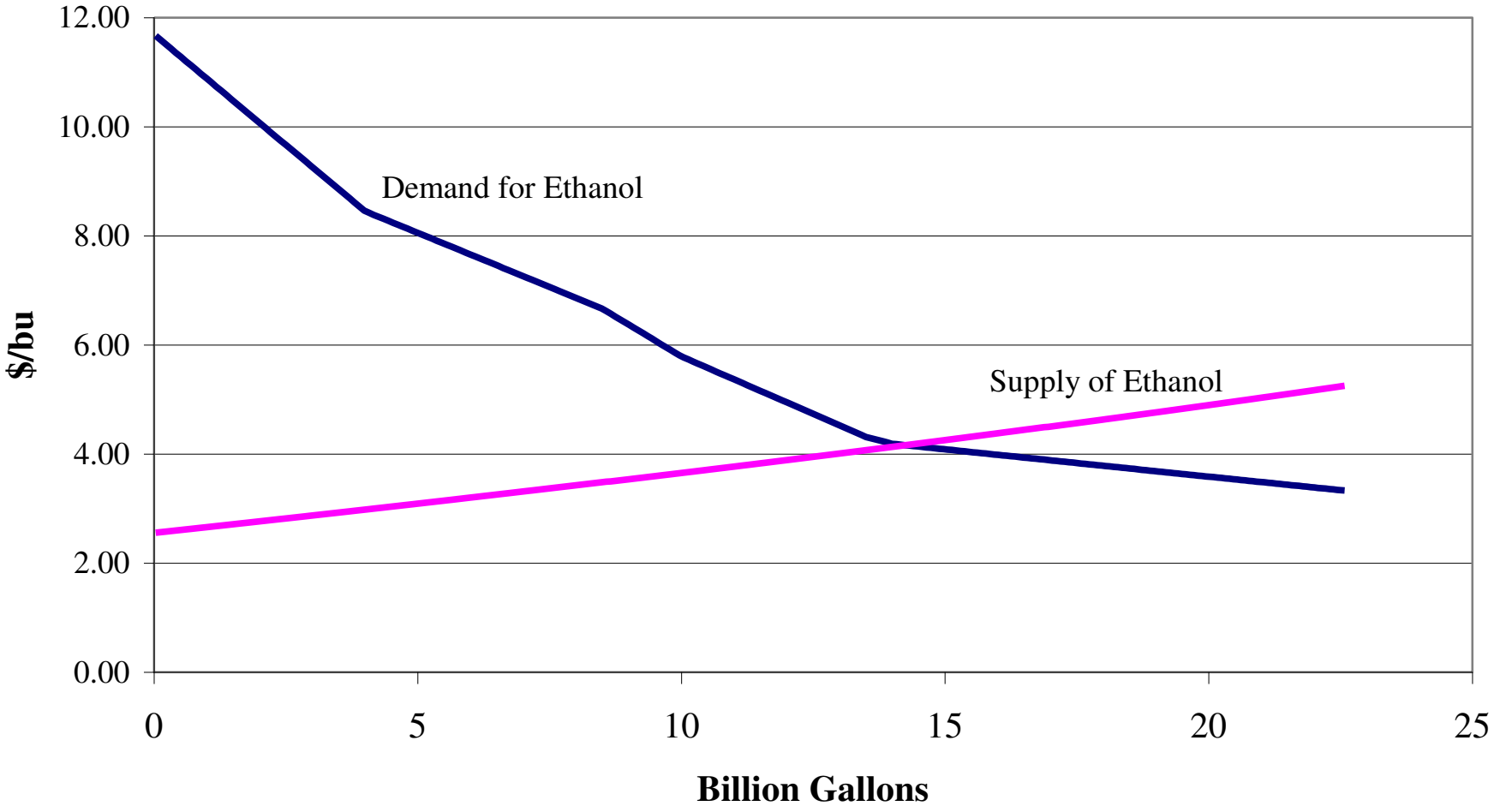
- Two crops: Corn and all others
- Allocate fixed land between corn and other crops
- Increase corn demand from ethanol
  - Price of corn determined by size of ethanol industry in equilibrium
- In model equilibrium,
  - Input use optimized (input prices exogenous)
  - Land allocation optimized (land quality is heterogeneous)
  - Product markets clear
  - Land market clears


Corn Available for Ethanol
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
$/bu
0
5000
10000
15000
20000
Million Bushels
Nonethanol Demand
Supply of Corn

Excess Supply of Corn



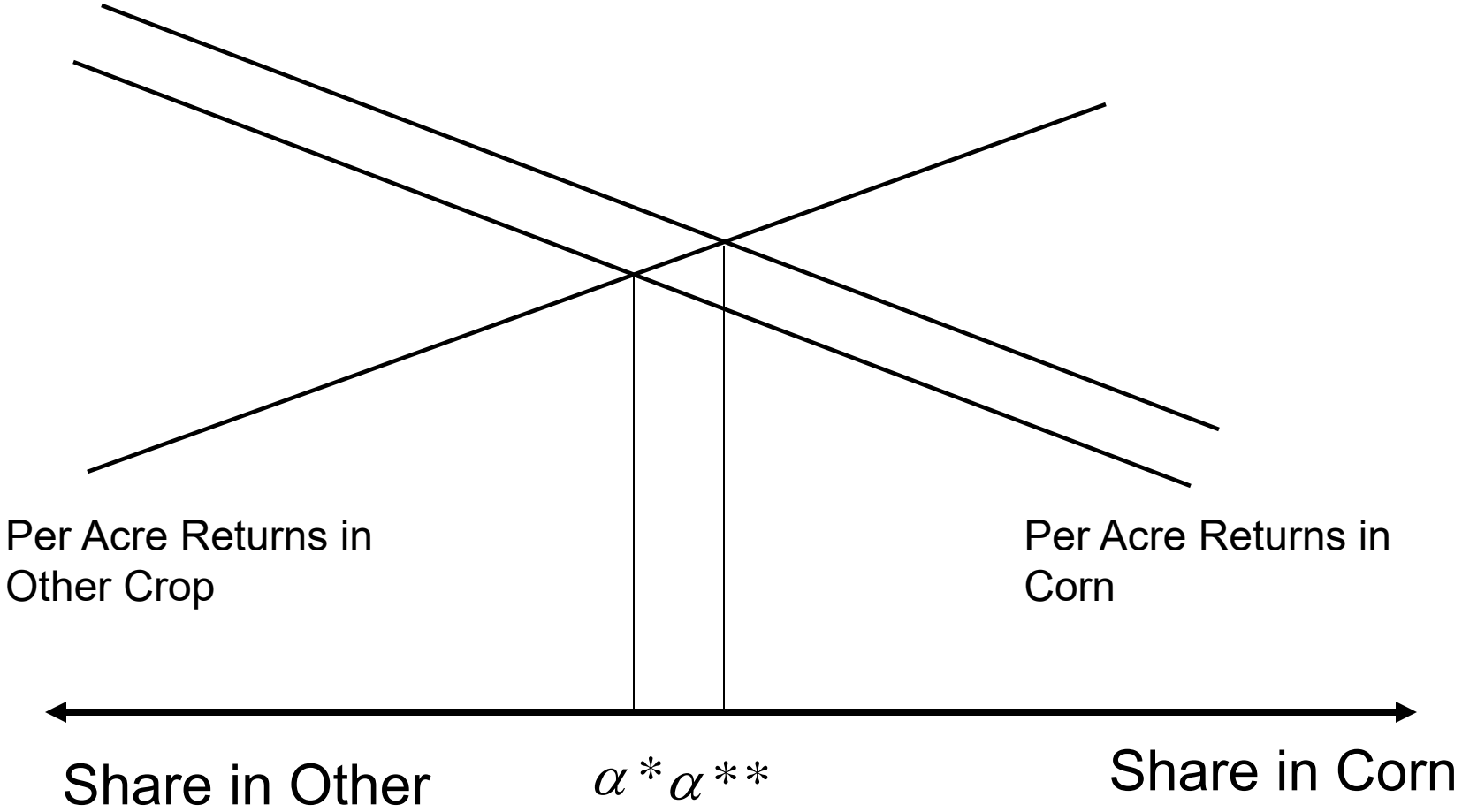
What is the Market Price of Corn with No Government Intervention? (Price of gas = $3.00)



Simplifying Assumption

- Demand for ethanol very elastic
  - Allows the long-run price of corn to be determined by the price of crude oil
  - Regardless of what affects the supply of corn and the non-fuel demand, the long-run price of corn is determined by fuel prices.

Land Allocation



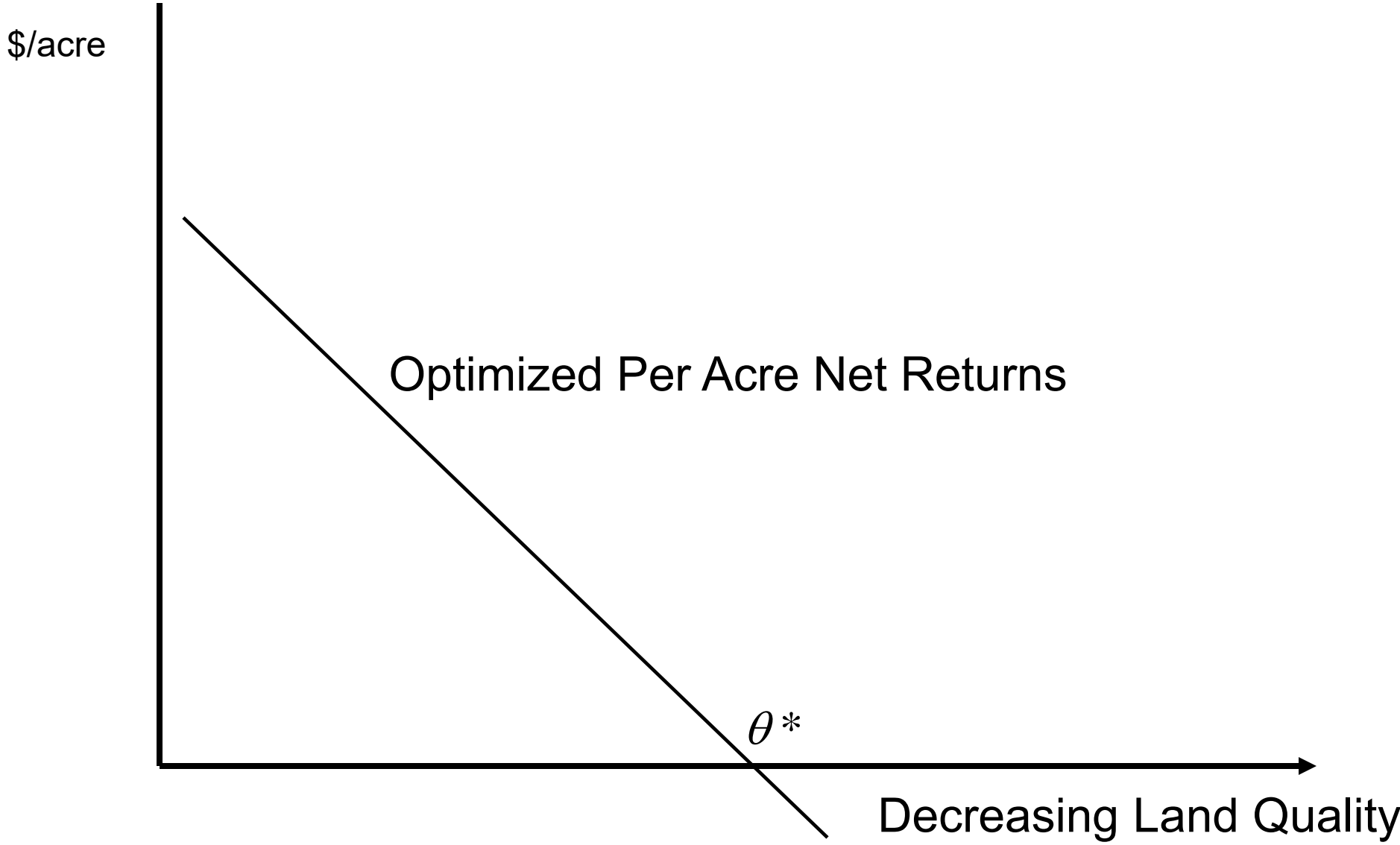
Input Use

- Set value of marginal product equal to input cost for all inputs and all crops

Land Market Equilibrium

- For given market prices of corn and other crop
  - Each parcel of land is allocated to corn and other crop
  - Each crop on each parcel of land has optimized input use
  - Land is brought into production until net returns of the marginal parcel equal zero

Land Market Equilibrium with Fixed Market Price



Crop Supply Curves

$$Q_i^S(p_c, p_o) = \int_0^{\theta^*(p_c,p_o)} y_i[z_i^*(p_c, p_o; \theta), \alpha_i^*(p_c, p_o; \theta); \theta]\alpha_i^*(p_c, p_o; \theta)u(\theta)d\theta$$

yield function

input use

share of land

land quality

distribution of land

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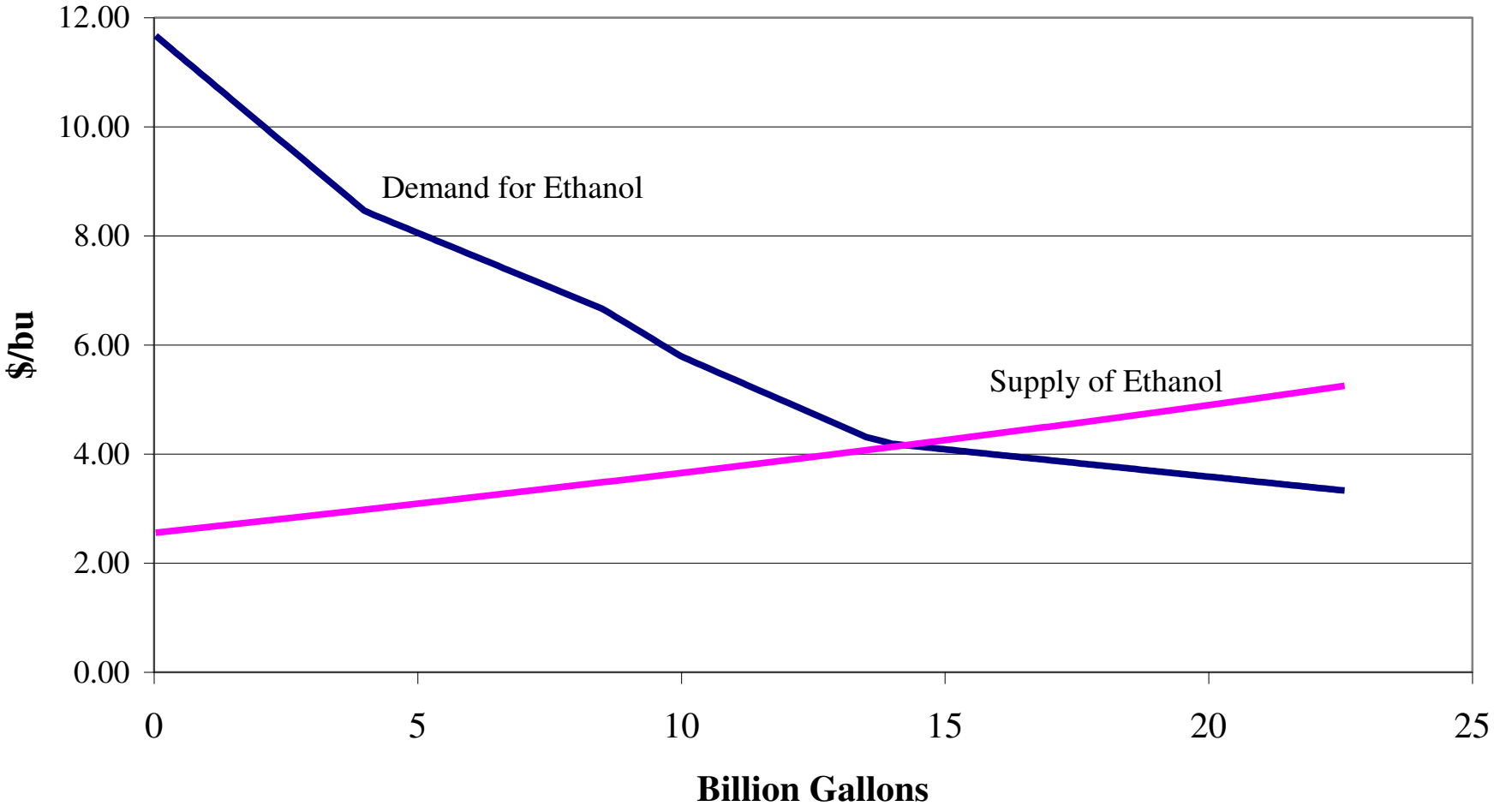
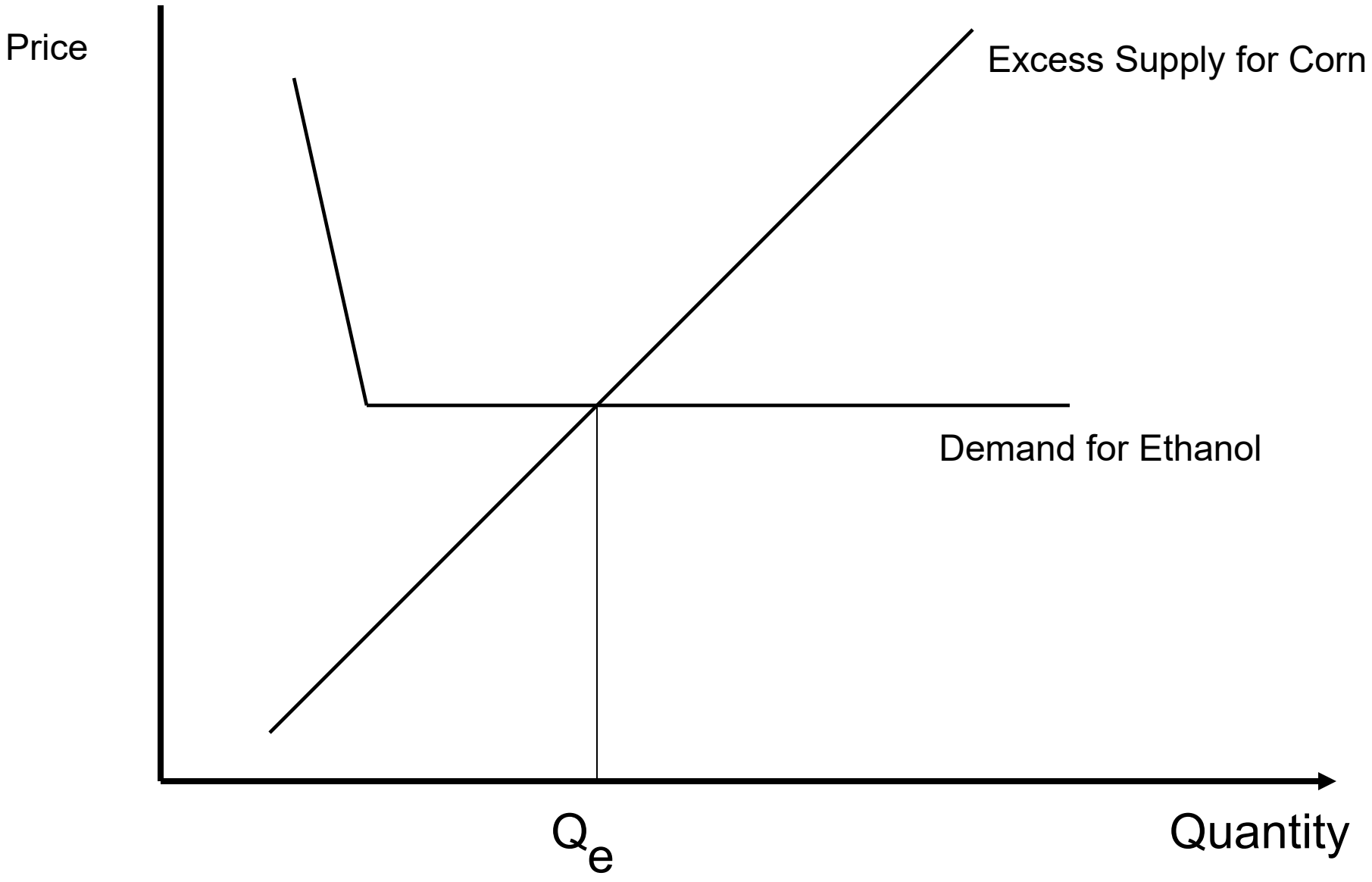
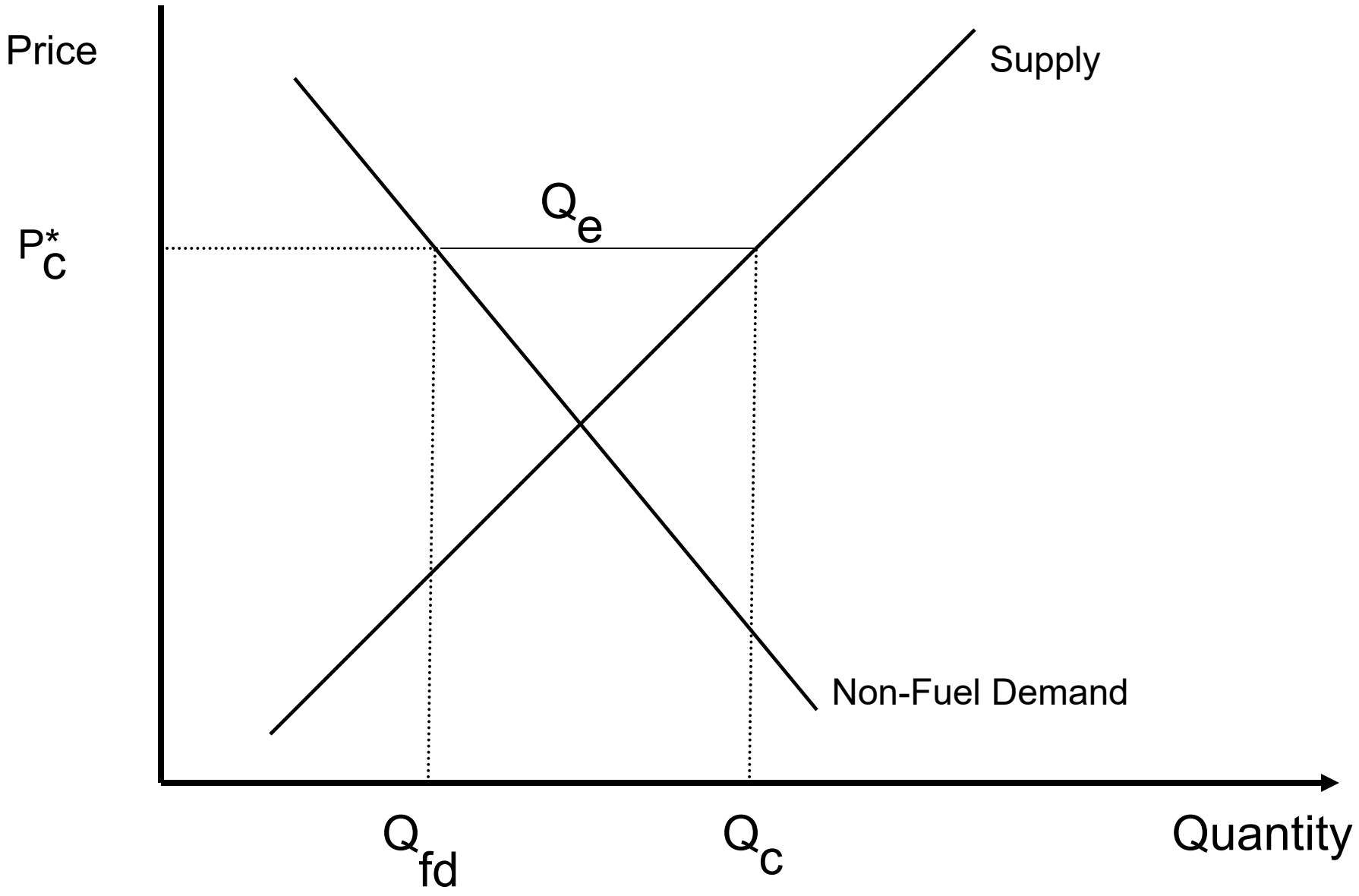


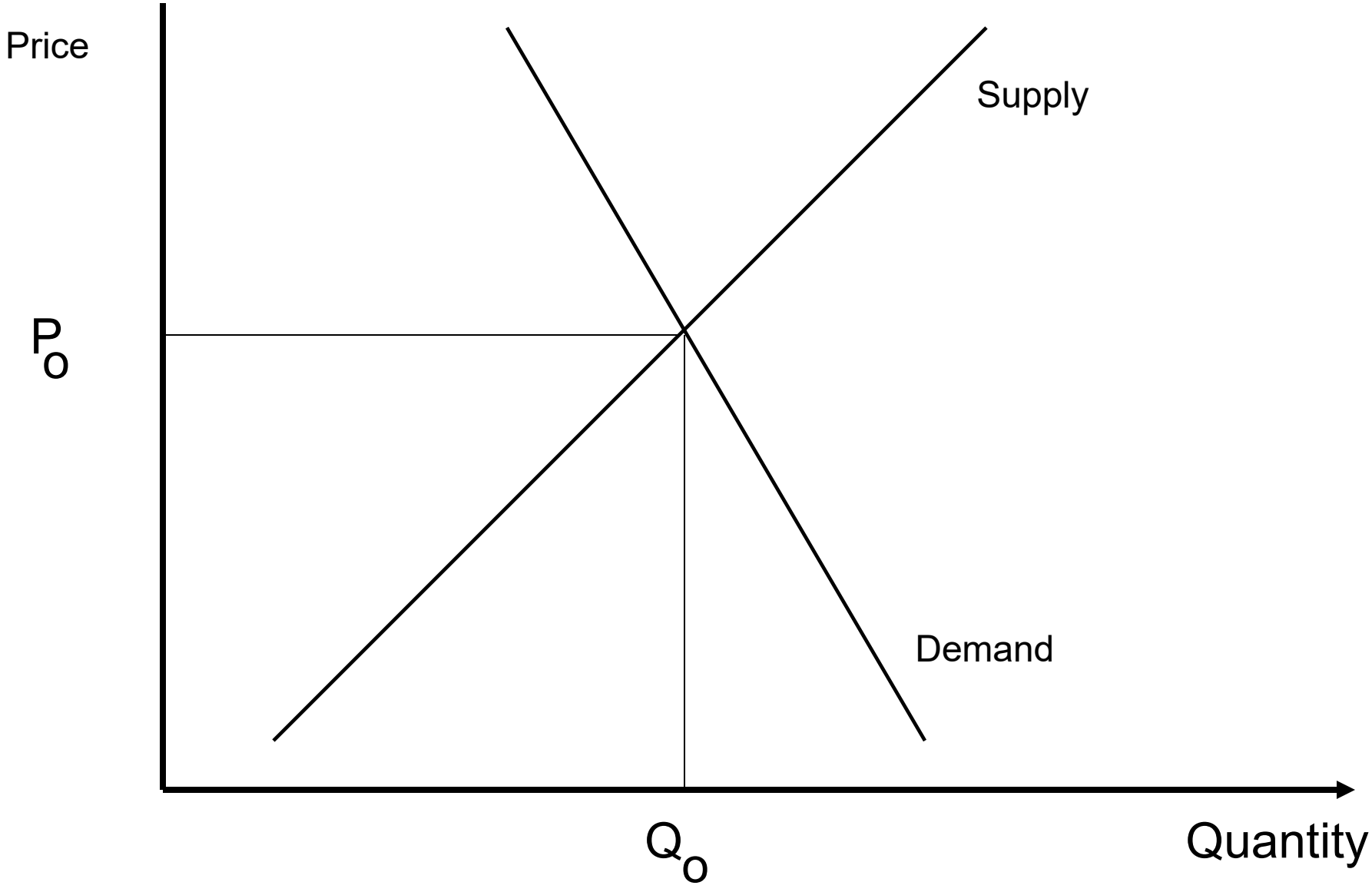
Ethanol Market Equilibrium



Corn Market Equilibrium



Other Crop Product Market Equilibrium



Direct vs. Indirect Land Use

- Direct: Land used to produce feedstock
  - With expansion, feedstock comes from land that was producing corn, land that was producing other crop, and land that was idle
- Indirect: All other land use changes
  - With expansion, other crops produced on old land and on new land as a direct result of biofuels

This is a distinction without a difference. Just look at total changes in GHG emissions before and after expansion accounting for all changes

Jointly Determined

- Total planted acreage jointly determined with input use, land share allocation, market prices
- Solve for optimal input use, total land, and land allocation as a function of market prices
- Then solve for market-clearing prices using the functional relationships

Common Sense Results

- If the marginal product of input use does not decrease as land share increases then
  - Input use and land share do not decrease with own output price and do not increase with other crop's output price
- Increases in output price will not decrease total land used

Impact of Price Change on Supply

- Change in quantity supplied as price increases has three components
  - **Total land effect**, holding input use and share constant
  - **Land share effect**, holding input use and total land constant
  - **Input use effect**, holding land share and total land constant
- Cross price: Is total land effect (positive) dominated by land share and input effects (negative)

Price Impact on Other Crop

$$\frac{dp_o}{dp_c}\frac{p_c}{p_o} = \left[-\varepsilon^{S}_{o,p_c} + \varepsilon^{D}_{o,p_c}\right]\left[\varepsilon^{S}_{o,p_o} - \varepsilon^{D}_{o,p_o}\right]^{-1}$$

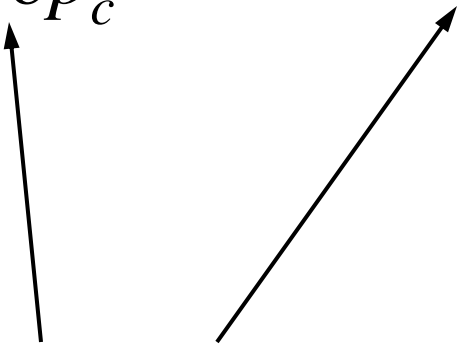
If cross price elasticity of supply is negative, and cross price elasticity of demand is positive, then price of other crop increases

If cross price elasticity of supply is positive, then price of other crop increases if cross price elasticity of demand is positive enough

Other crop is aggregate so cross price demand elasticity positive and cross price supply elasticity negative so price of other crop will increase

Impact on Land Use

$$\frac{d\theta^*(p_c, p_o)}{dp_c} = \frac{\partial\theta^*(p_c, p_o)}{\partial p_c} + \frac{\partial\theta^*(p_c, p_o)}{\partial p_o}\frac{dp_o}{dp_c}$$



Positive

Likely positive in aggregate

Role of Crop Yields

- Fact:
  - Most of the increase in crop production over the last 30 years has come about by increased productivity, not increases in land use
  - e.g. “Global production of cereals grew by 43% between 1980 and 2006 while land use fell by 6%.”

Monsanto News Release

- Monsanto projects 60% rise in US maize output by 2022
- **FO Licht's World Ethanol & Biofuels Report** Wednesday April 16 2008

- Monsanto has projected that corn yields will increase to 245 bushels per acre by 2022, when the US will produce 15 bln gallons of ethanol from corn. Based on an increase in production to 3.0 gallons per bushel with advances in starch recovery techniques, US demand for corn acreage should be expected to rise to 23% of overall corn acreage (based on 2008 plantings of 86 mln acres), leaving 16 bln bushels of corn for livestock and export markets. This is an increase of 60% from current levels.

Why Have Crop Yields Increased?

- Will increases in corn prices increase crop yields (and feed conversion efficiencies) beyond what they would have been anyways?
- If so,
  - How large is the effect?
  - What are the impacts on equilibrium land use

Adoption of Technology

- The treadmill theory
  - Early adopters have a profit incentive to adopt exogenously-determined technologies
  - Later adopters must adopt technologies to stay in business
  - Crop technology is putty-clay
- Analog
  - Innovators have incentive to develop new technologies irrespective of price level
  - Higher prices may increase the return to innovation
  - But profits from innovation always high

Alternative Theory

- Innovators look at crops with the highest price and then develop technologies for them
  - Price-induced technology development
- Price increases induce farmers to adopt technologies and intensify input use
  - There are profitable “off the shelf” technologies and crop yields follow neoclassical production functions

In Normal Market

- With inelastic demand, yield increase decreases revenue
  - Land market out of equilibrium because too much land is in production
- With elastic demand, yield increase increases revenue
  - Land market out of equilibrium, more land will enter

Impact of Yield Increase

$$y_i^{new}(z_i, \alpha_i; \theta) = y_i^{old}(z_i, \alpha_i; \theta) + \delta_i$$

$$y_i^{new}(z_i, \alpha_i; \theta) = \psi_i y_i^{old}(z_i, \alpha_i; \theta)$$

Result

- ***Proposition 3***. *When corn price is set equal to the breakeven price in ethanol production, if corn and other crops are substitutes in demand, then at market equilibrium*

$$\frac{d\theta^*}{d\delta_c} > 0$$

Explanation

- Demand for corn is long-run elastic when linked to energy markets and corn ethanol is a small share of transportation fuels
- Price change from yield-increasing technology small, so no disincentive to expand production
- Yield increasing technology increases land rent, so bring more land into production

A Last Result

- ***Proposition 5***. *For a given mandate , if corn and other crops are substitutes in demand, then*

$$\frac{d\theta^*}{d\delta_i} < 0$$

Explanation

- In equilibrium will minimize the amount of land needed to meet an ethanol mandate
- An exogenous yield increase will reduce the amount of land needed to meet the mandate.
- Demand for non-fuel is inelastic, so a yield increase will reduce price substantially, thereby reducing land rent and amount of land in production

Lessons

- Linking of energy and food production means that changes in energy price will bring more land into production
- Exogenous yield increase will bring even more land into production unless biofuels are capped or market share of biofuels becomes large
- If we do not want food prices and land in production determined by energy prices, then we need to de-link food and energy prices by capping biofuels production