TILBURG UNIVERSITY

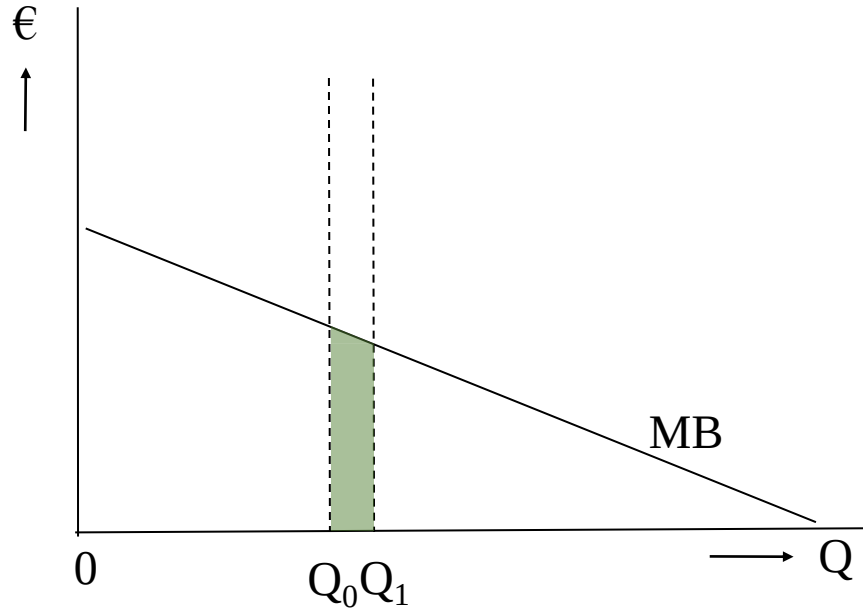
Environmental Economics

Valuation, Part I

Theory and revealed preference methods

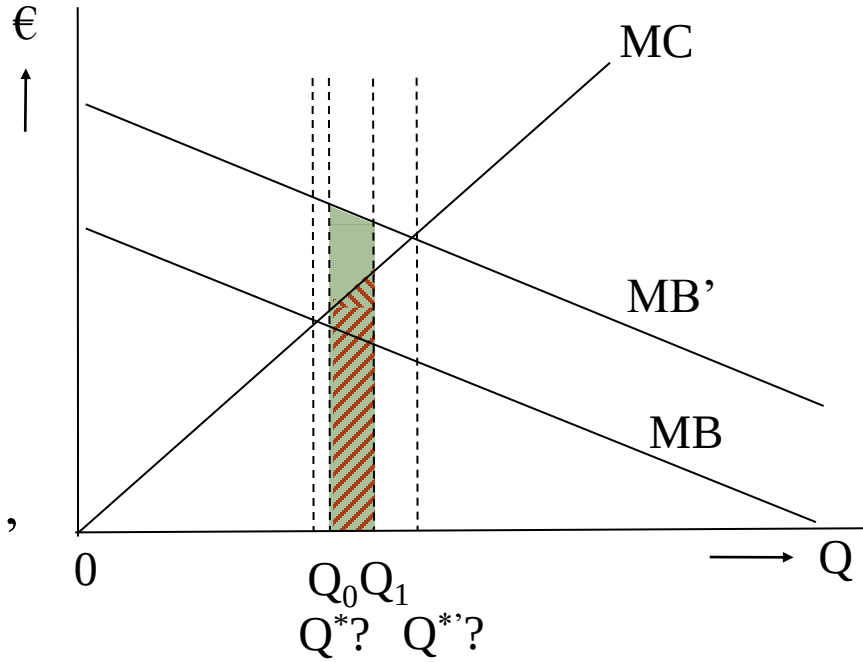
Introduction

- Environmental policies:
  - Benefits and costs (and possibly winners and losers)
- Benefits of env. policy that increases environmental quality from Q_0 to Q_1:
  - Area underneath the MB function
- But then there are costs too
  - Cost for firms, or public expenses
  - Direct costs, and oftentimes also indirect costs
    - Example: phasing out lead additives to gasoline
      - Increases the price of gas (replacing lead by other, more expensive additives),
      - but also results in speeding up car obsolescence (old engines need to be replaced)
- Does environmental policy increase aggregate welfare, yes or no?



Introduction (2)

- Costs of implementing the policy
  - Surface underneath MC, between Q_0 to Q_1
  - Consists of implementation costs, but also maybe a reduction in (the sum of) producer and consumer surplus (eg, if quantity produced decreases)
- If marg. benefit function = MB, do not implement
  - But should be implemented if marg. benefit function is MB'
- We need to be able to estimate the benefits and costs
  - To determine if projects (from Q_0 to Q_1) are welfare-enhancing: Societal cost-benefit analyses
    - But also to find optimal environmental quality (Q^* or $Q^{*'}$?)
  - Challenging: costs are difficult to estimate, but benefits even more difficult
- E.g., oil spill: costs of foregone fishing, but also (irreversible?) damage to wildlife…
  - Experts may have an opinion on that, but "citizens" too!



Introduction (3)

- Setup of this class and the next
- This class
  1. What is the value of an improvement in environmental quality? Theory!
  2. Measuring the value of environmental quality: Stated and revealed preference methods
  3. Revealed preference methods: Hedonic Pricing
  4. Conclusions
- Wednesday's class: stated preference techniques…

1. Theory: Valuation of public goods

- Intuitive measures of value:
  - Willingness to Pay (WTP):
    - the *maximum* amount of money one would pay to obtain an improvement or avoid the imposition of a harm
    - is equal to the amount that would leave the agent indifferent between

      (i) paying that amount, but receive the improvement/avoid the harm, and

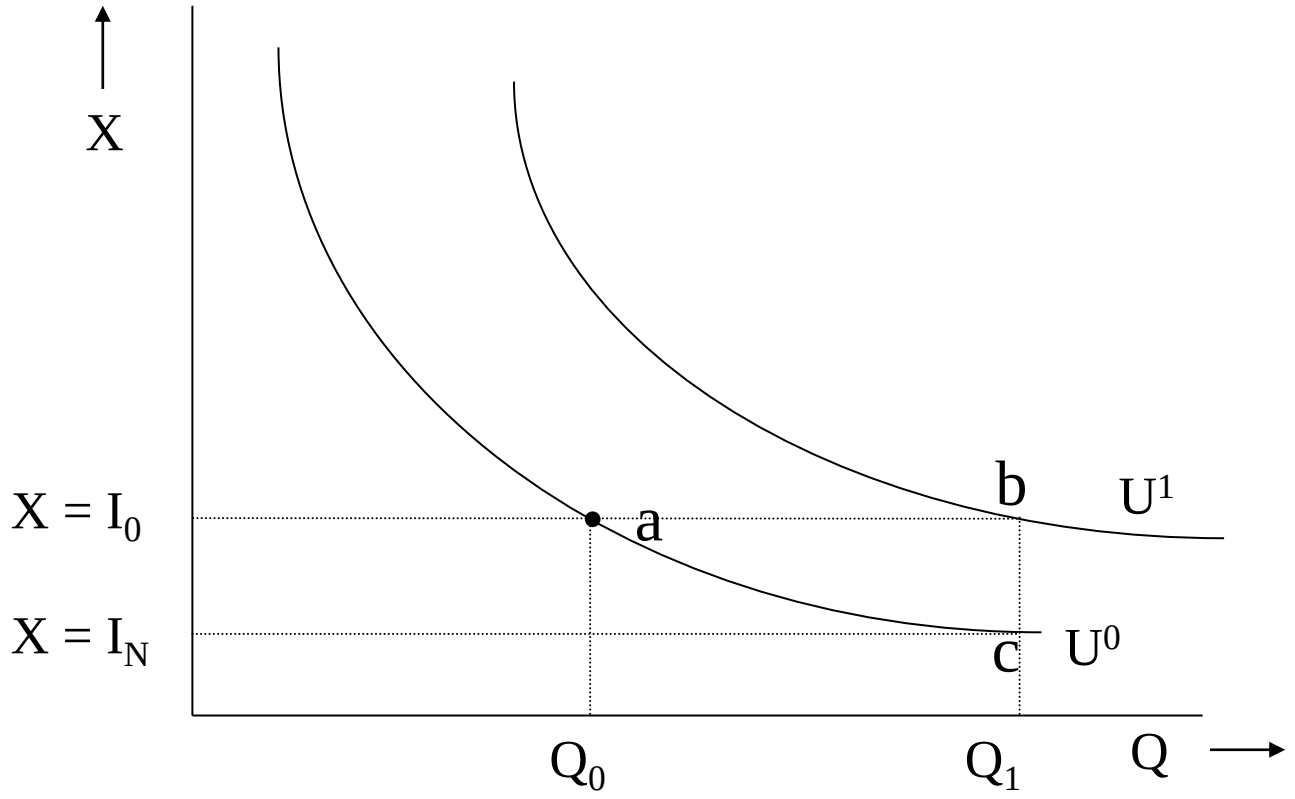
      (ii) not paying that amount, but forego improvement/do undergo the harm
  - Willingness to Accept (WTA):
    - the *minimum* amount of money one would demand to forego an improvement or agree to the imposition of a harm
- Intuitive and correct, but also confusing – as they vary with the *direction* of change

Theory: Valuation of public goods (2)

- Two concepts of valuation measures:
  - Compensating Surplus, and Equivalent Surplus
  - Related to WTP/WTA, but not one–to–one
- Assume:
  - Utility depends on
    - disposable income (I, spent on normal consumption good, X, purchased at price 1), and
    - env. service (Q, measured in terms of quantity or quality; level exogenously determined)
  - $U = U(X, Q)$ – indifference curves…!
    - All combinations of X and Q that yield the same level of utility (U). Mathematically?
    - Totally differentiating: $dU\big|_{U=U^0} = 0 = (\partial U/\partial Q)\,dQ - (\partial U/\partial X)\,dX$

      $\rightarrow \left.\frac{dX}{dQ}\right|_{U=U^0} = \frac{\partial U / \partial Q}{\partial U / \partial X} \left(= MRS\big|_{U=U^0}\right)$. Graphically?

Theory: Valuation of public goods (3)



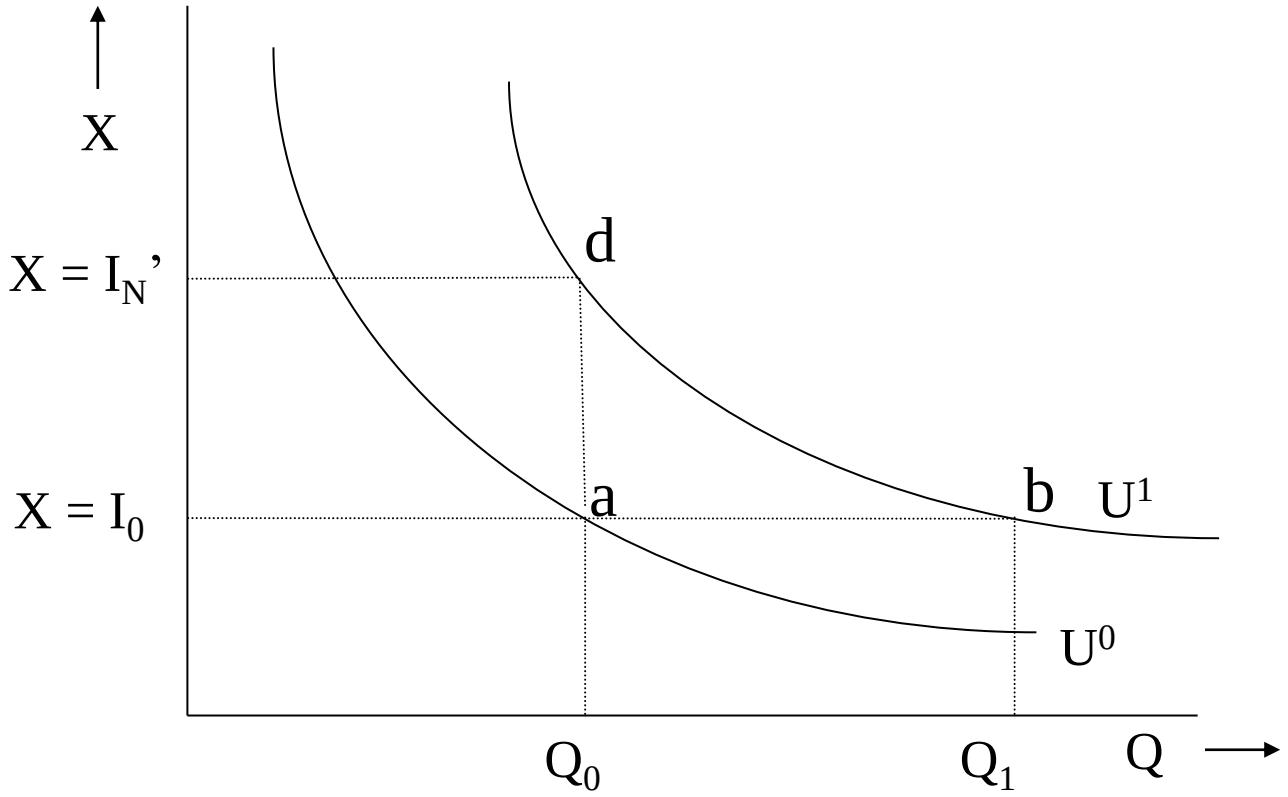
What is agent's WTP to obtain improvement from, say, Q_0 to Q_1?

Compensating surplus = bc (= $I_0 - I_N$); $U^0 = U(I_0,Q_0) = U(I_0 - CS,Q_1)$

Theory: Valuation of public goods (4)

- Compensating Surplus of a quality improvement:
  - How much income can be taken away from individual to keep her at *original* utility (U^0)?
- Compensating Surplus defined as $U^0 = U(I_0,Q_0) = U(I_0 - CS,Q_1)$
  - Reference point for Compensating Surplus is initial level of utility (in this case, U^0)
- Equivalent Surplus…?
  - Suppose environmental policy improvement was announced – but subsequently cancelled
  - How much extra money should be given to individual to keep at the promised utility (U^1)?

Theory: Valuation of public goods (5)



What is agent's WTA to *forego* an improvement from, say, Q_0 to Q_1?

- Equivalent surplus = ad (= I_N' – I_0); $U^1 = U(I_0,Q_1) = U(I_0 + ES,Q_0)$

Theory: Valuation of public goods (6)

- Equivalent Surplus of a quality improvement:
  - How much income should be given to individual to compensate her for *not* improving the environmental quality…?
  - … Individual should end up at *new* level of utility (U^1)
- Equivalent surplus defined as $U^1 = U(I_0,Q_1) = U(I_0 + ES,Q_0)$
  - Reference point for Equivalent Surplus is the *new* level of utility (in this case, U^1)
- All fairly subtle:
  - CompS measures WTP for an improvement, and EqS measures WTA to forego an improvement
  - But what if we want to value a deterioration?

Theory: Valuation of public goods (7)

- Compensating Surplus measures WTP for a quality improvement
  - How much income can be taken away from individual to keep her at original utility (U^0)?
- In case of a deterioration, Compensating Surplus measures WTA
  - Because the reference point for CompSurplus is initial level of utility – in this case, U^1
  - With deterioration, U^1 is the initial utility level, and hence reference level for comp. surplus
    - $U^1 = U(I_0,Q_1) = U(I_0 + CS,Q_0)$
    - CS is the amount needed to keep indiv. at original utility (U^1) if env. quality falls; WTA!
- Similarly, Equivalent Surplus measures WTA to forego improvement…
  - …and WTP to avoid a deterioration
  - Because EqS takes the utility *after* the possible change as a reference point
- So two measures of valuation: CompS and EqS (that translate into WTP and WTA)
  - But do they yield the same value? We first need to know how to measure them…

2. How to measure WTP and WTA?

- Two types of methods:
  - Stated preference methods, and revealed preference methods
- Stated preference methods:
  - Contingent valuation, choice experiments
  - Survey methods – next class!
- Revealed preference methods:
  - Exploit complementarities between environmental quality and a private good
    - E.g., money spent on visiting the Grand Canyon (Travel cost method)
    - Or houses in neighborhood close to Schiphol airport sell for less than identical homes with less noise pollution (Hedonic pricing method)
  - Remainder of this class (and of the assignment): Hedonic Price Method (HPM)

3. Hedonic Pricing Method

- Most important revealed preference method: Hedonic Pricing Method (HPM)
  - Prices of varieties of a good vary with differences in "attributes", including "env. quality"
- Example: estimate value of air quality using housing values. Data needed:
  - characteristics of house: e.g., # of square feet, # of rooms, full bath (y/n)
  - characteristics of the neighborhood: distance to city center, crime rates
  - environmental variable to be valued: measure of air quality ("excellent", or "poor")
- Regress sales price of the property on all attributes of the good…
  - $P = 25{,}899 + 790\ln(SQFT) + 2{,}572*ROOMS - 1{,}516*DIST \ldots + 12{,}057*AQ$
  - $\partial P/\partial AQ = \$12{,}057$; implicit value of air quality being "excellent" rather than "poor"
  - coefficient on air quality (AQ) is *exact* (?) measure of value air quality?
- Is it really that simple…?

Hedonic Pricing Method (2)

- Suppose it is indeed that simple – how to use in a CBA?
  - Calculate mean WTP, or check how WTP varies with characteristics
  - Then if there is a project to reduce air pollution (at costs *I*) that affects *N* people
    - Implement project if $\sum_{i=1}^{N} \hat{WTP}_i \geq I$
- Relatively straightforward… but if it is easy, not necessarily also ok to use it?
  - Ethical considerations matter too:
    - Estimating value of clean air vs value of letting the Sumatran tiger survive in the wild…
  - E.g., Improved health (= reduced mortality and/ or morbidity) key effect of env. policy
    - Are we really going to impose dollar value on saving human lives…?

Hedonic Pricing Method (3)

- But don't we place values on our own lives every day too?
  - Running a red light, getting too tanned, cycling without a helmet, boarding a plane?
  - Unconscious decision making, or comparing the benefits of the risky activity to the costs…
- And what are those costs?
  - Lifetime income forgone if you died?
  - Or something else? Value of a Statistical Life (VSL)!
- Explanation of the method – HPM applied to estimate the VSL
  - Wage-risk relationship: Wage (W) regressed on chance of dying in the workplace (RISK)
    - $\partial W/\partial RISK$ = *worker's* marginal willingness to pay (MWTP) to reduce RISK by one unit
  - If RISK ≡ deaths per X workers per yr, then VSL = X x $\partial W/\partial RISK$ (properly corrected)
    - Because dRISK is saving one additional life among a group of X workers per year!
- If we can use HPM to estimate VSLs – we can also use it for all other values too?

3.1 Estimating VSL using HPM

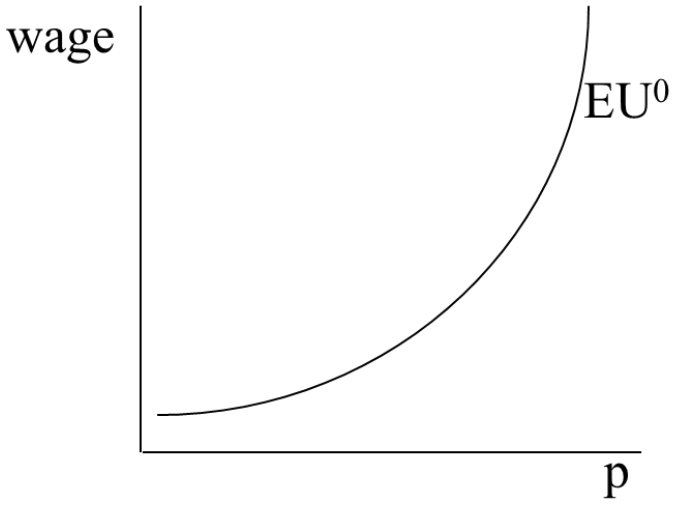
- Data needed: characteristics (or indicators) of (hourly) wages (2000 hrs/ yr)
  - Work environment: job requirements (e.g., min. educ. levels), sector, unionized
  - Human cap.: education level, work experience (yrs with present employer, full or part time)
  - Personal characteristics: age, gender, urbanized
  - Risk: (obj. or subj.) probability of dying in workplace (e.g., # deaths per 4000 workers per yr)
- Regress (hrly) wage rate on job and worker characteristics…
  - ln(wage) = 2.07 + 0.091 UNION – 0.292 SCHOOL1 + 0.192 MALE + … + 0.008 RISK
  - ∂ln(wage)/ ∂RISK = 0.008: one unit increase in perceived risk, 0.8% higher wage rate
    - Why? $\frac{\partial \ln(wage)}{\partial risk} = \frac{\partial \ln(wage)}{\partial wage}\frac{dwage}{drisk} = \frac{1}{wage}\frac{dwage}{drisk} = 0.008 \rightarrow \frac{dwage}{drisk} = 0.008\ wage$
  - And then VSL equals 0.008 x (hrly wage x 2000) x 4000!
- Is it really that simple…? Theory behind HPM!

3.2 Theory behind HPM

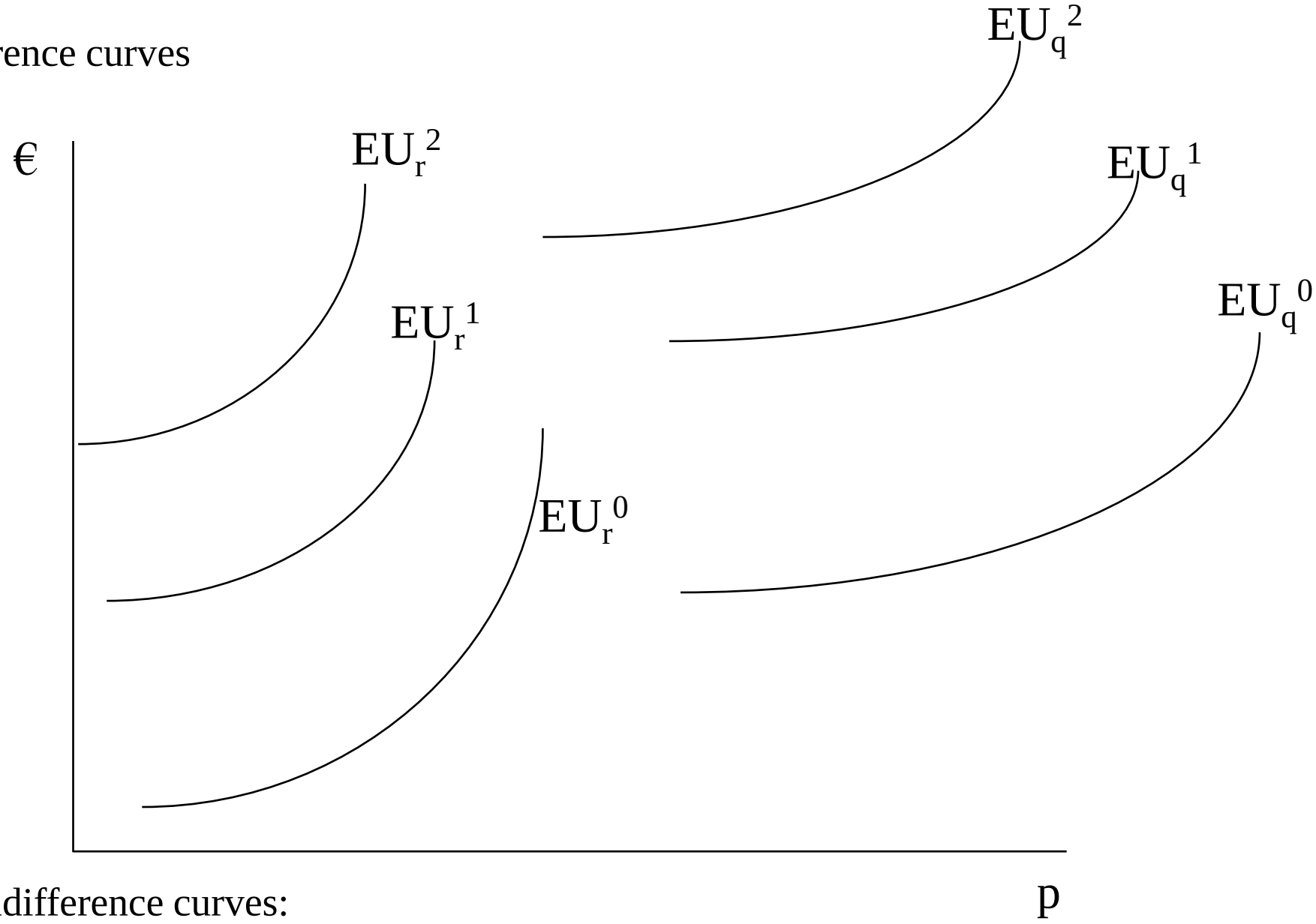
- Does the approach make sense? Is $\partial \ln(\text{wage})/\partial p$ true value?
  - True valuation: (marginal) WTP or WTA; movement along indifference curve
  - Utility function of worker
    - Depends on state: $U^A(w)$ if alive, $U^D(w)$ if dead; $U^A(w) > U^D(w)$
    - Probability of dying in the workplace: p
    - Expected utility: $EU = (1 - p)\, U^A(w) + p\, U^D(w)$
  - Indifference curve:
    - all combinations of wage rates (w) and probabilities of dying (p) that yield the same level of expected utility (say EU^0)

Theory behind HPM (2)

- Indifference curve: $(1 - p)\, U^A(w) + p\, U^D(w) = EU^0 \rightarrow EU^0 = U^A(w) - p\,(U^A(w) - U^D(w))$
  - Totally differentiating: $dEU^0 = 0 = -(U^A(w) - U^D(w))\, dp + ((1 - p)\partial U^A/\partial w + p\, \partial U^D/\partial w)\, dw$
- Defining $U_w^Z(w) \equiv \partial U^Z(w)/\partial w$, worker's Marg. WTP is $dw / dp = \dfrac{U^A(w) - U^D(w)}{(1 - p)U_w^A + pU_w^D}$
  - $dw / dp > 0$, and $d(dw/dp)/dp = d^2w / dp^2 > 0$…
  - Upward-sloping and convex!
- So is the first derivative of a simple wage-risk regression indeed equal to MWTP?
  - i.e., is $\partial W/\partial p = \dfrac{U^A(w) - U^D(w)}{(1 - p)\, U_w^A + p\, U_w^D}$

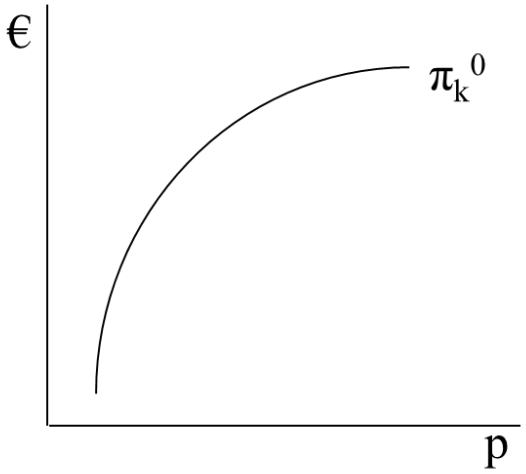


Workers' side: indifference curves



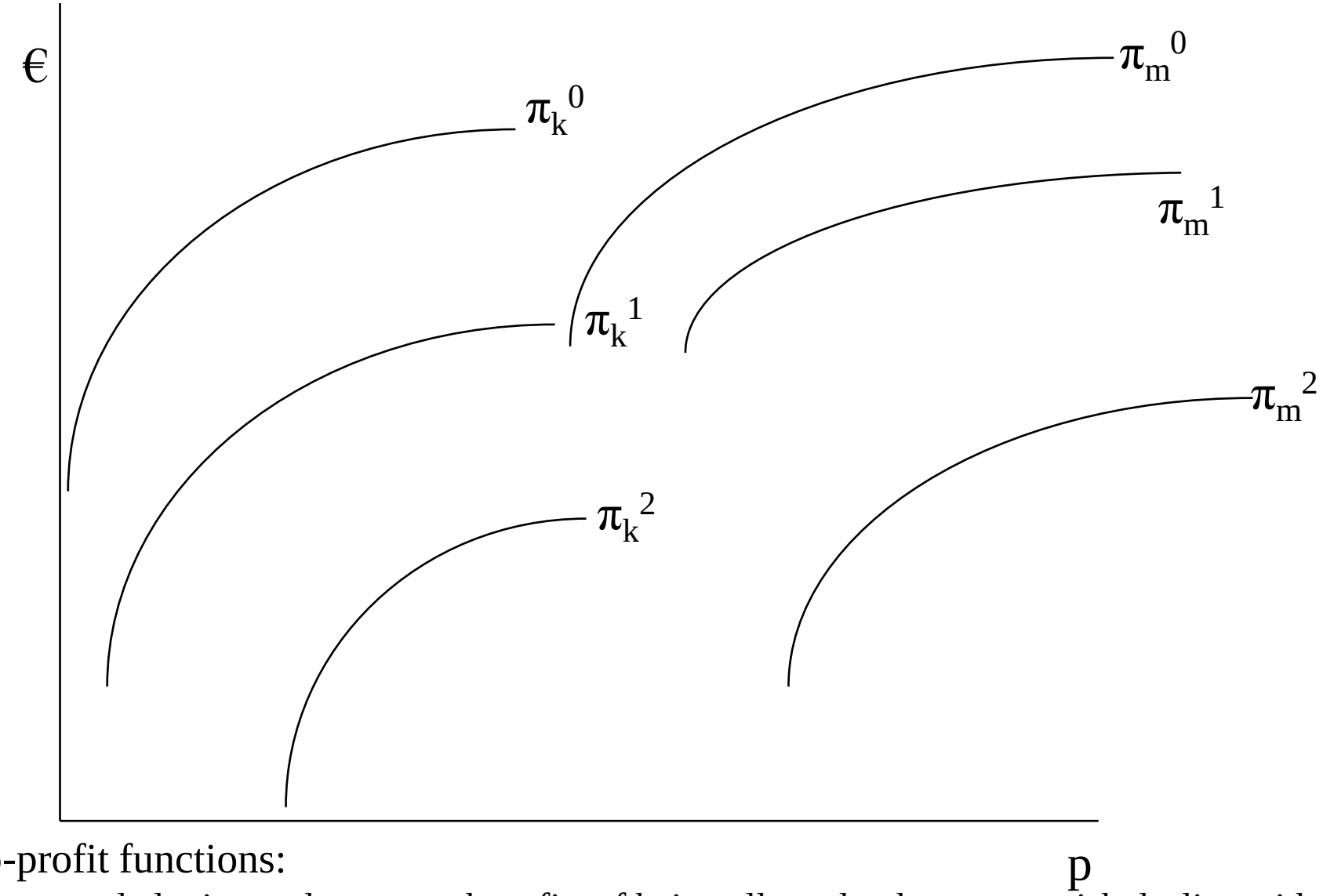
- Indifference curves:
  - upward-sloping and convex; willing to accept additional risk requires ever more compensation
  - utility levels higher the farther away the IC is from the horizontal axis
- Which of the two workers (q,r) is more willing to accept risk?

Theory behind HPM (4)



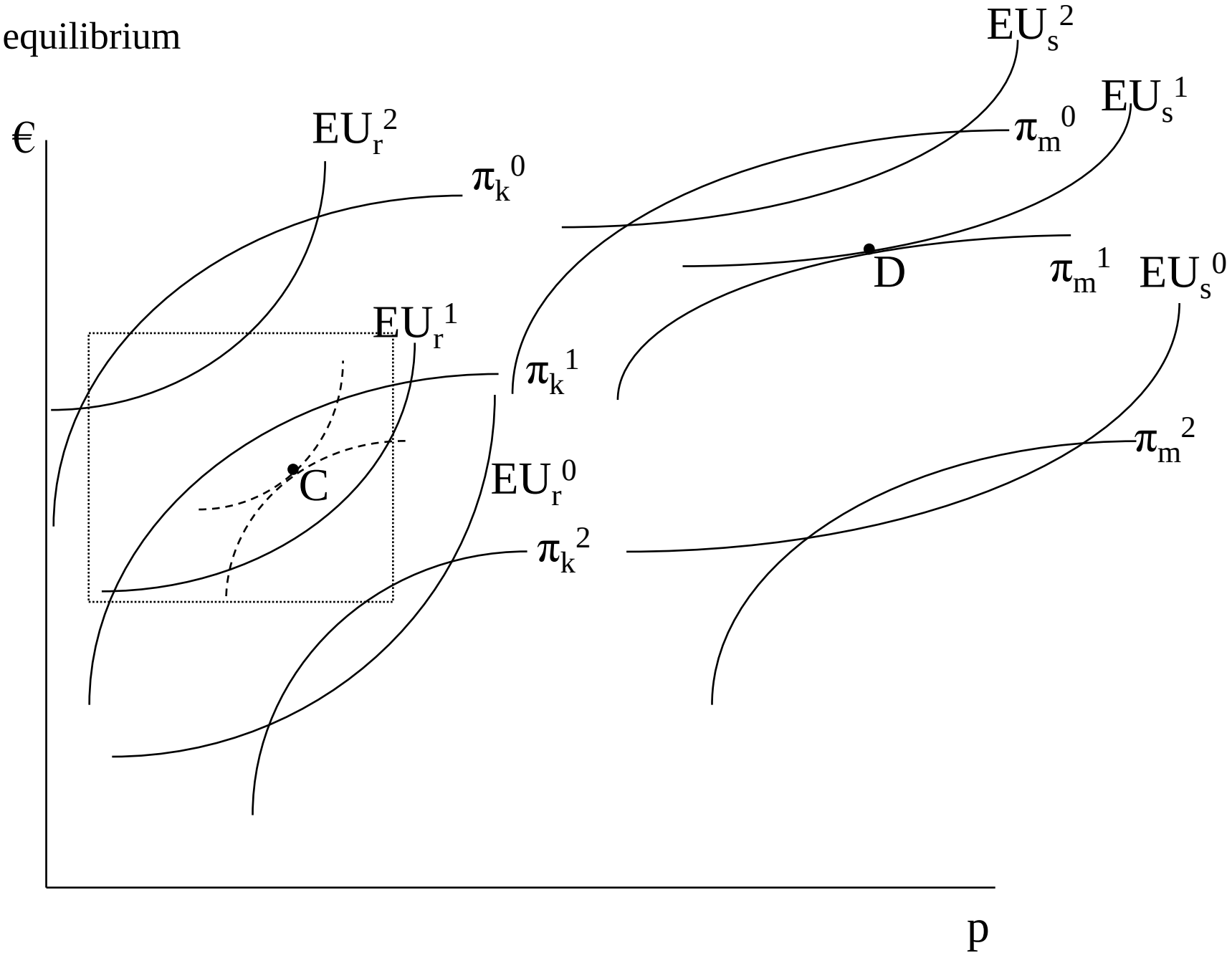
- Firm's decision making process:
  - Suppose just one worker in each firm
  - Firm's objective: maximize profits
    - max $\pi = X(p) - c(s) - w$,
      - where X(p) is productivity gain of having slightly higher risk, and *s* is safety ($s \equiv 1 - p$)
      - Assumptions: $\partial X/\partial p > 0$, $\partial^2 X / \partial p^2 < 0$; $\partial c/\partial s > 0$, $\partial^2 c / \partial s^2 > 0$
        - and note that because $s \equiv 1 - p$, we have $\partial s / \partial p = -1$
- Isoprofit functions: $X(p) - c(s) - w = \pi^0$
  - All combinations of wages paid (w) and safety provided (s) that yield same profit level
  - Totally differentiating: $d\pi^0 = 0 = (X_p - c_s \partial s/\partial p)\, dp + dw$ (with $\partial s/\partial p = -1$)
  - WTP of the firm to be allowed to increase risk (= reduce safety) by one unit:
    - $dw / dp = X_p + c_s > 0$, $d^2w / dp^2 < 0$… upward–sloping and concave!

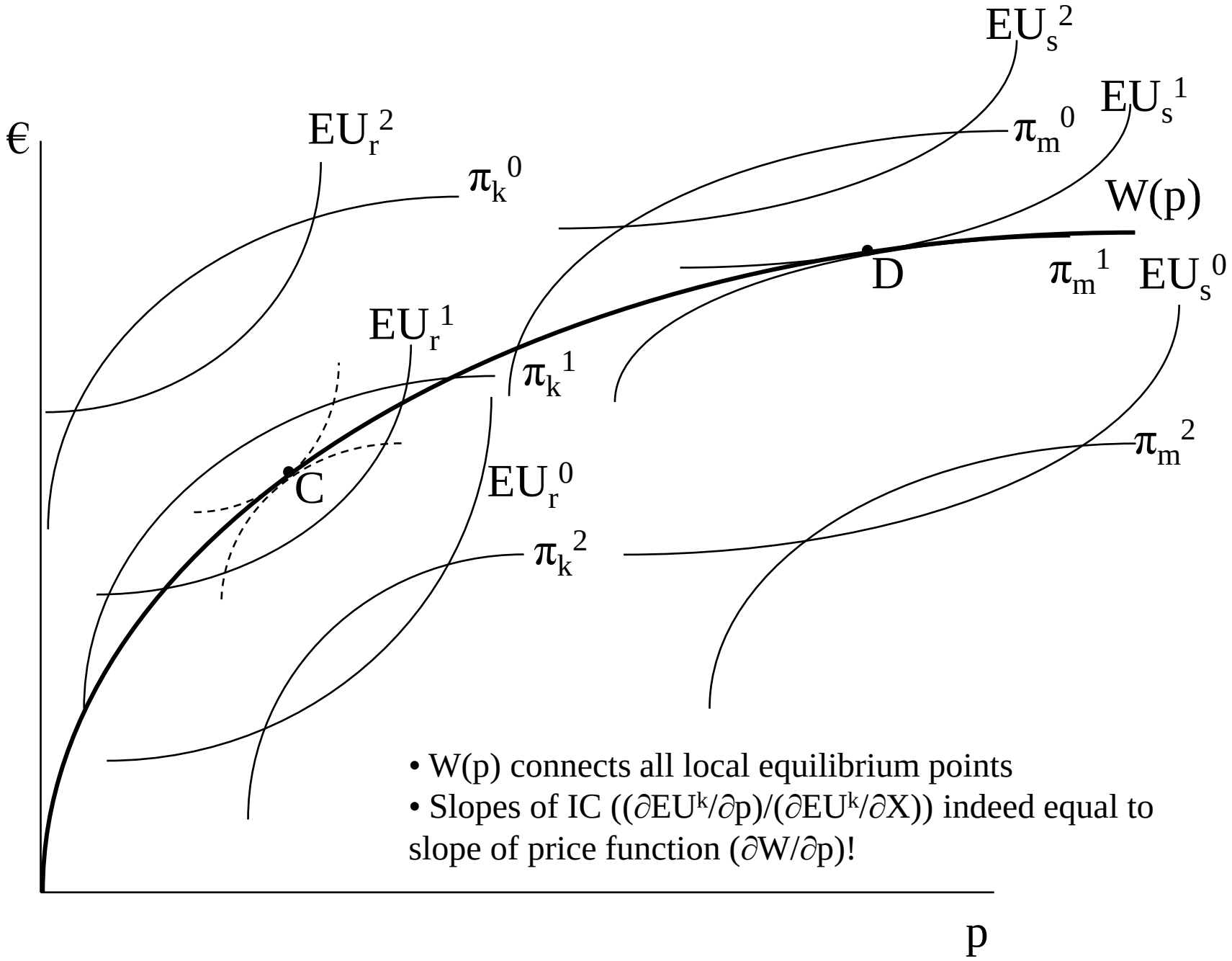
Firms' side: iso-profit functions



- Iso-profit functions:
  - upward-sloping and concave; benefits of being allowed to have more risk decline with risk
  - profit levels higher the closer the isoprofit function is to the horizontal axis
- Which of the two firms is better at providing more safety (= less risk), k or m?

Search for local market equilibrium

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W(p)
D
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• W(p) connects all local equilibrium points
• Slopes of IC $((\partial EU^k/\partial p)/(\partial EU^k/\partial X))$ indeed equal to slope of price function $(\partial W/\partial p)$!

4. Conclusions

- Coeff. on risk in wage–risk regr. is true marg. value of (a very small prob. of dying)
  - VSL = MWTP x (1 / unit of risk)
- Can be used in env. cost-ben. analysis if…
  - aware of work-rel. risks/ sort accordingly?
  - sample representative of pop. targeted by the policy?
  - (type of) death avoided pol. similar to work-deaths?
- Group assignment…
  - Number of workers dying per 4000 per yr
    - MortalityRisk_lumberjacks = 10 (/4000) /yr
    - VSL = 4000 x MWTP/yr
  - See .pdf description in Canvas Modules!