Shadow Pricing, Direct Price Effects

1. Shadow Pricing

[C&B Ch. 5; DoF Ch. 3; FP Ch. 1.6, 6; S&W Ch. 8]

The NPV formula can be written as

$$NPV = \sum_t \frac{b(t) - c(t)}{(1+r)^t}$$

where $b(t) = \sum_i b_i \, p_i = b_0 p_0 + b_1 p_1 + b_2 p_2 + \cdots$

and $c(t) = \sum_j c_j \, p_j = \ldots$

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Now, we assume here that we have the the quantities b_i benefits and c_j costs.

What of the prices p_i and p_j?

We want the true costs and benefits.

True prices reflect opportunities forgone (by suppliers, by consumers)
$\longrightarrow$ ***shadow prices.***

A *shadow price* better approximates the true *opportunity cost* or *marginal valuation* of a product or resource or service.

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4. **of unemployment with minimum wages,**
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2. **of a price change,**
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4. **of unemployment with minimum wages,**
5. **of a tariff (a tax on imports).**

Efficiency Cost-Benefit Analysis

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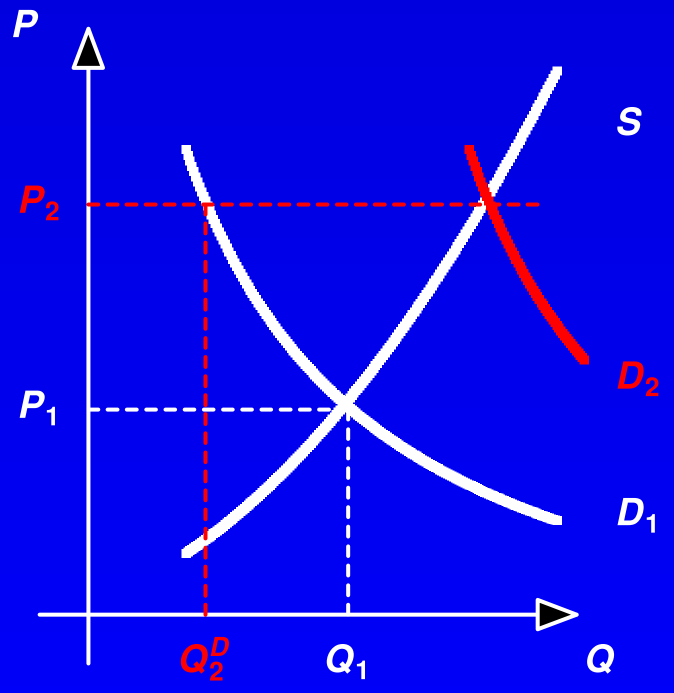
***C&B's Pricing Rule.* [C&B p.93]**

Item to be valued	Valued at equilibrium point on a: Demand Curve	Valued at equilibrium point on a: Supply Curve
Output	Satisfies additional demand	Satisfies existing demand from alternative source
Input	Sourced from an alternative market source	Sourced from additional supply

(See also the Table on p.30 of the DoF *Handbook*.)

The Area under the Demand Curve is the Value of that Quantity

A demand curve shows the maximum the buyer is prepared to pay for each unit bought. As the price rises, buyers choose to buy less. They forgo the value to them of buying and using the forgone quantity: area = value forgone, as price $P_1 \rightarrow P_2$.



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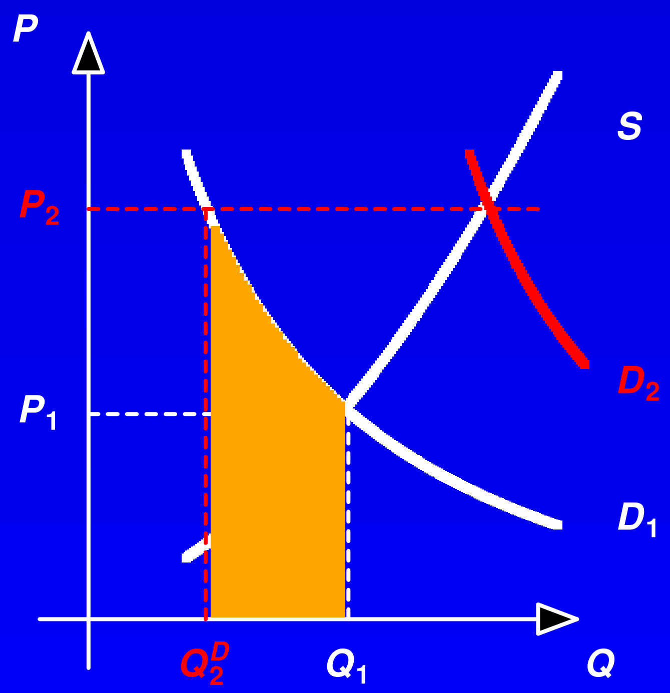
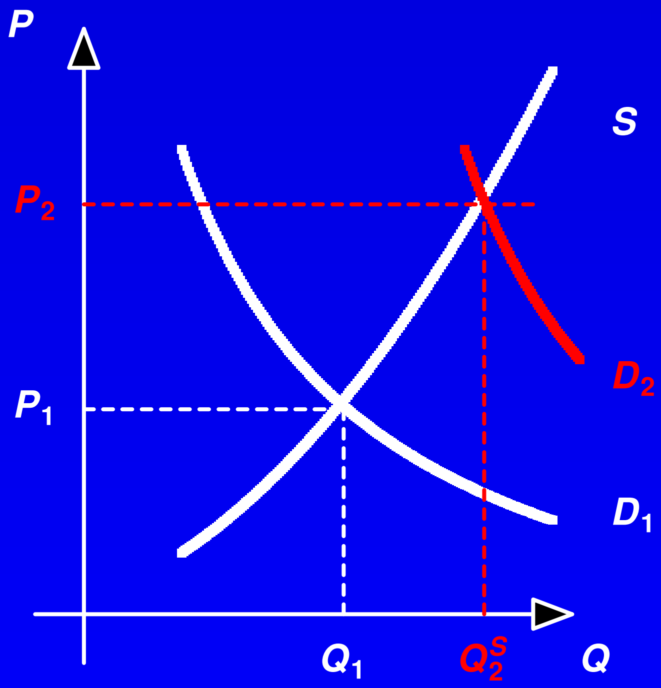


Remember: the value of the last unit bought (the marginal value to the buyer) = the price of that unit.

The Area under the Supply Curve is the Cost of that Quantity

To a firm in a competitive market, its supply curve shows the cost of supplying each unit. A higher price induces more units to be offered for sale: the area under the supply curve is the total cost of supplying those units, as price $P_1 \rightarrow P_2$.



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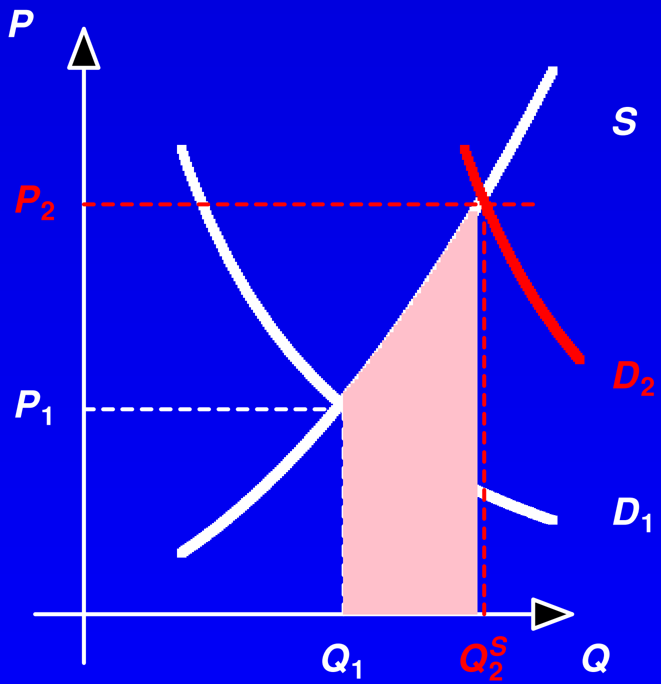

Remember: the marginal cost of supply (the cost of supplying the last unit sold) = the price of that unit.

1.1 Example 1: A Tax [C&B pp. 108–110; S&W Ch. 8.3]

Q:

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- **places a wedge between the marginal cost (supply) and price (demand)**

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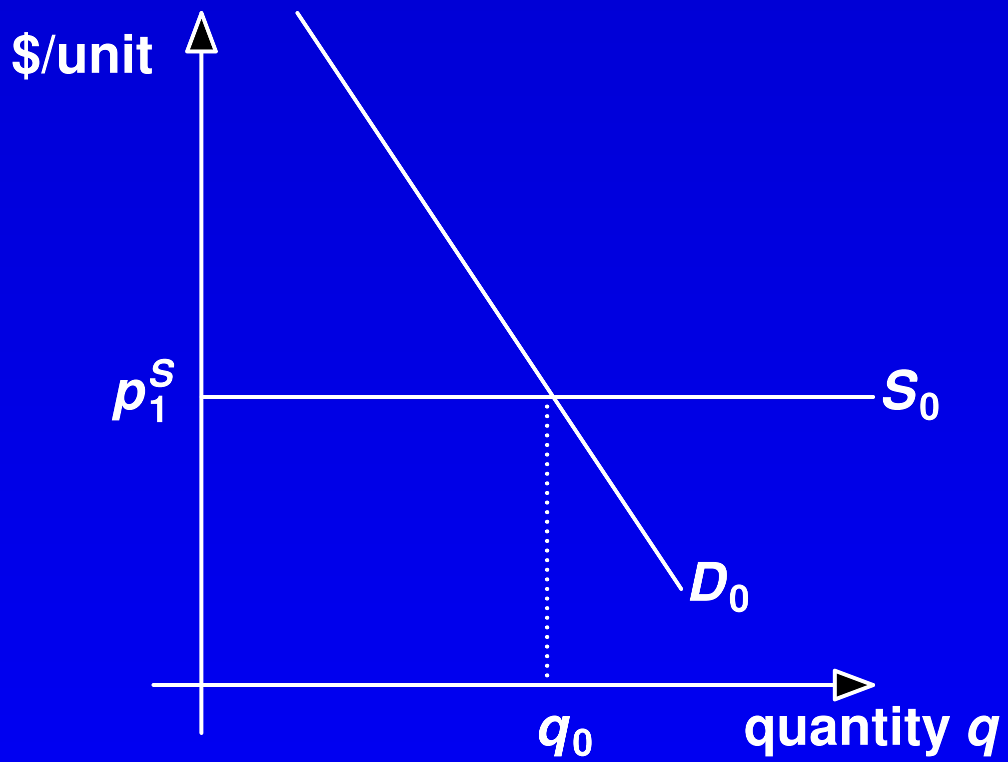
- **Suppose the good is an input into a project:**

A Tax (cont.) — *Infinitely elastic supply*



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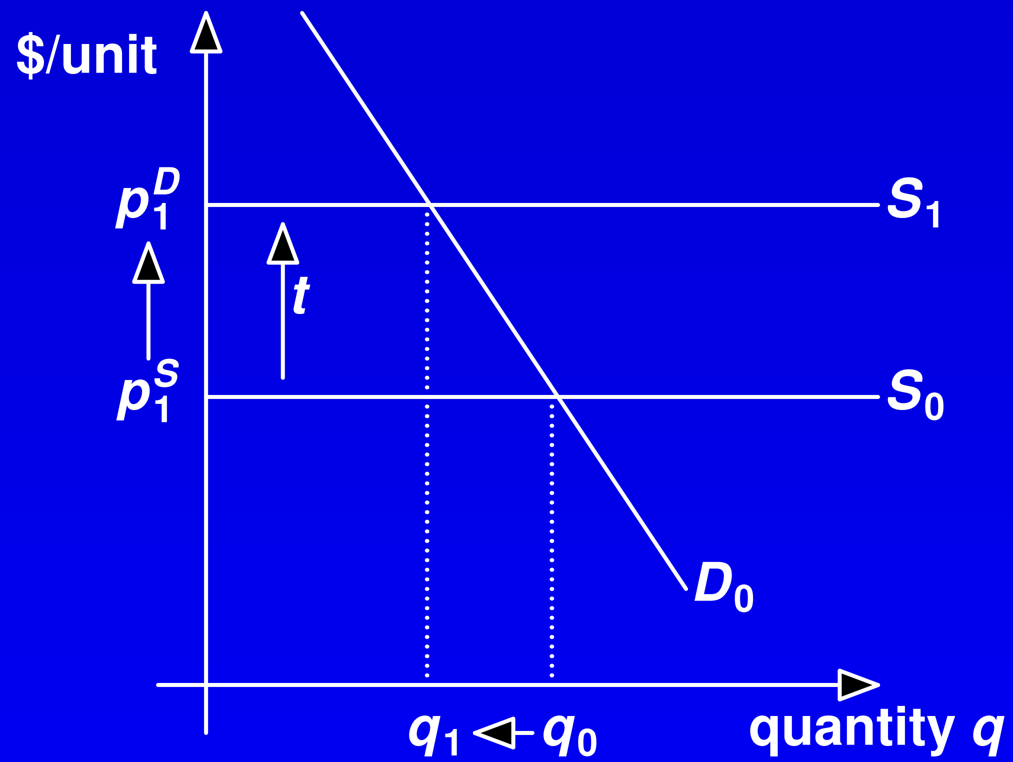
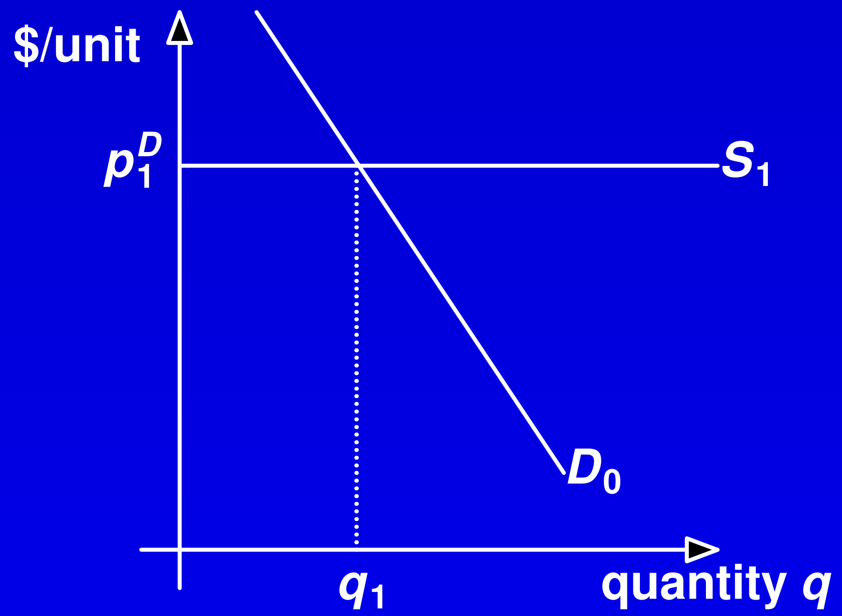


Because of the tax, the (tax-inclusive) demand price p_1^D is greater than the (tax-exclusive) supply price p_0^S.

The diagram shows the Tax Revenue and the Dead-Weight Loss as the tax is imposed, pushing up the effective supply, and reducing the quantity demanded, from q_0 to q_1.

A Tax (cont.)



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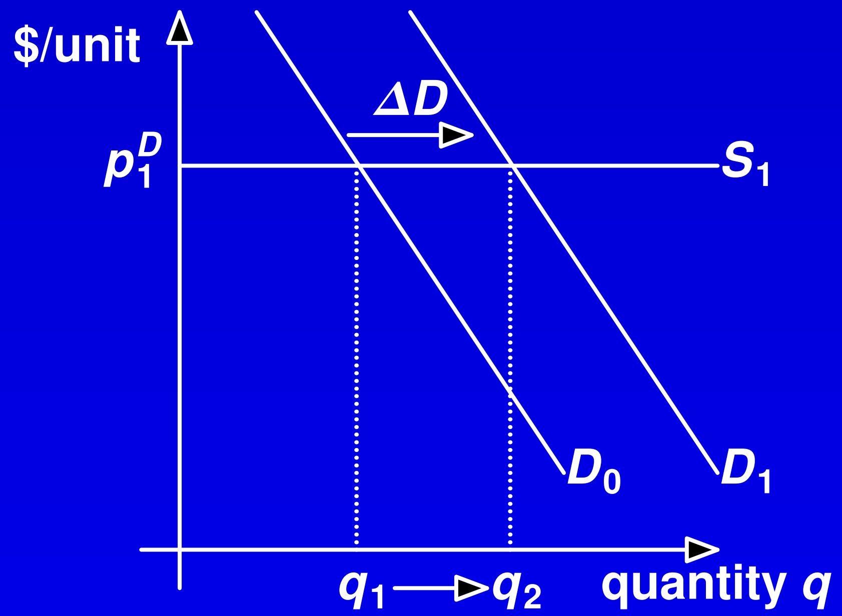

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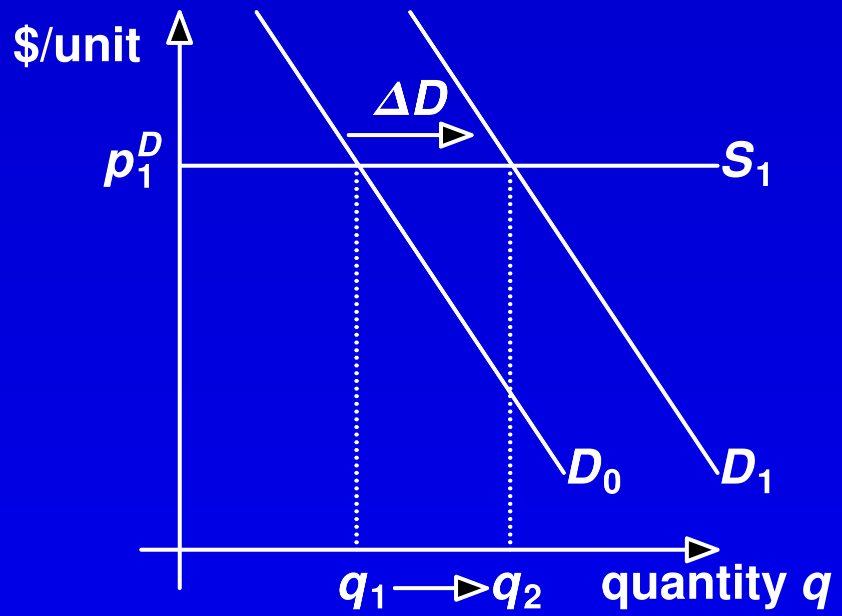

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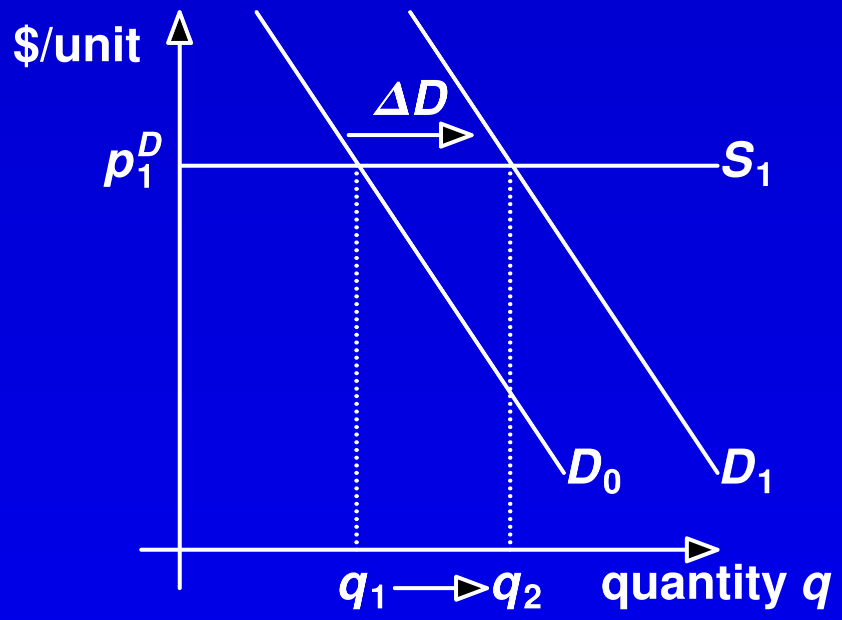

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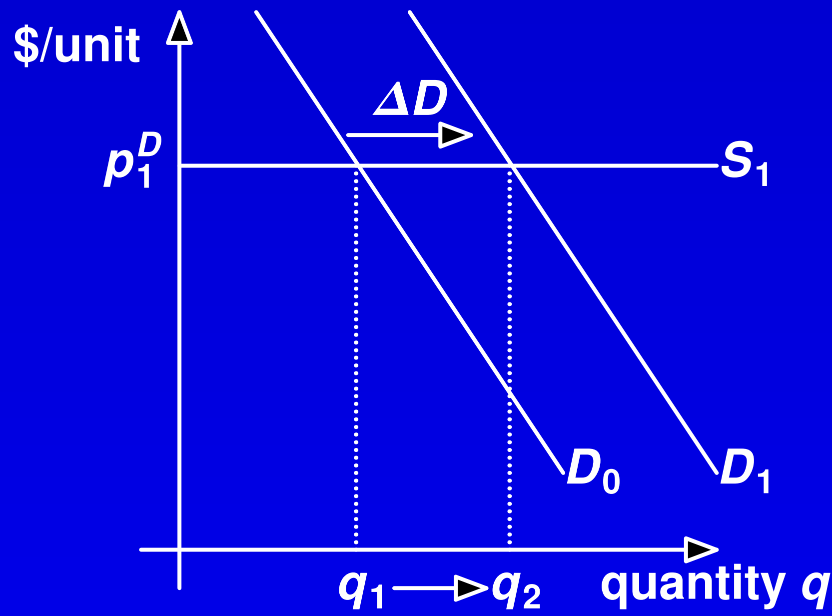

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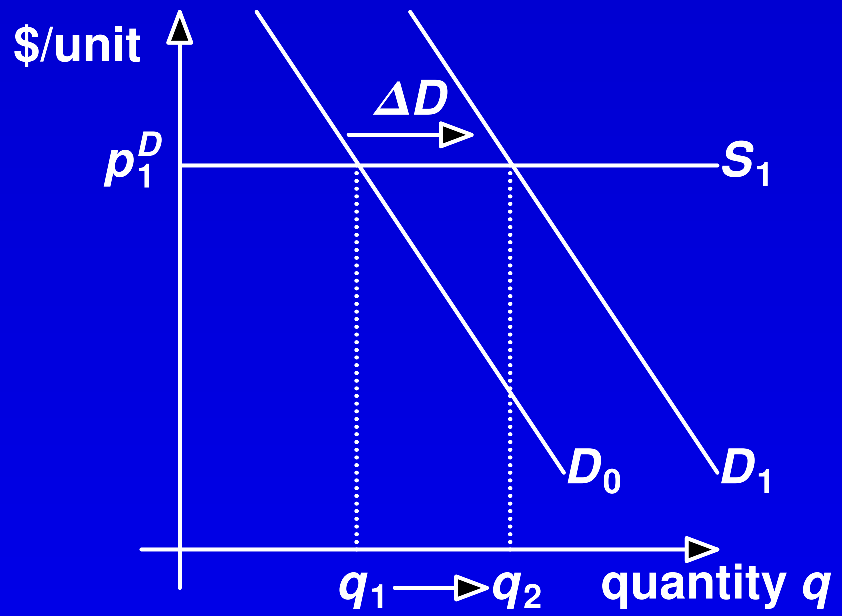

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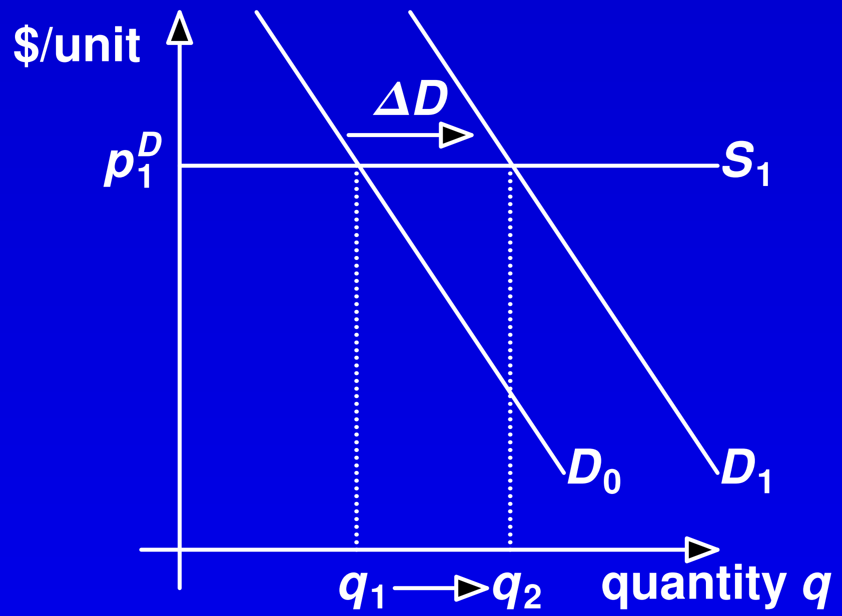

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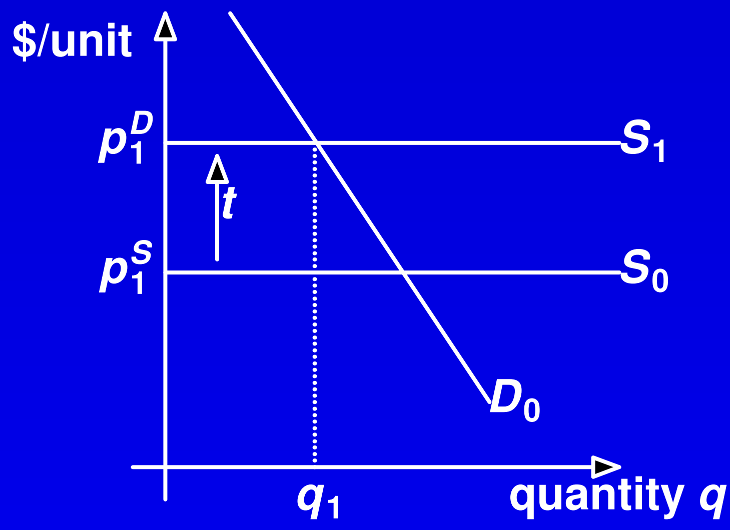
- **But there is no change in p_1^D with the increase in demand.**
- **Because of the tax, the project pays the higher, tax-inclusive price p_1^D.**
- **Is this *the shadow price*?**
- **Does p_1^D reflect the opportunity cost associated with the extra quantity?**
- **No, in general, but it depends on the purpose of the tax (i.e., revenue or "green" tax?).**

A Tax (cont.) —

e.g. oil at world price plus a local excise of *t*:



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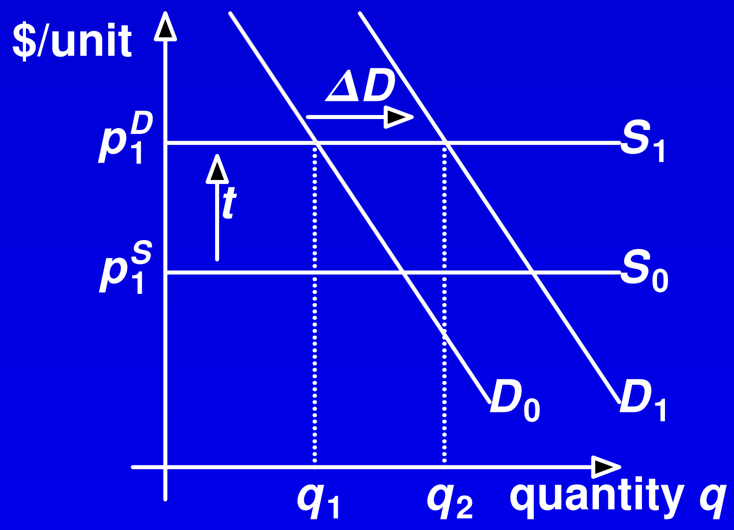

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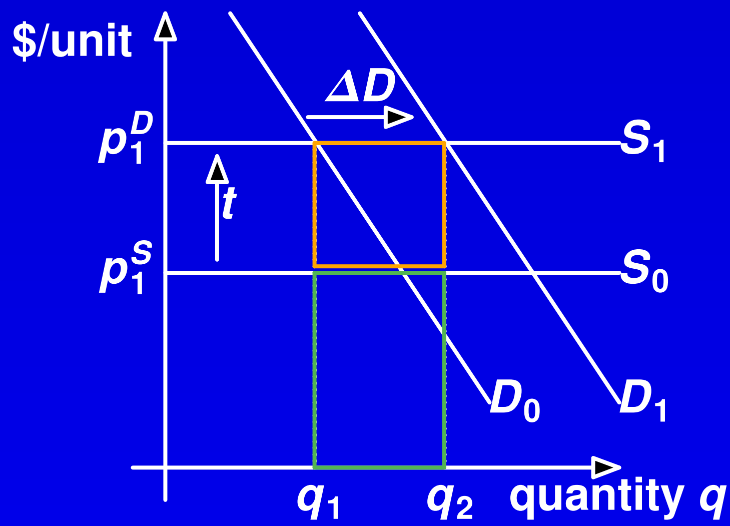

Consumers value the increase in demand (ΔD) at the tax-inclusive price p_1^D.

Suppliers' price is unchanged at p_1^S.

Shadow price = $p_1^D - t = p_1^S$ = unchanging tax-exclusive price, p_1^S.

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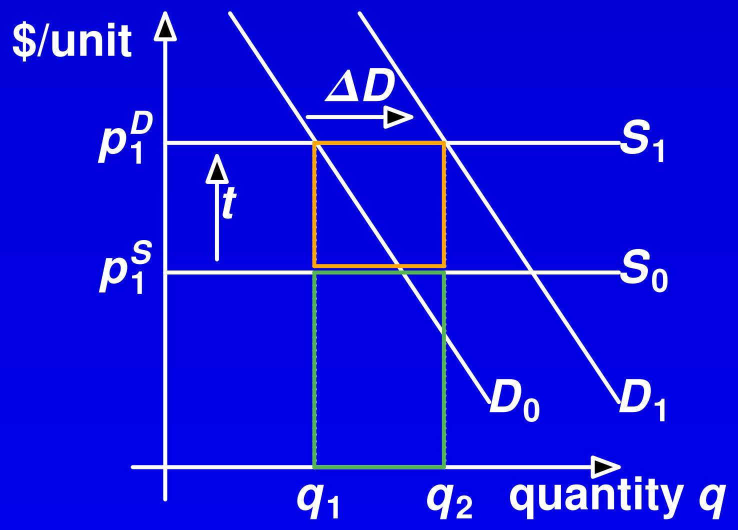

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This is only the case if there is *no effect on existing purchasers of output,* since there is no increase in price with perfectly elastic supply.

$\therefore$ the ex-tax price p_1^S is the shadow price.

1.2 Example 2: Shadow prices and opportunity costs when prices change

[C&B pp. 92–96; FP Ch. 2.2.2, 2.3.2; DoF 3.4]

Q:

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Q: There is a local market for irrigation water. The going price is $50/megalitre. A new cotton farm is planned, but its size and thirst for water are such that the going price of water will rise to $60/megalitre, given its demand of 10,000 megalitres/year. At the lower price the NPV of the project is positive, but at the higher price negative. At the higher price the incumbent users cut their consumption by 1000 megalitres/year.

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A: **The shadow price is between \$50 and \$60/megalitre, say \$55 (assuming linear supply and demand curves). The existing users bear a cost of \$55 $\times$ 1000 = \$55,000/year for the water they can no longer afford (the *displaced* water).**

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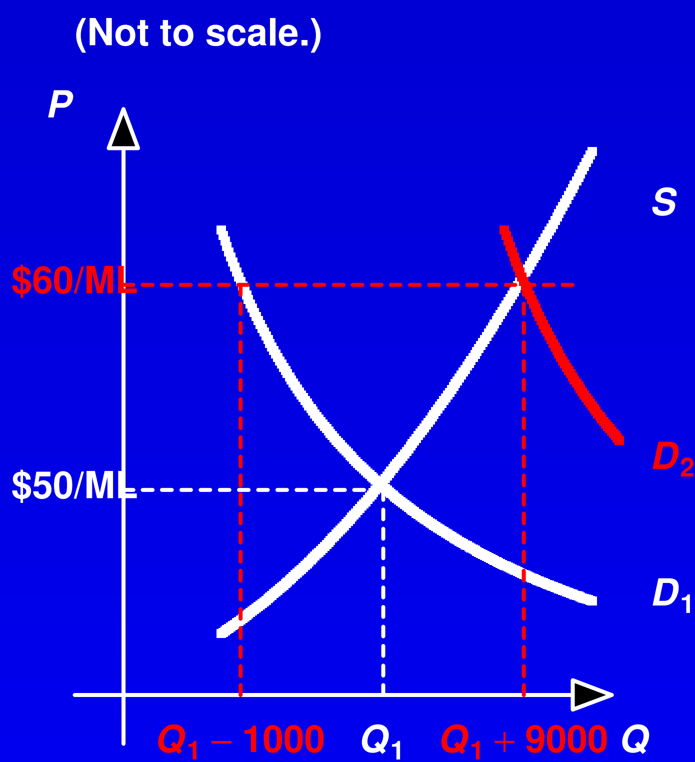
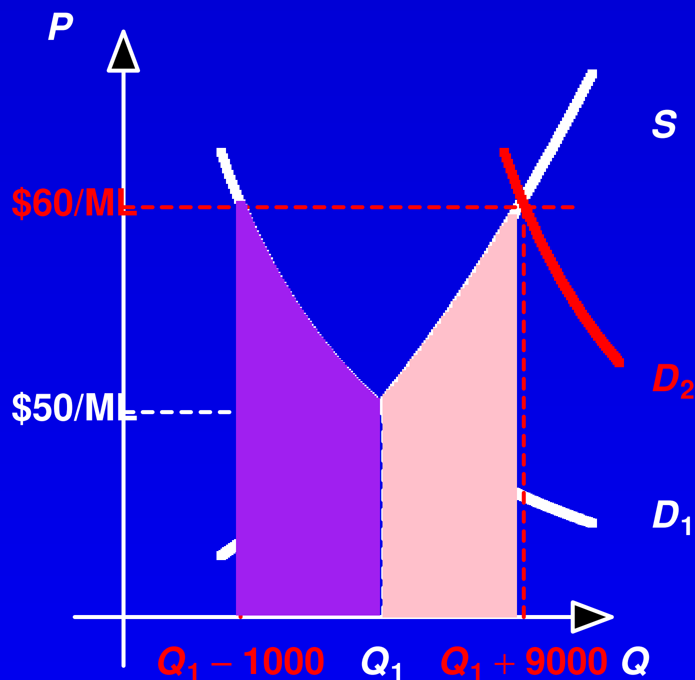
A: **The shadow price is between $50 and $60/megalitre, say $55 (assuming linear supply and demand curves). The existing users bear a cost of $55 × 1000 = $55,000/year for the water they can no longer afford (the *displaced* water). The shadow cost to the new farm is $550,000/year, which includes $55,000 to outbid the exiting users for 1000 megalitres/year, and the opportunity cost of $495,000 to induce the increased supply of 9000 megalitres of water (the *incremental* water).**

Prices Change (cont.)



Prices Change (cont.)

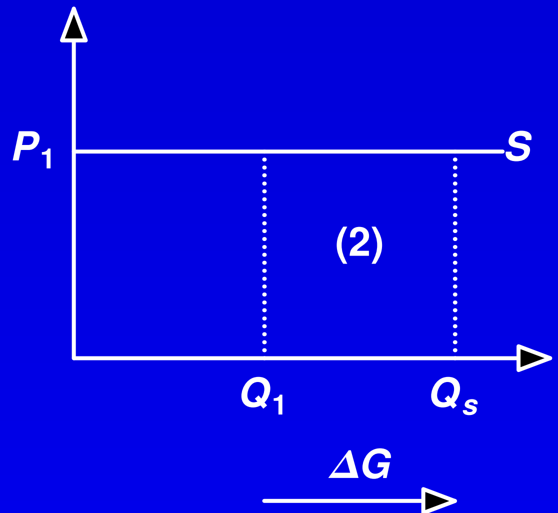
(Not to scale.)



value of displaced water = \$55,000
cost of supplying incremental water = \$495,000
$\therefore$ total cost = \$550,000 $\rightarrow P_S$ = \$55

For a FA, cost = \$60 $\times$ 10,000 = \$600,000
For a CBA, cost = \$55 $\times$ 10,000 = \$550,000

Prices Change (cont.)



Case 2.1

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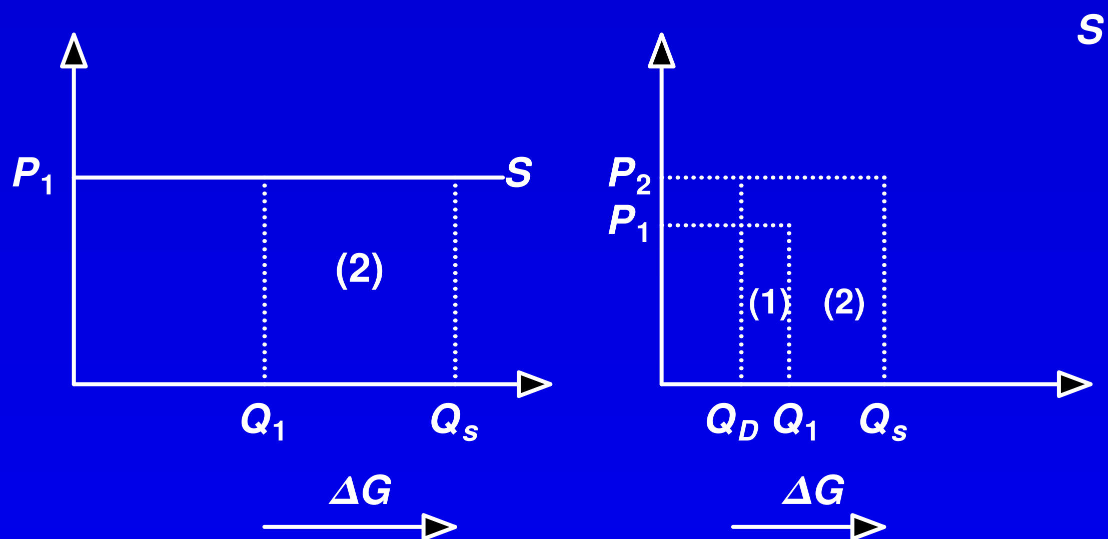
Prices Change (cont.)



Case 2.1

(No price change)

Case 2.2

(Price change)

Case 2.1: **(No price change)**

resource opportunity cost = total social costs for increased factor supply (2)

$$= P_1 \bullet \Delta G$$

Case 2.2: **(Price change)**

resource opportunity cost $=$ **total social costs**
$P_1 \bullet \Delta G$ **for increased factor supply (2)**

$+$ **value of reduced use of inputs in the rest of society as a response to higher prices, or opportunity costs. (1)**

$$P_1 \bullet \Delta G < \text{Area } [(1) + (2)] < P_2 \bullet \Delta G$$

$$\therefore \; P_1 < P_s < P_2$$

$\rightarrow$ P_s **is the "effective or shadow price":**

$P_s \bullet \Delta G$ **is the resource cost = area (1) + area (2)**

Prices Change (cont.)

Note: be conservative

if NPV > 0 with P_2 ~ cost then GO

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Prices Change (cont.)

Note: **be conservative**

if NPV > 0 with P_2 ~ cost **then GO**

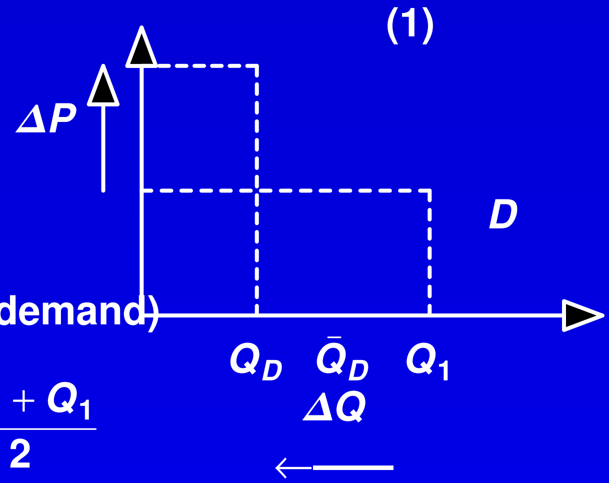
if NPV < 0 with P_1 ~ cost **then STOP**

$$\text{if} \begin{cases} NPV(P_2) < 0 \\ NPV(P_1) > 0 \\ NPV(P_s)\ ? \end{cases} \qquad \text{then must find } P_s$$

The point is so avoid the cost and effort of deriving a better estimate of the shadow price P_s *if it won't make any difference to the decision.*

Some Equations and Harberger's Method

Area under Demand Curve



area

$\approx \eta^P \bar{Q}_D \Delta P$

(η^P: price elasticity of demand)

$$\& \ \bar{Q}_D = \frac{Q_D + Q_1}{2}$$

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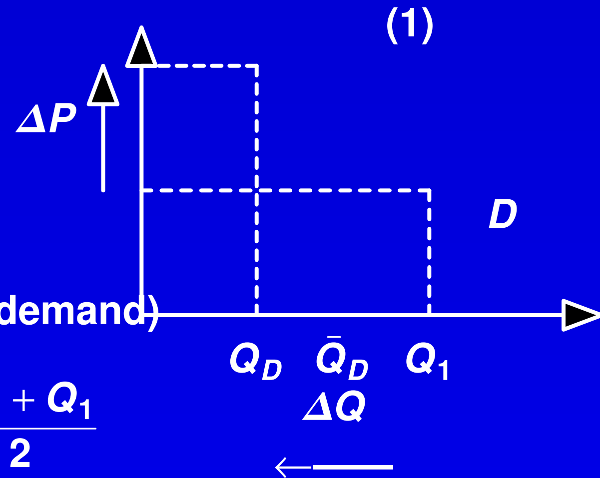


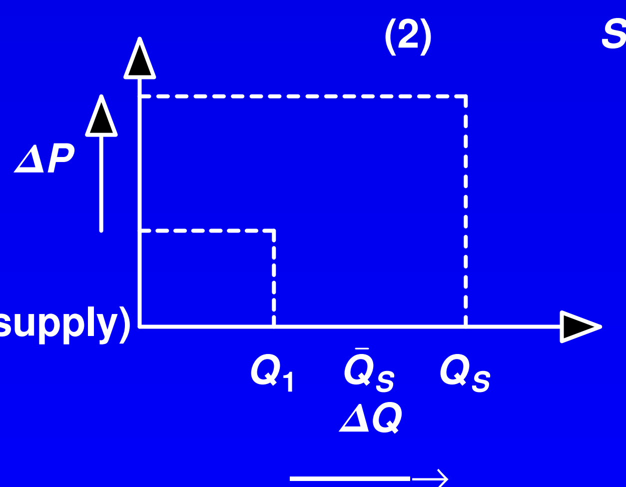
$$\& \ \bar{Q}_D = \frac{Q_D + Q_1}{2}$$

Area under Supply Curve

area

$\approx \kappa^P \bar{Q}_s \Delta P$

(κ^P: price elasticity of supply)



$$\& \ \bar{Q}_S = \frac{Q_1 + Q_S}{2}$$

***Case 2.2: Prices change*. (NFX: Not For Exam)**

From above, social cost (1) + (2) $= P_s \bullet \Delta G$

$$= \Delta P\,(\eta \bar{Q}_D + \kappa \bar{Q}_s)$$

$$\therefore\ P_s = \frac{\Delta P\,(\eta \bar{Q}_D + \kappa \bar{Q}_S)}{\Delta G} \quad \text{shadow price}$$

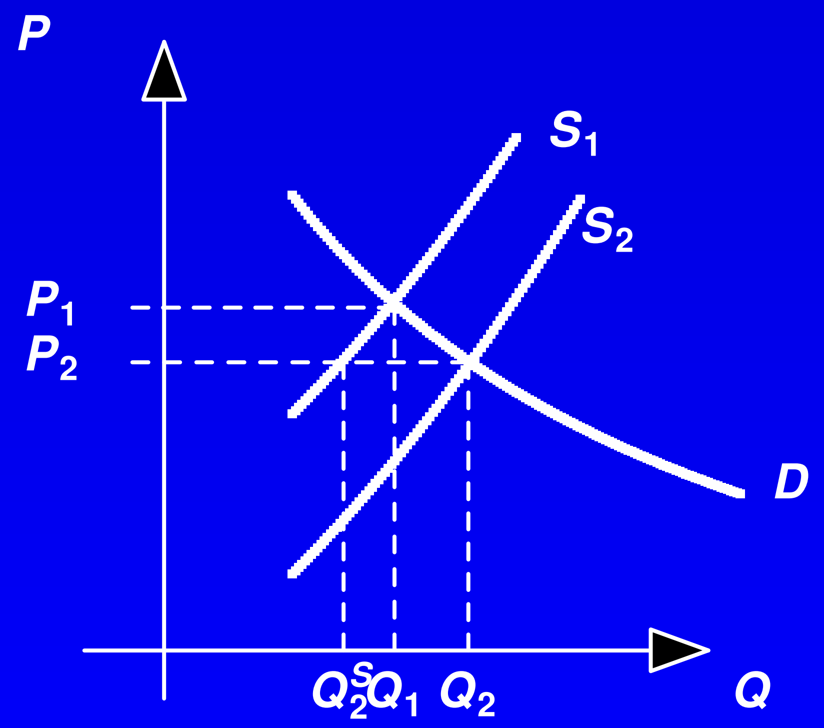
$$= \frac{\Delta P \left(\eta \, \frac{Q_1 + Q_D}{2} + \kappa \, \frac{Q_1 + Q_S}{2} \right)}{\Delta G}$$

$$= \frac{\Delta P \eta \left(Q_1 + \frac{Q_D}{2} + \frac{Q_S}{2} \right)}{\Delta G} \quad (\text{if } \eta = \kappa)$$

— a means of obtaining the shadow price P_s from Q_1, ΔP, η, κ, Q_D, Q_S, and ΔG.

The Project's Output Drives Prices Down

The project produces an output which is sold: FA benefit = revenue = selling price × quantity. With no change in price, same with CBA. If the output price falls, some marginal producers cut back or cease: a benefit. FA revenue is too low.



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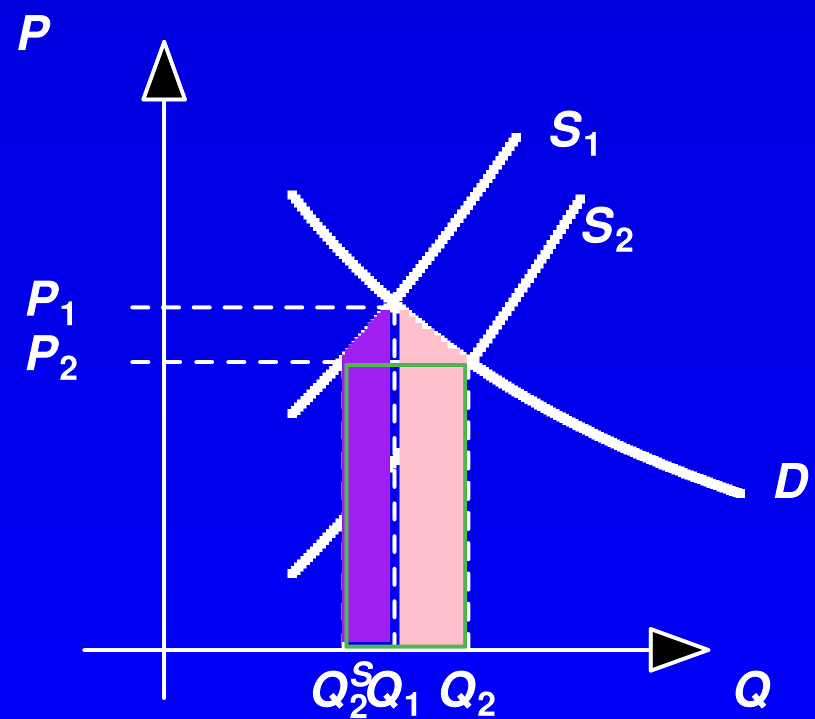

value of the displaced production
value of the incremental production
P_1 < shadow price < P_2

1.3 Example 3: **Prices change with a tax wedge. [DoF 3.5]**

Q:

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Q: **In the cotton-farm example, assume that the prices of $50 (before) and $60/megalitre (after) include a tax of $4/megalitre, to raise revenue. What now is the shadow cost of water to the new farm?**

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1.3 Example 3: **Prices change with a tax wedge. [DoF 3.5]**

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A: We have to adjust for both the induced price increase and the tax wedge between suppliers of water and users of water.

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The value of the *displaced* 1000 megalitres of water for the existing farmers who cannot afford to pay $60/megalitre is still $55,000 year: we use the tax-inclusive price of $55/megalitre because they evidently value this water at $50/megalitre at least, but not at $60/megalitre.

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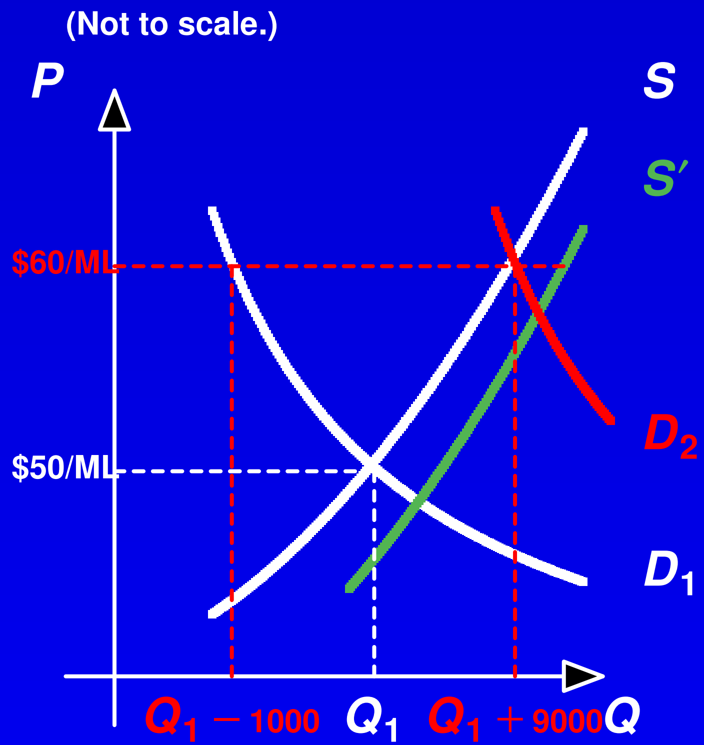
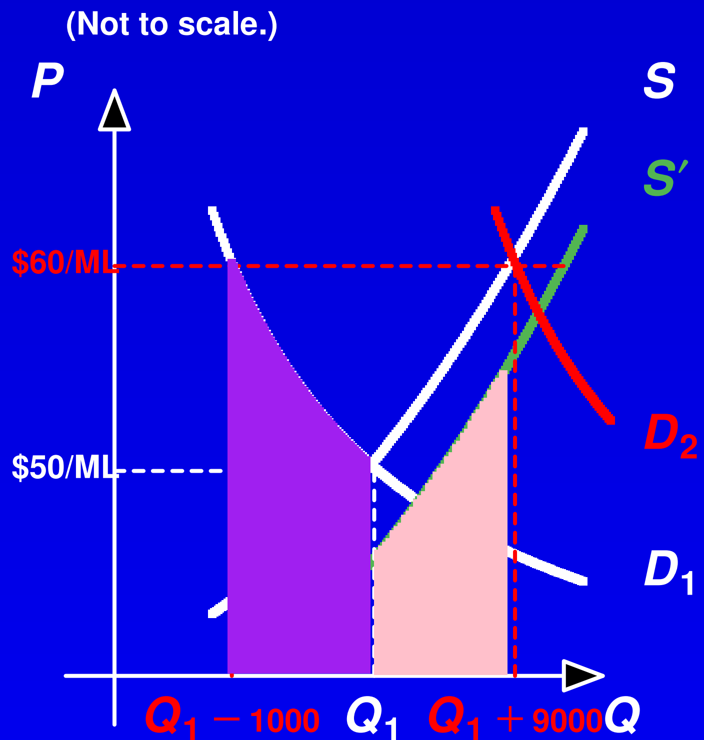
The shadow cost of the *incremental* water is between \$46 and \$56/megalitre (the tax-exclusive prices), since that's what the suppliers of water receive to induce them to increase supply; say \$51 $\times$ 9000 megalitres/year = \$459,000/year.

$\therefore$ Total shadow cost = \$55,000 + \$459,000 = 514,000/year.
$\therefore$ Shadow price = \$51.40/megalitre

Price Change & Tax (cont.)



Price Change & Tax (cont.)

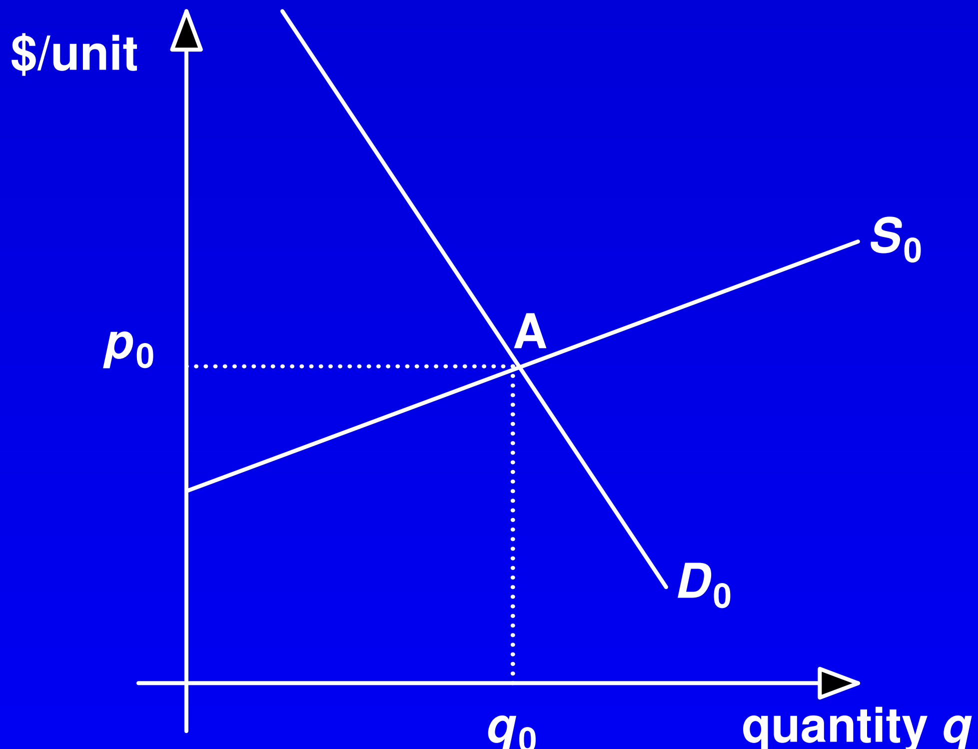


value of displaced water = \$55,000 (still)
cost of supplying incremental water = \$459,000
$\therefore$ total cost = \$514,000 $\rightarrow P_S$ = \$51.40

For a FA, cost = \$60 × 10,000 = \$600,000
For a CBA, cost = \$51.40 × 10,000 = \$514,000

Price Change & Tax (cont.)

Elastic supply



Price Change & Tax (cont.)

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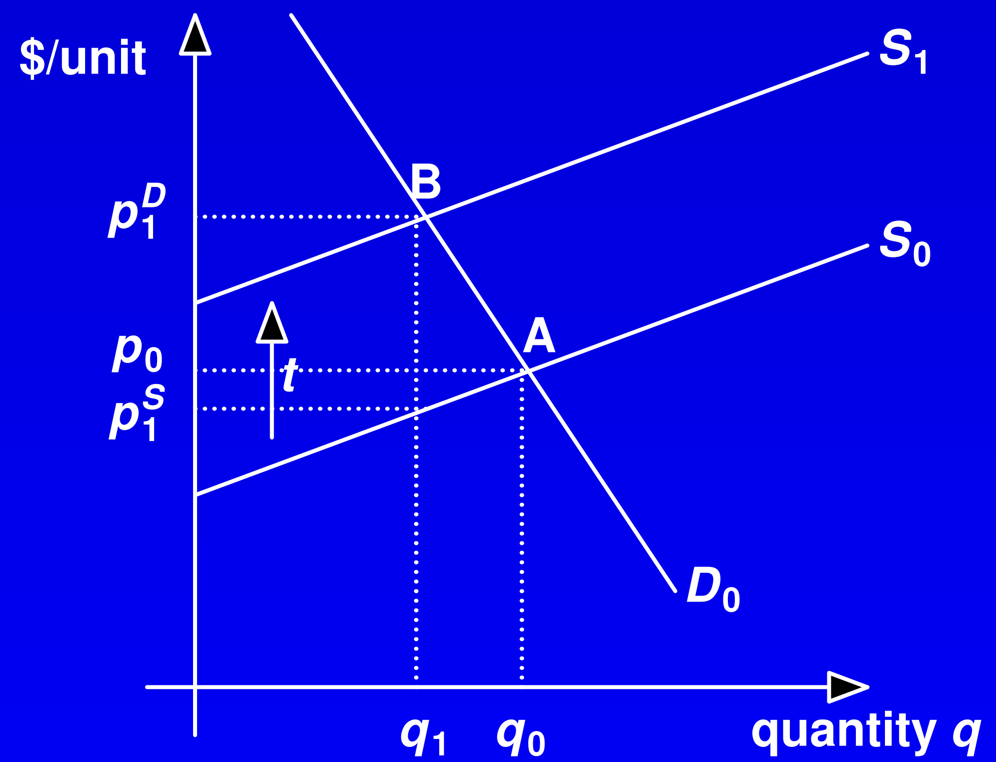

Figure 1

Price Change & Tax (cont.)

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-

Price Change & Tax (cont.)

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Price Change & Tax (cont.)

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Price Change & Tax (cont.)

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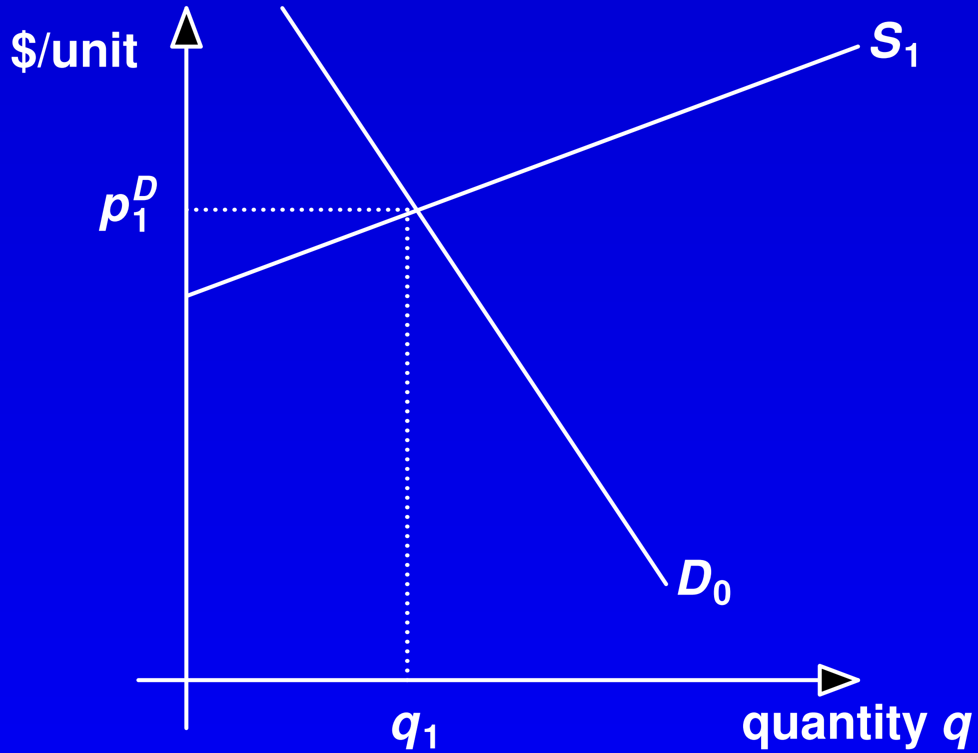
- The tax revenue is a *transfer* from consumers of the product to consumers in general (via tax receipts and government expenditure)

Price Change & Tax **(cont.)**



Price Change & Tax (cont.)

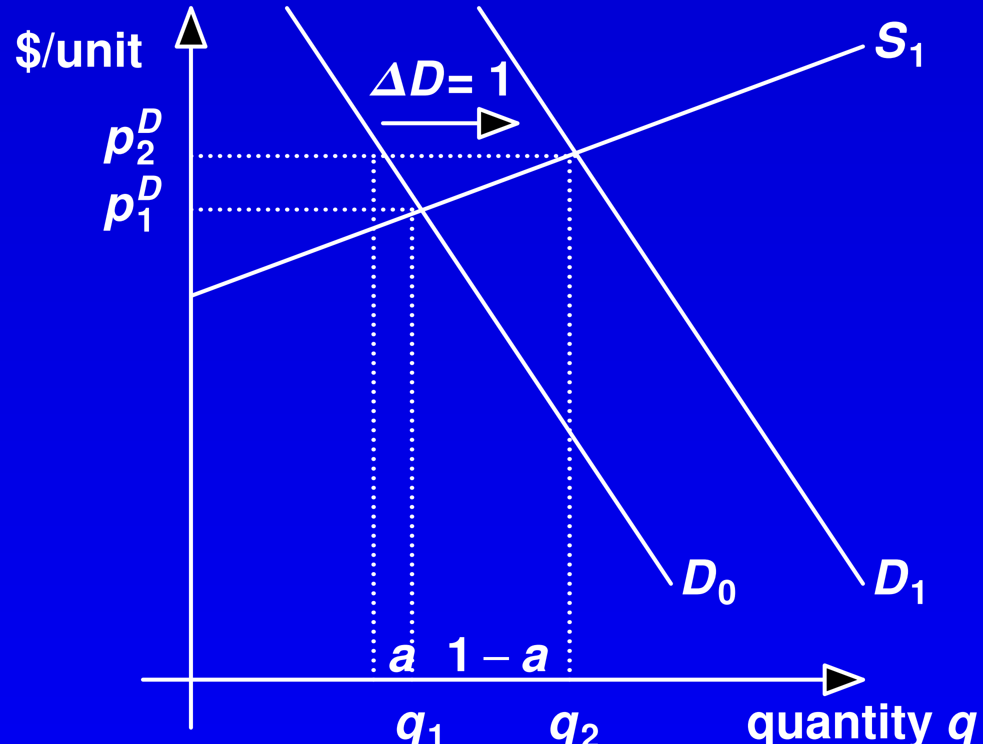


Figure 2

Price Change & Tax (cont.)

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•

Price Change & Tax (cont.)

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∴ unit social cost $= a$(gross-of-tax price) $+ (1 - a)$(net-of-tax price)

$$= a\, p_2^D + (1 - a)\,(p_2^D - t) = \text{shadow price}$$

Hence shadow price = a weighted average of the tax-inclusive and tax-exclusive prices, p_2 and $p_2 - t$, respectively.

Price Change & Tax (cont.)

How do we calculate the weights *a* and 1 – *a*?:

$\eta_D =$

Price Change & Tax (cont.)

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Price Change & Tax (cont.)

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and $\therefore\ a = -\dfrac{\eta_D}{\kappa_S - \eta_D}$

and Shadow Price = $ap_2 + (1-a)(p_2 - t)$:

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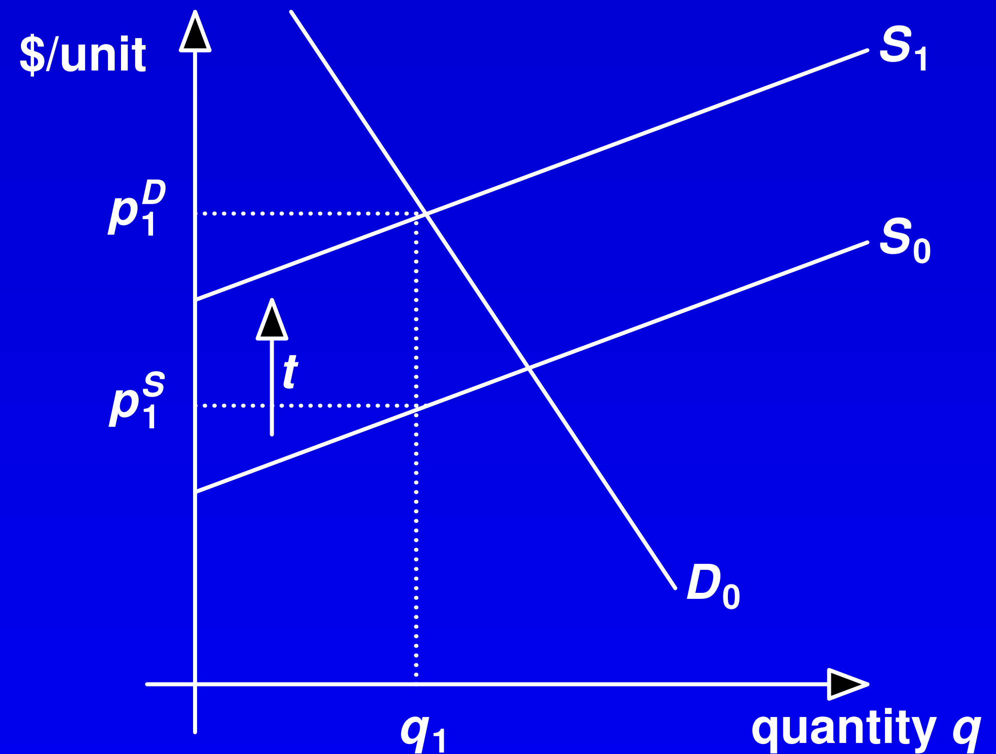
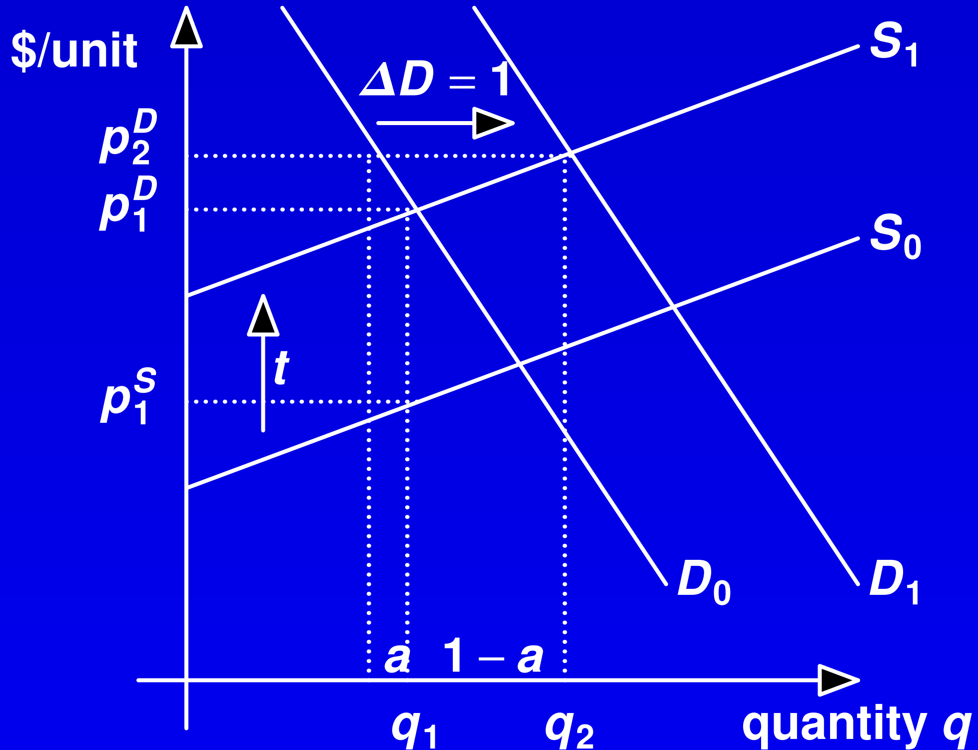
- also for an increase in supply of the good if the project results in more of the good

Price Change & Tax (cont.) — Figure 3



Price Change & Tax (cont.) — Figure 3



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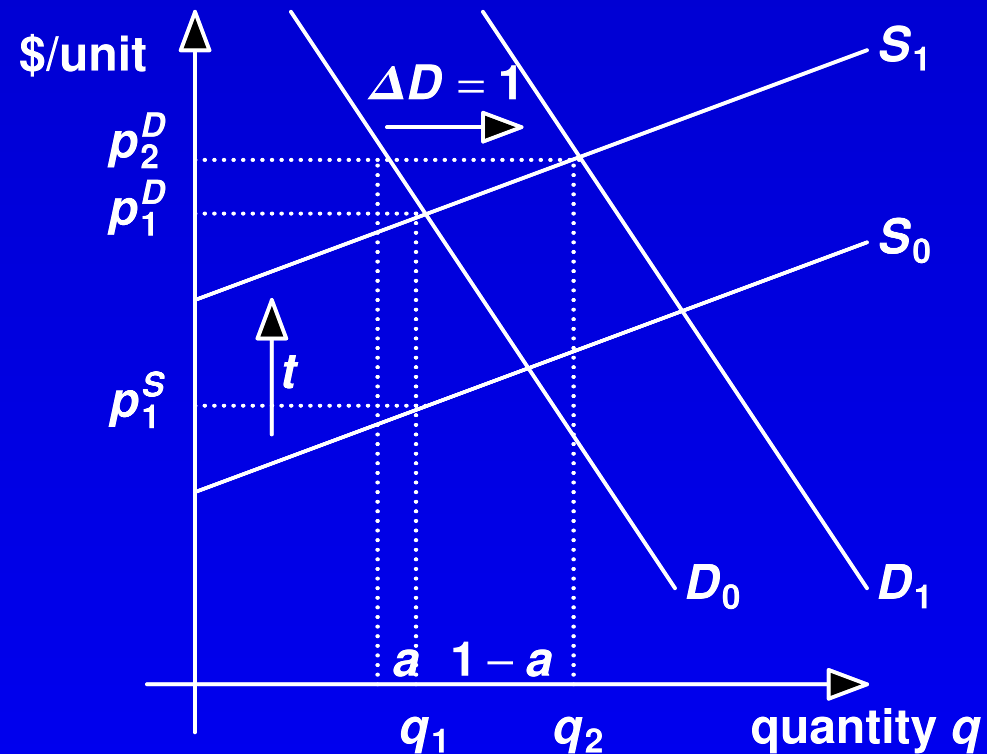
Price Change & Tax (cont.) — Figure 3



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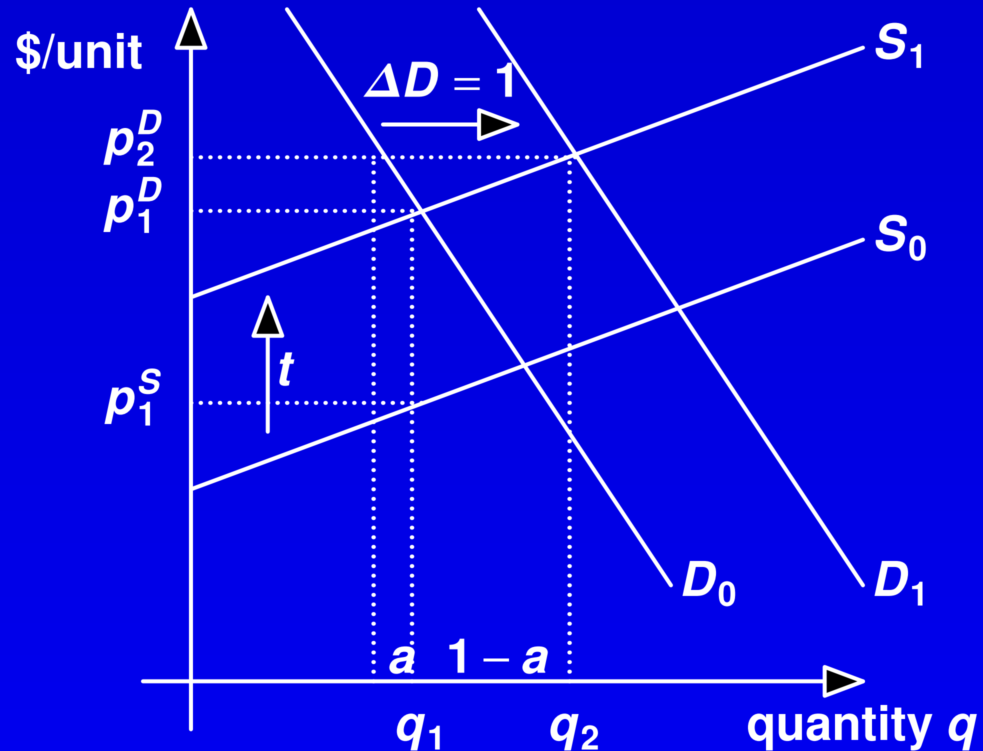
-

Price Change & Tax (cont.) — Figure 3



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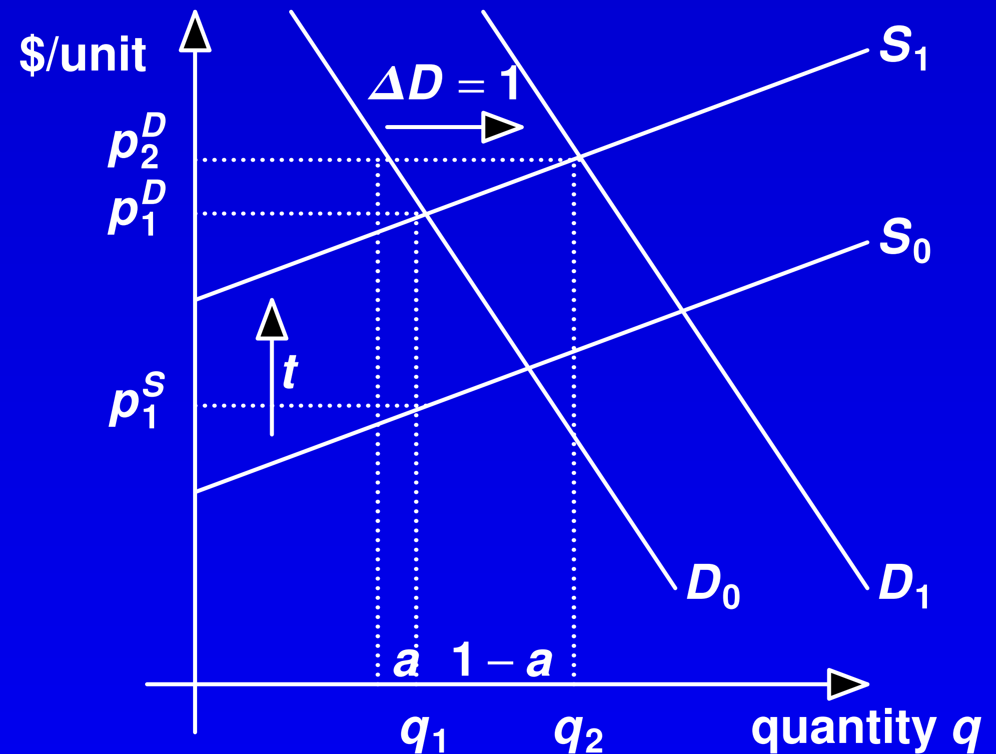
Price Change & Tax (cont.) — Figure 3



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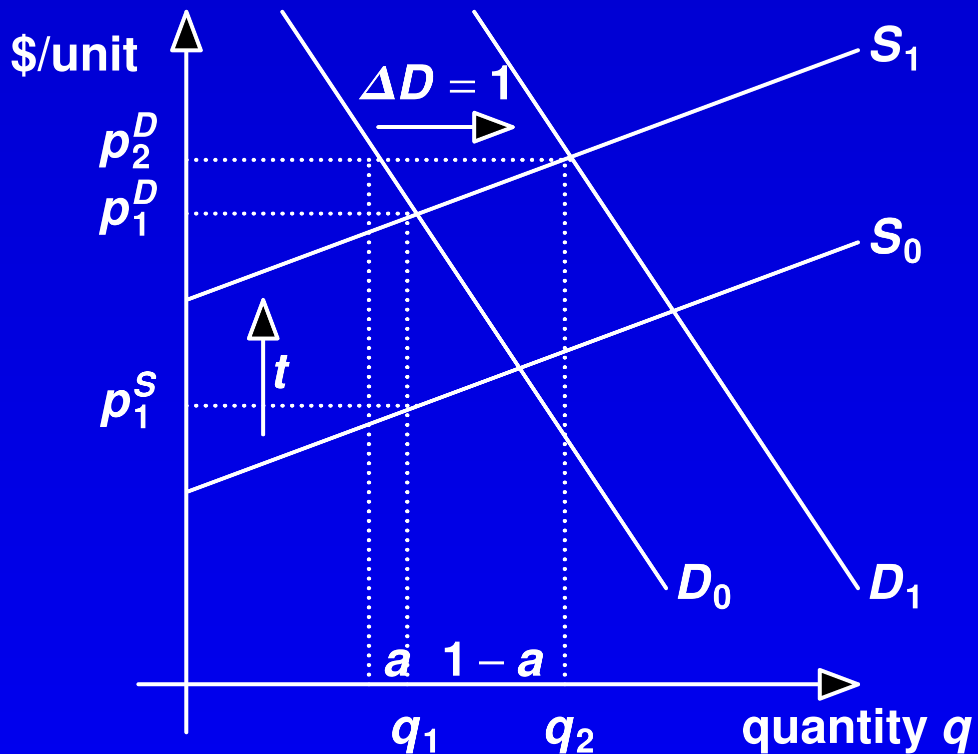
Price Change & Tax (cont.) — Figure 3



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- So $\Delta D \times p_S$ = the sum of the two areas

1.4 Example 4: **Shadow pricing of labour** [C&B pp. 96–98; FP Ch. 6.4.1, Ch. 10; DoF 3.9]

•

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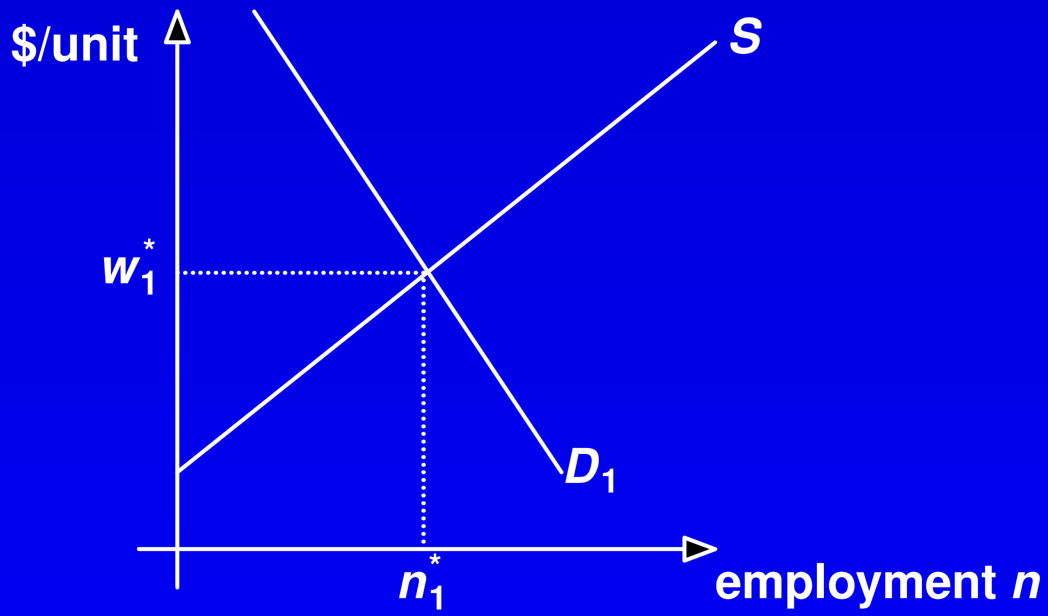
- **In a competitive labour market the shadow price of labour is simply the market wage:**



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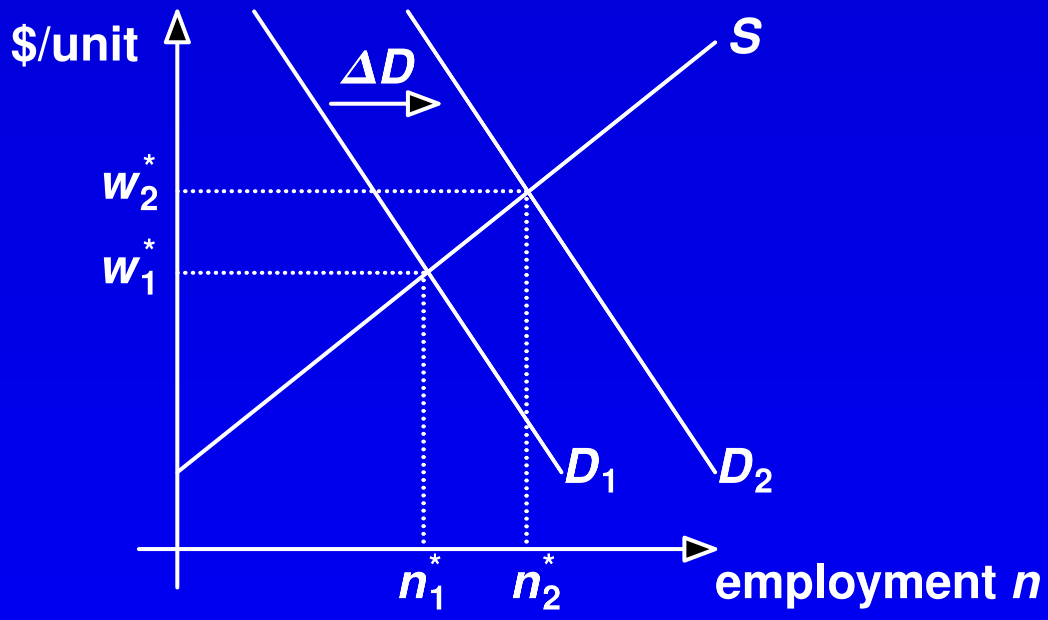

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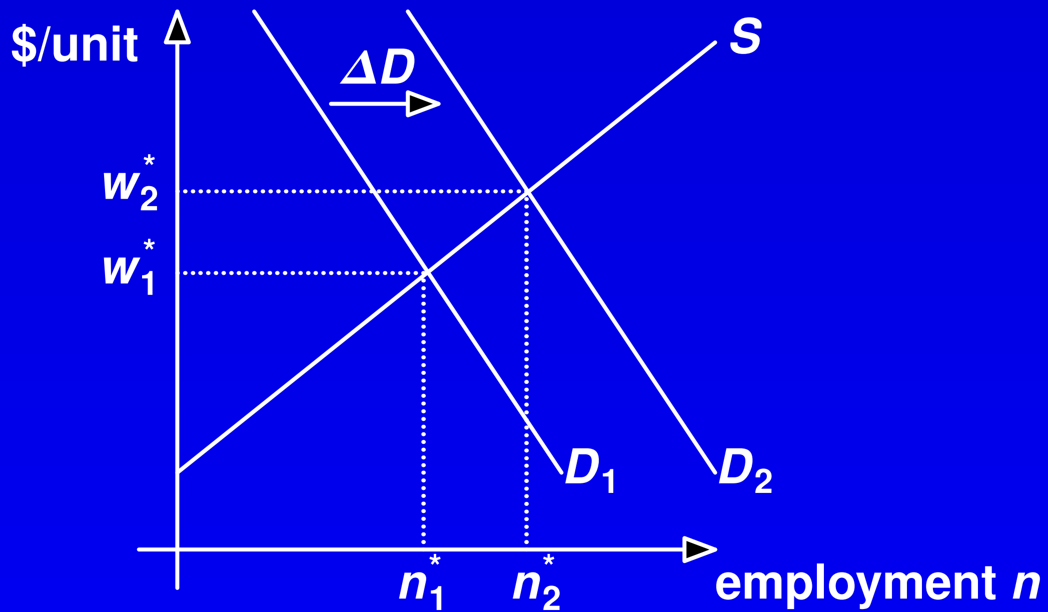

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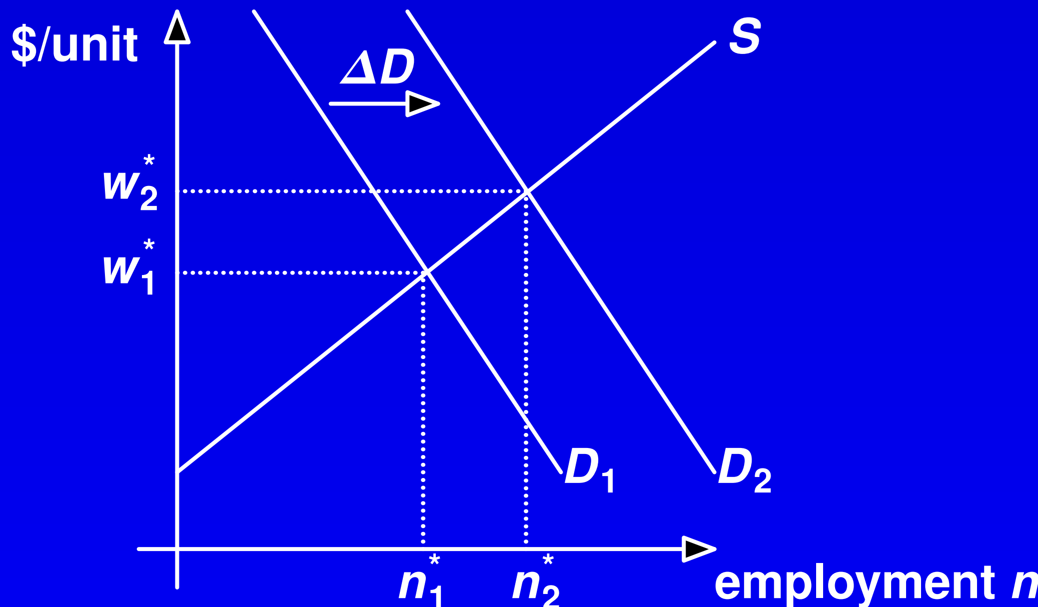

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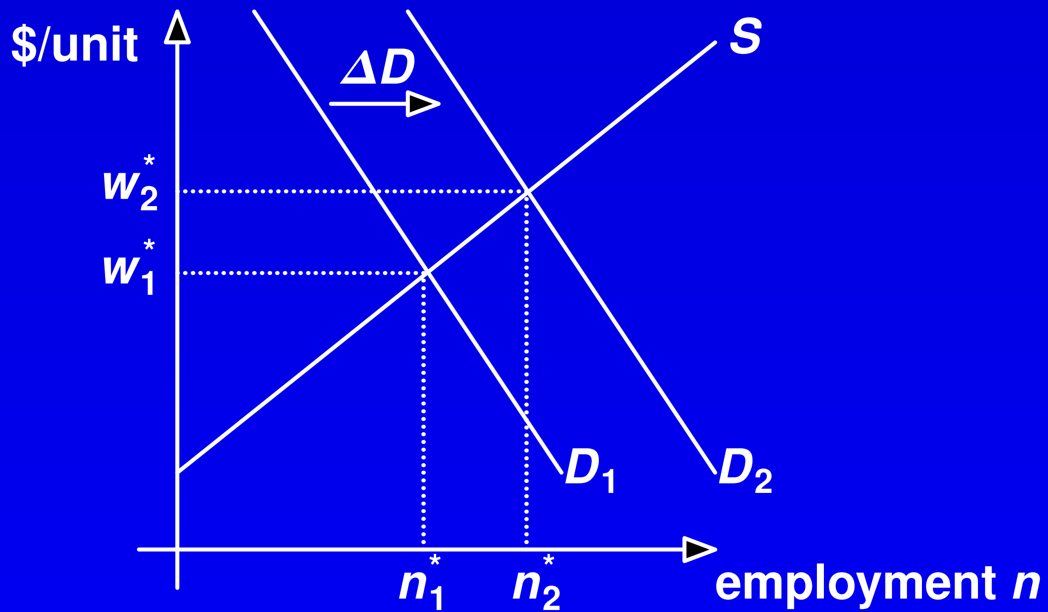

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- workers move from lower-paid to higher-paid jobs
-

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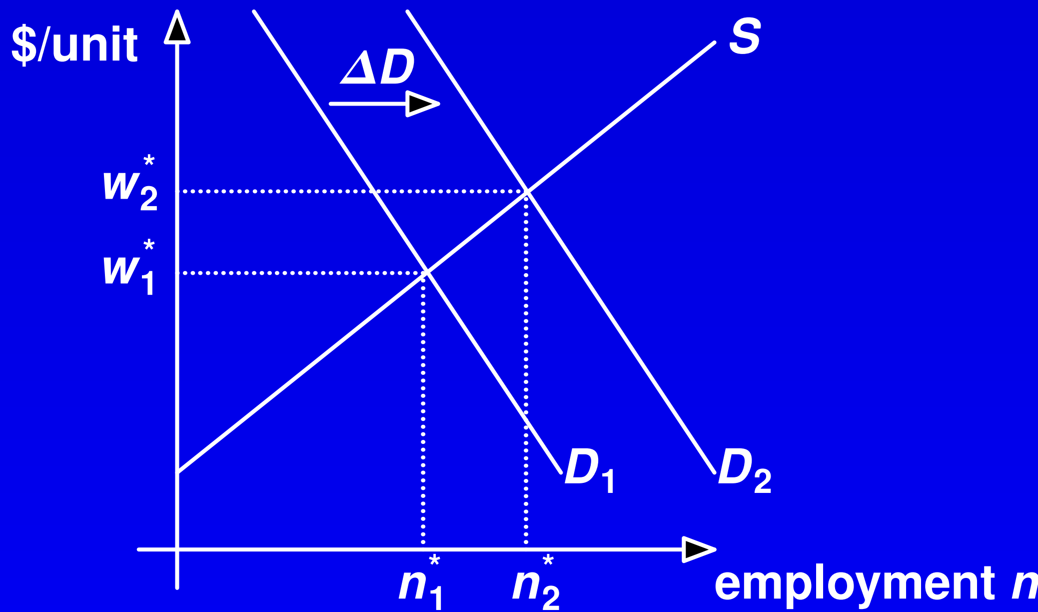
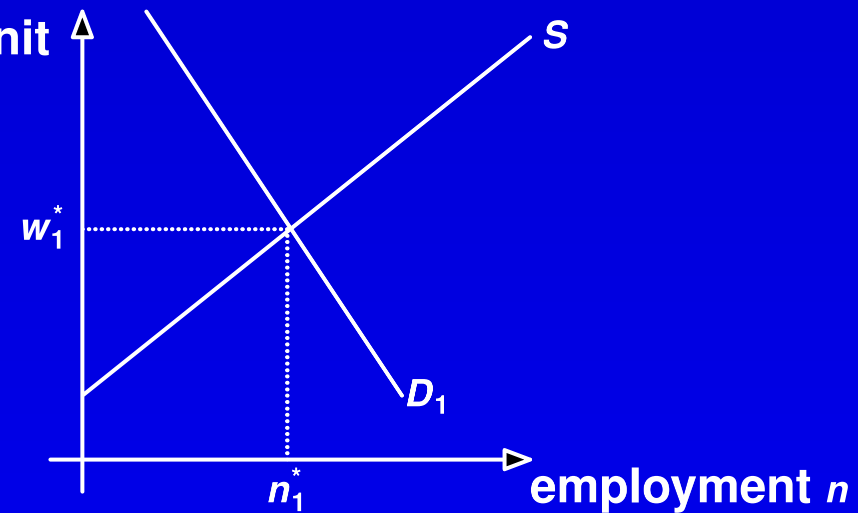


- But the project shifts the demand for labour from D_1 to D_2
- more jobs are "created" ($n_2^* - n_1^*$)
- workers move from lower-paid to higher-paid jobs
- and there is no "involuntary" unemployment

***Labour* (cont.) —** **Suppose there is a *minimum wage* $\bar{w}$ for labour set by the IRT. Then the employment level n_1 will be less than the competitive level, n_1^*.**



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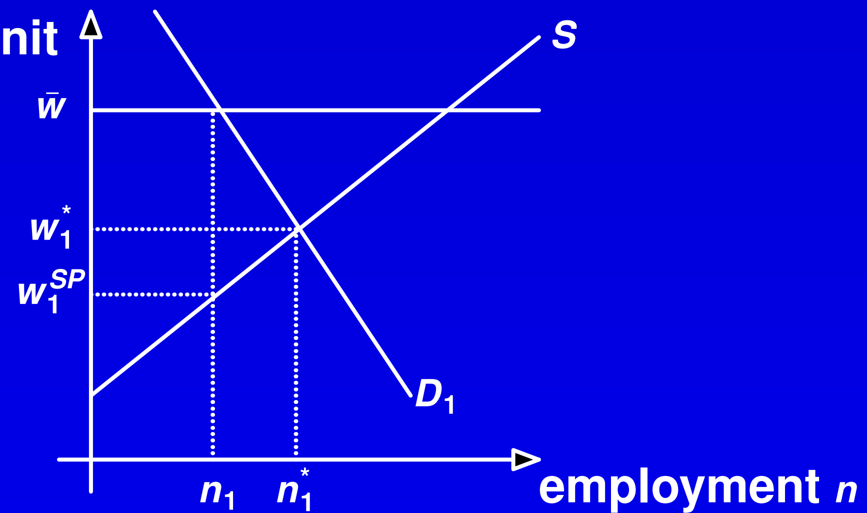

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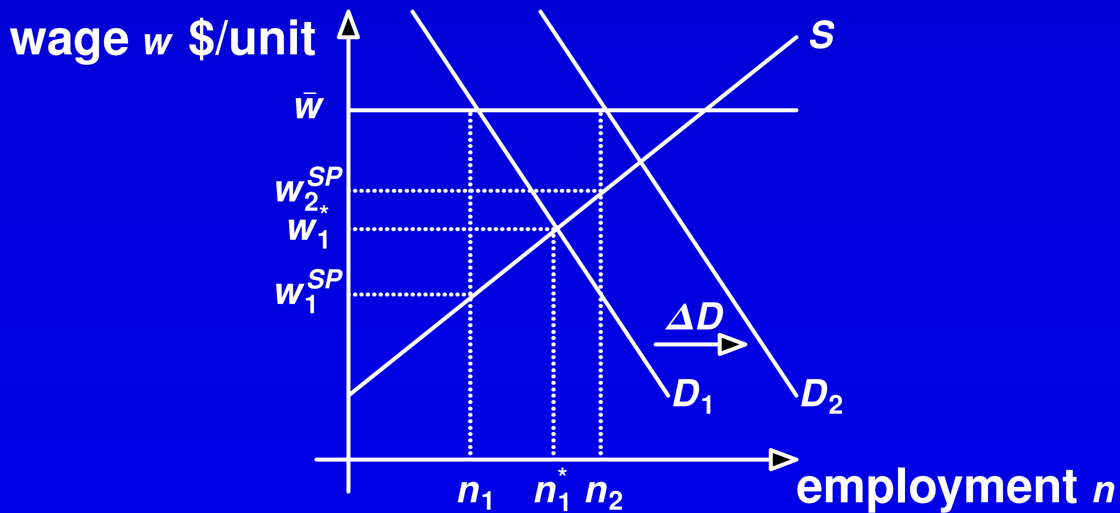

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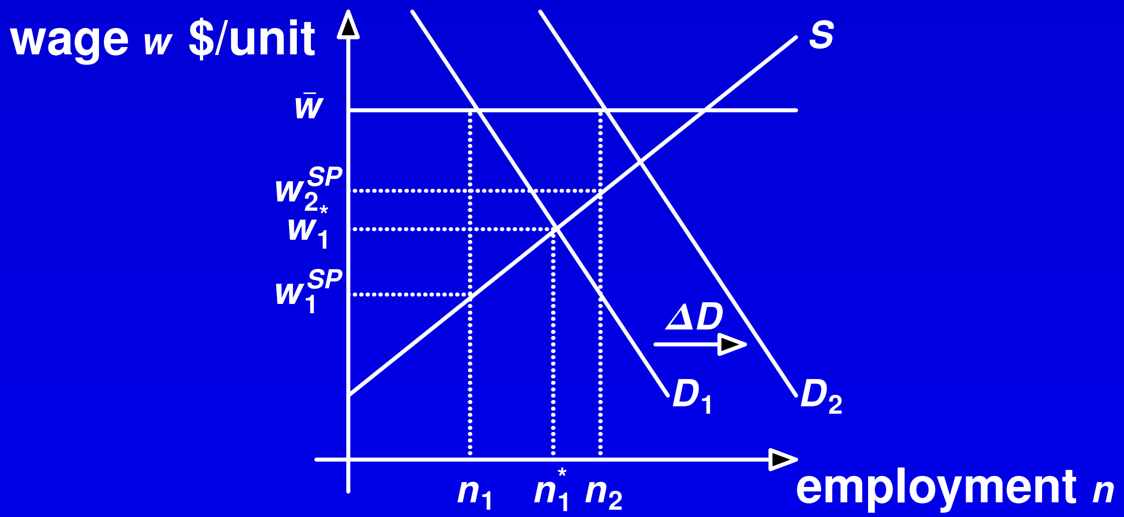

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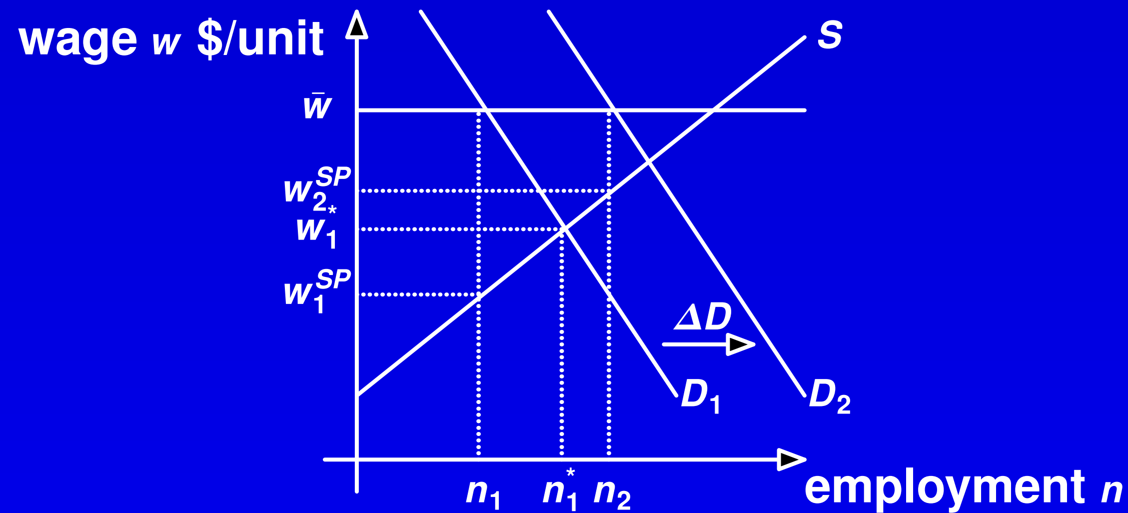

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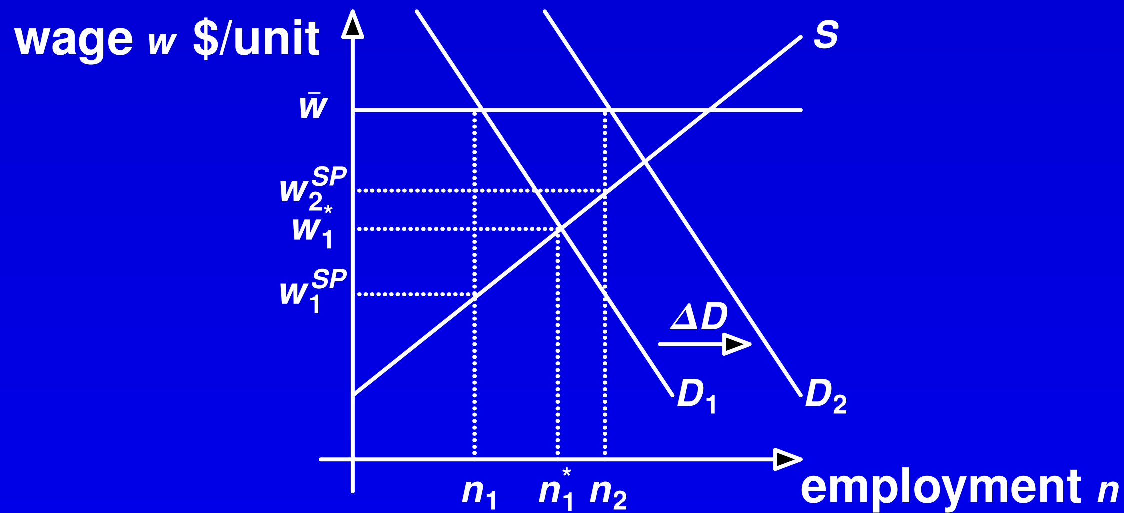

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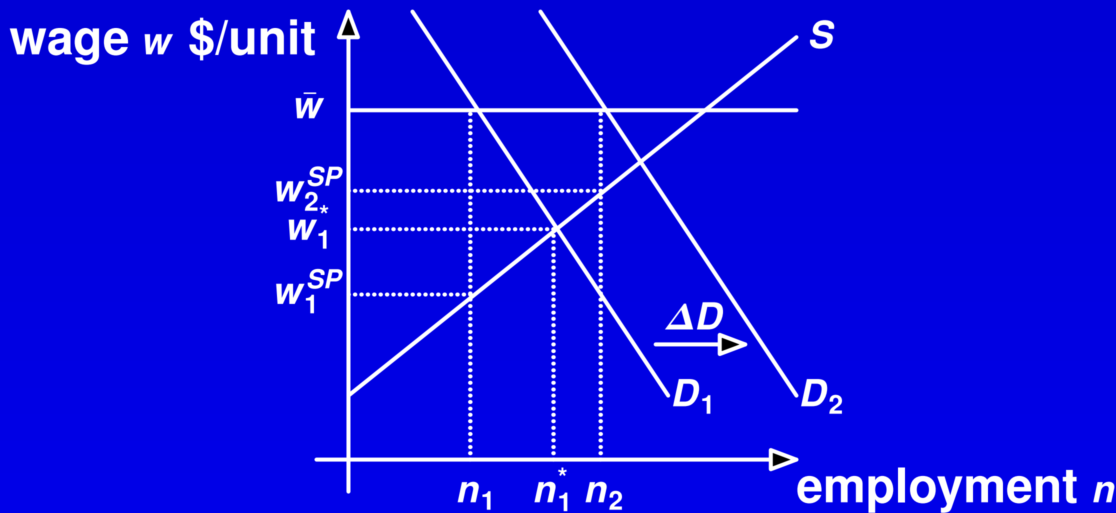

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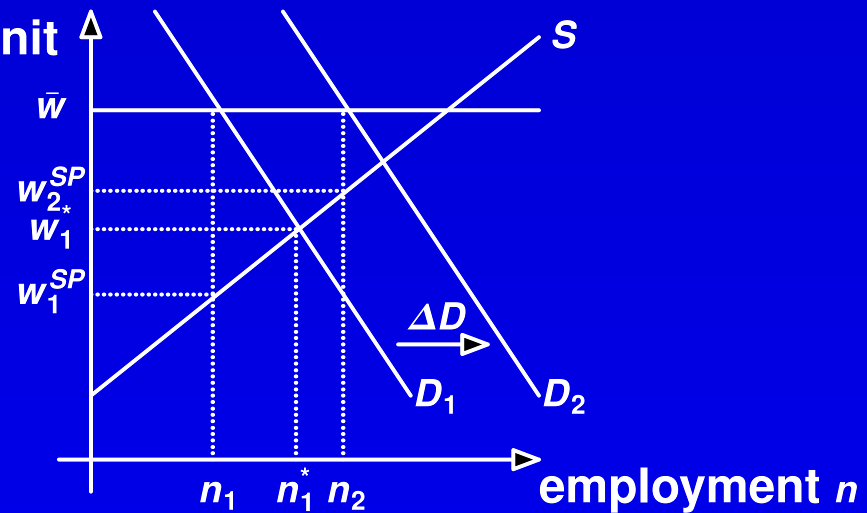

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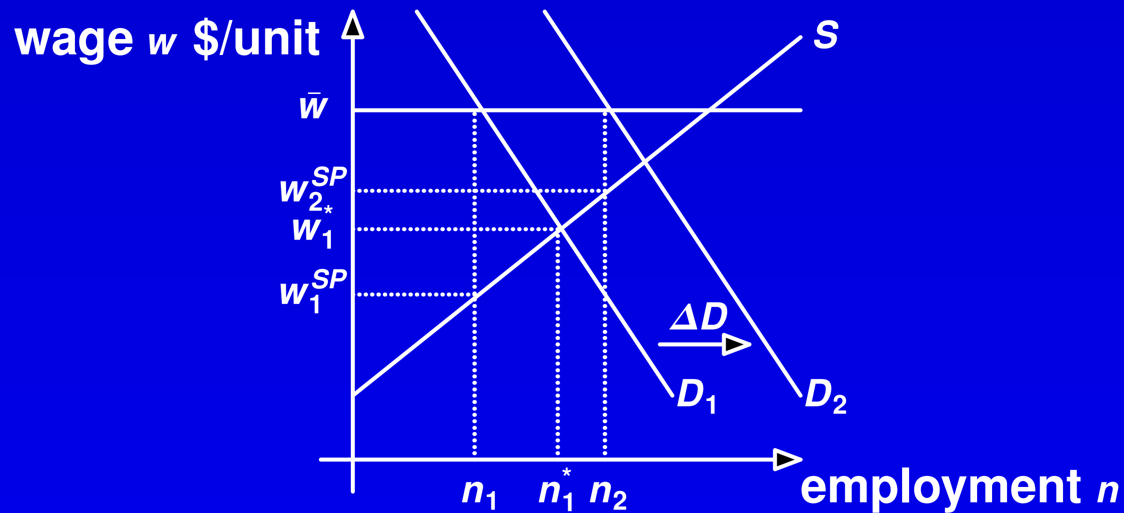

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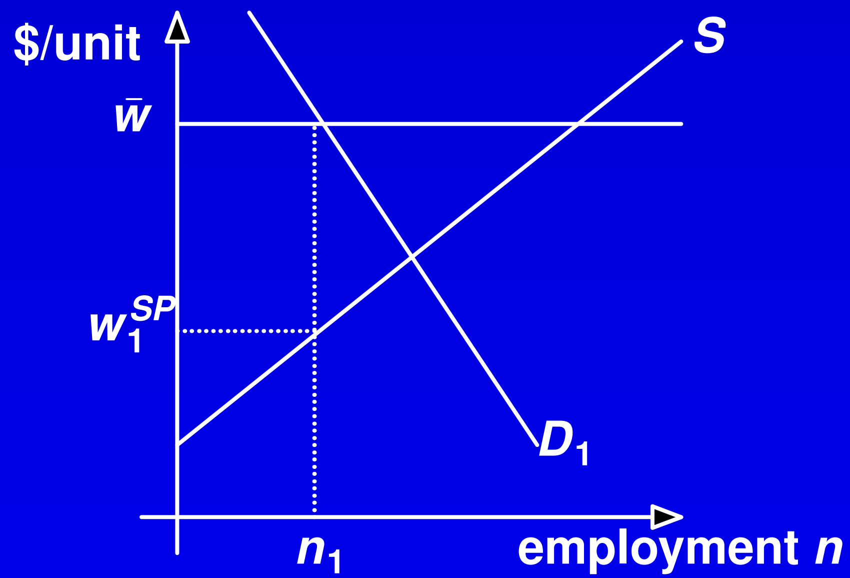
- **The average social cost (shadow price) is lower than the market price $\bar{w}$**
- **Why? Because there is *unemployment* at minimum wage $\bar{w}$.**

Labour (cont.)



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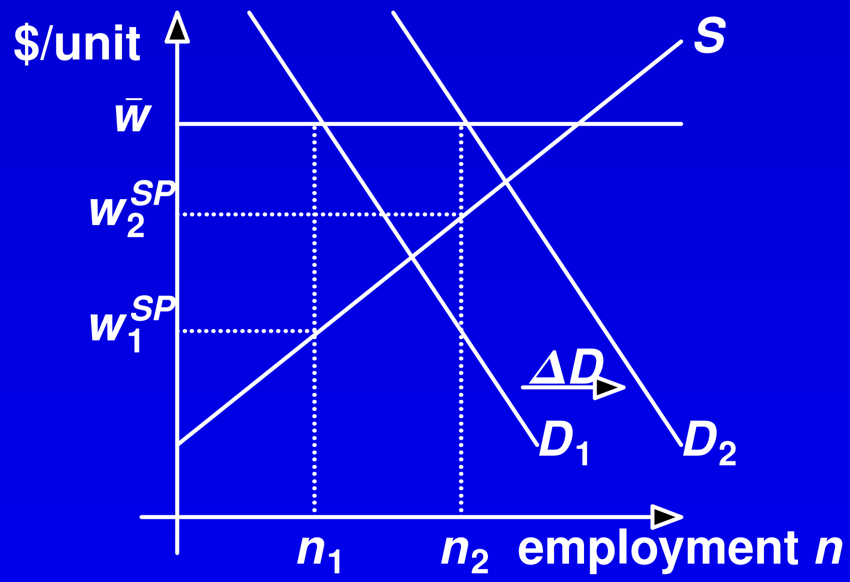

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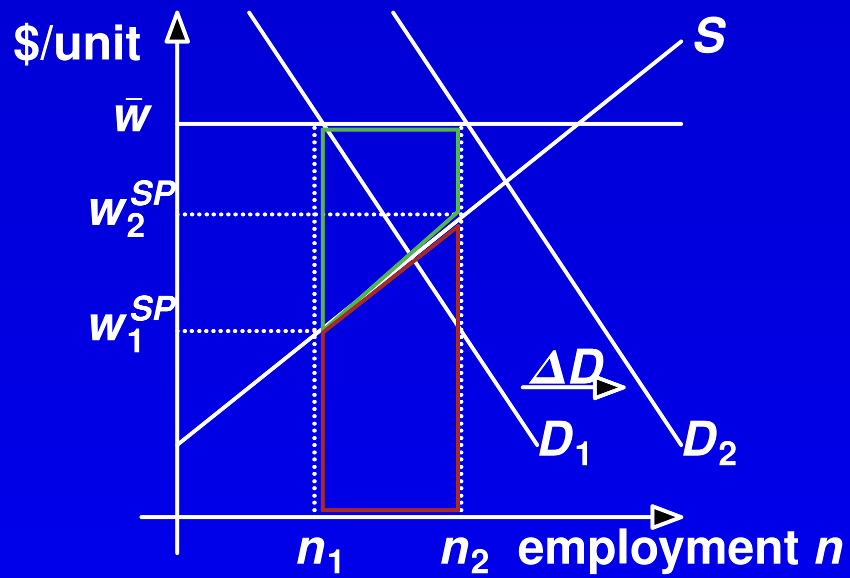

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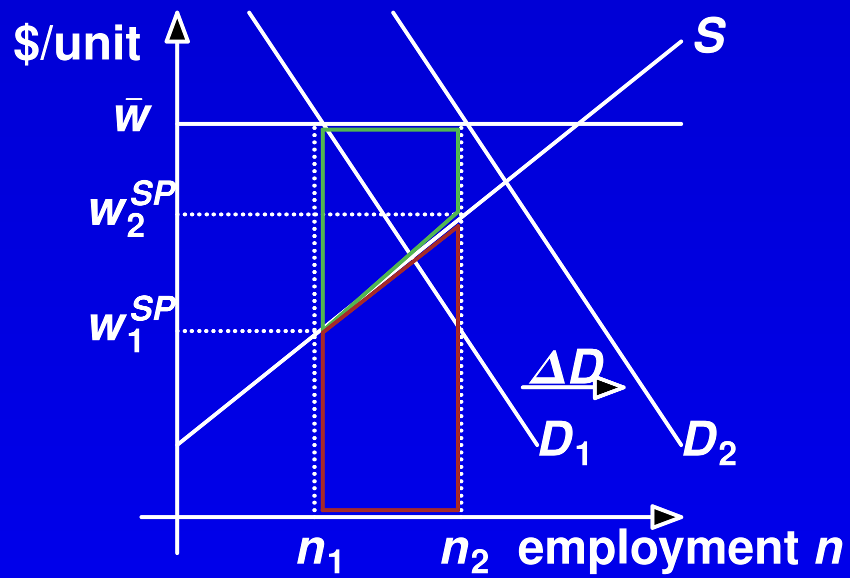

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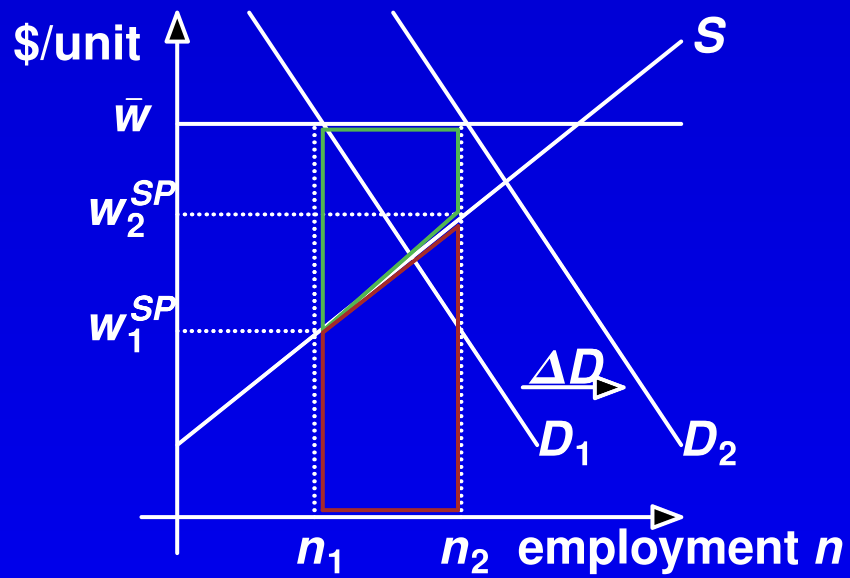
-

Labour (cont.)



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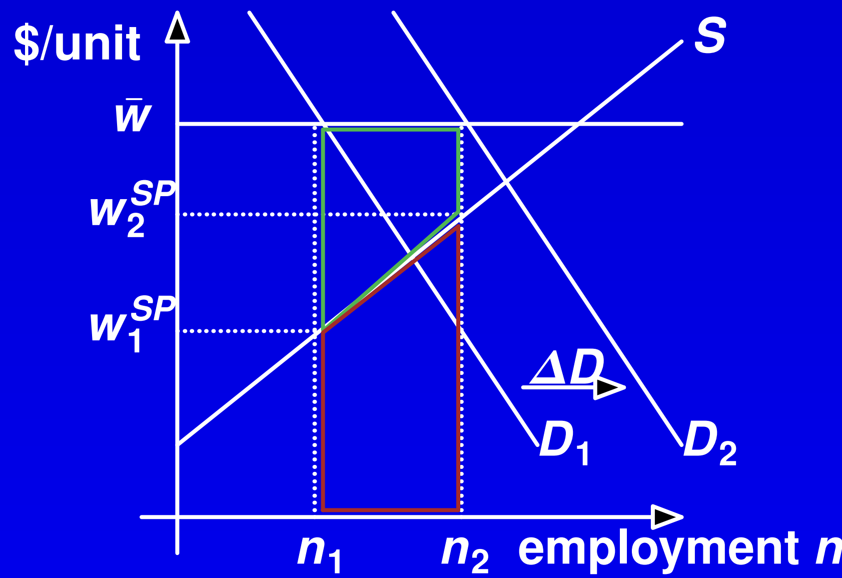

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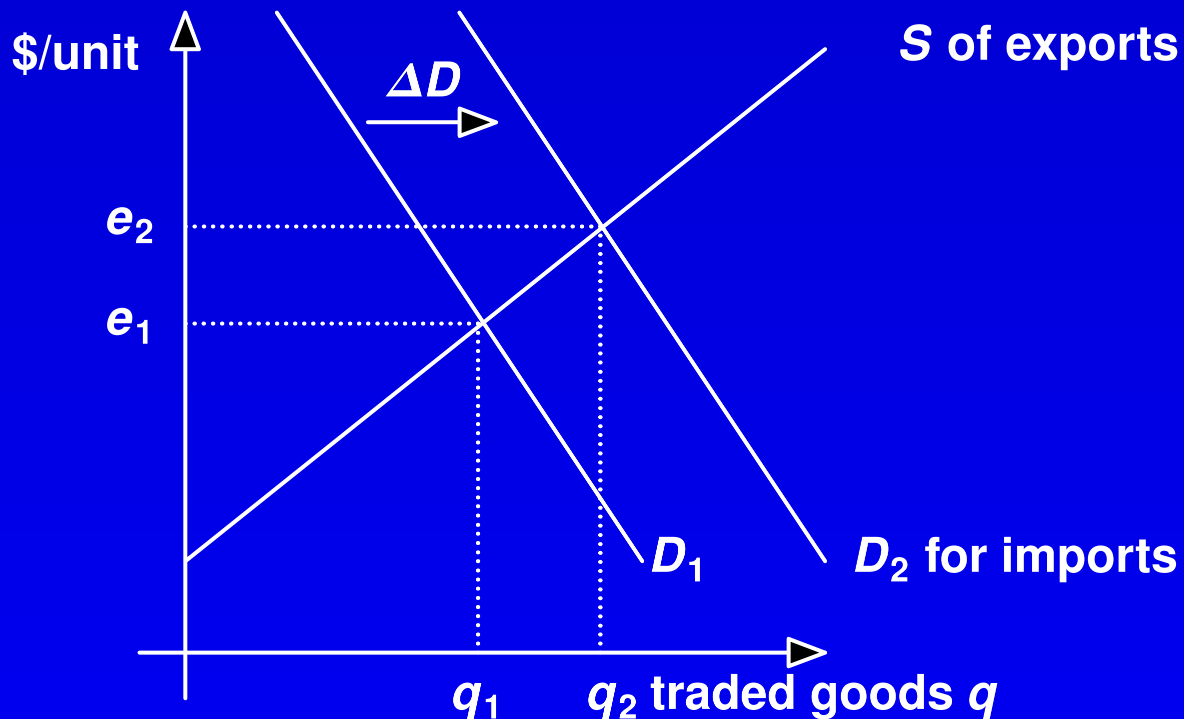
- **The opportunity cost of getting a job is less than $\bar{w}$, which is reflected in the supply curve. $w^{SP} = \frac{1}{2}(w_1^{SP} + w_2^{SP})$**

1.5 Example 5: **Foreign exchange [C&B Ch. 8; FP Ch. 9.2; DoF 3.8]**



Foreign Exchange (cont.)

In the figure:

•

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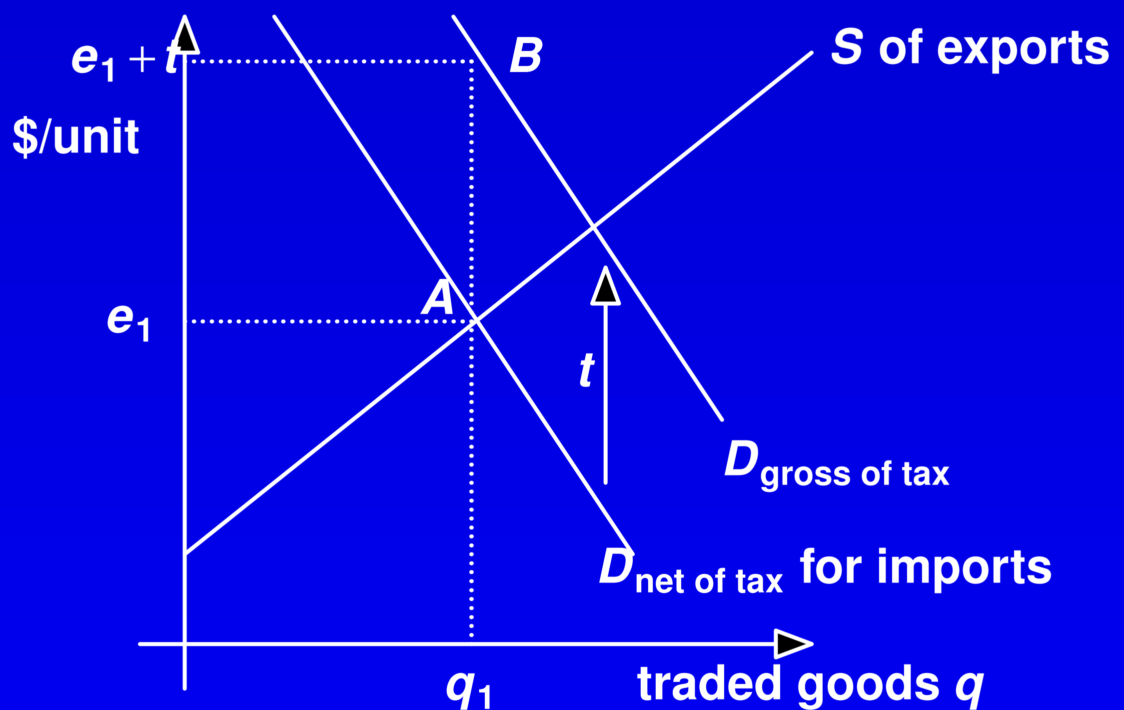
∴ an upwards sloping supply curve *S*.

Foreign Exchange (cont.)



A tariff (tax) of *t* is now imposed on imports

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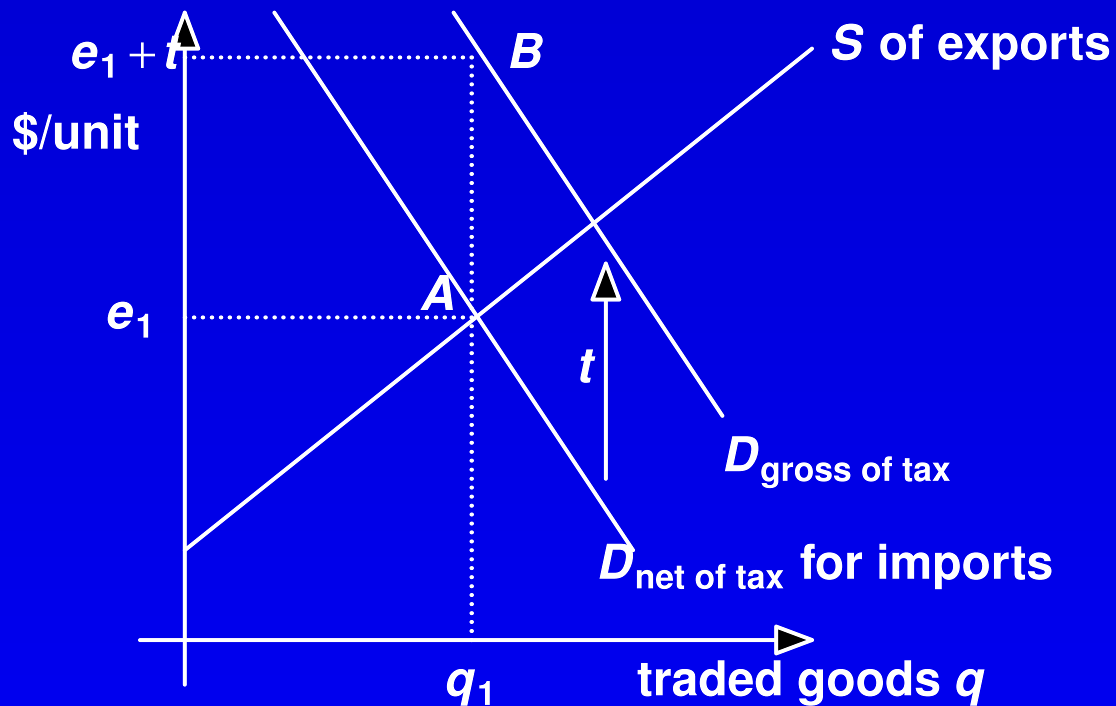
Foreign Exchange (cont.)



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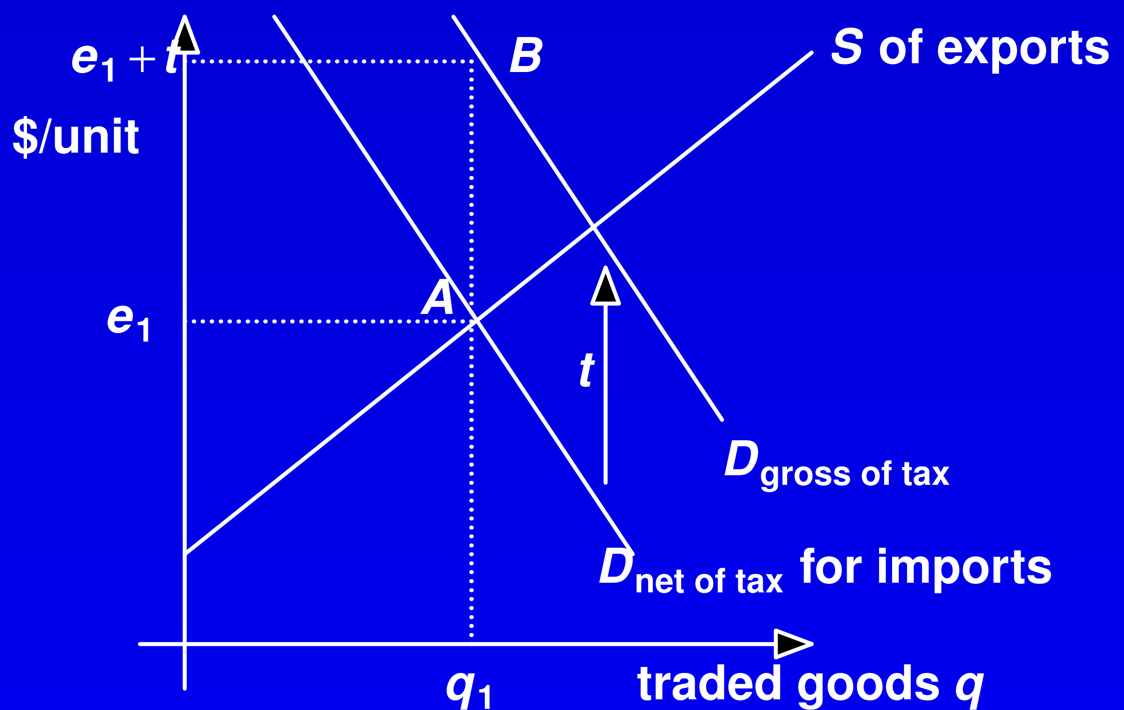

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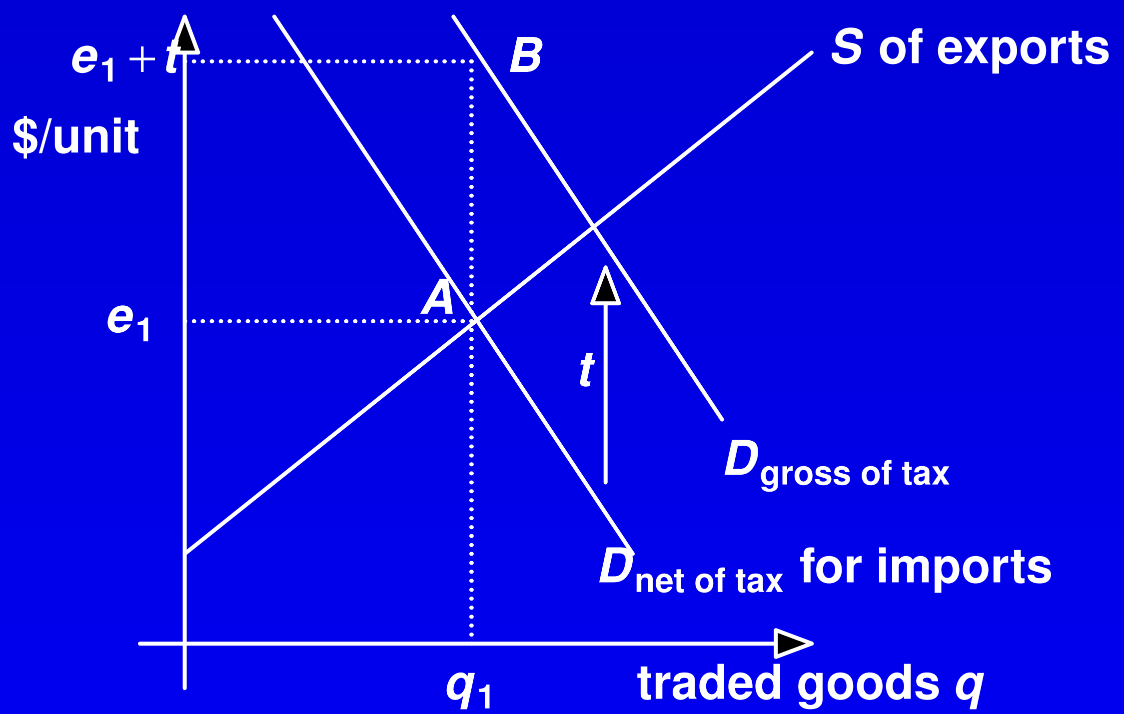
Foreign Exchange (cont.)



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- *A* represents the equilibrium value of exports
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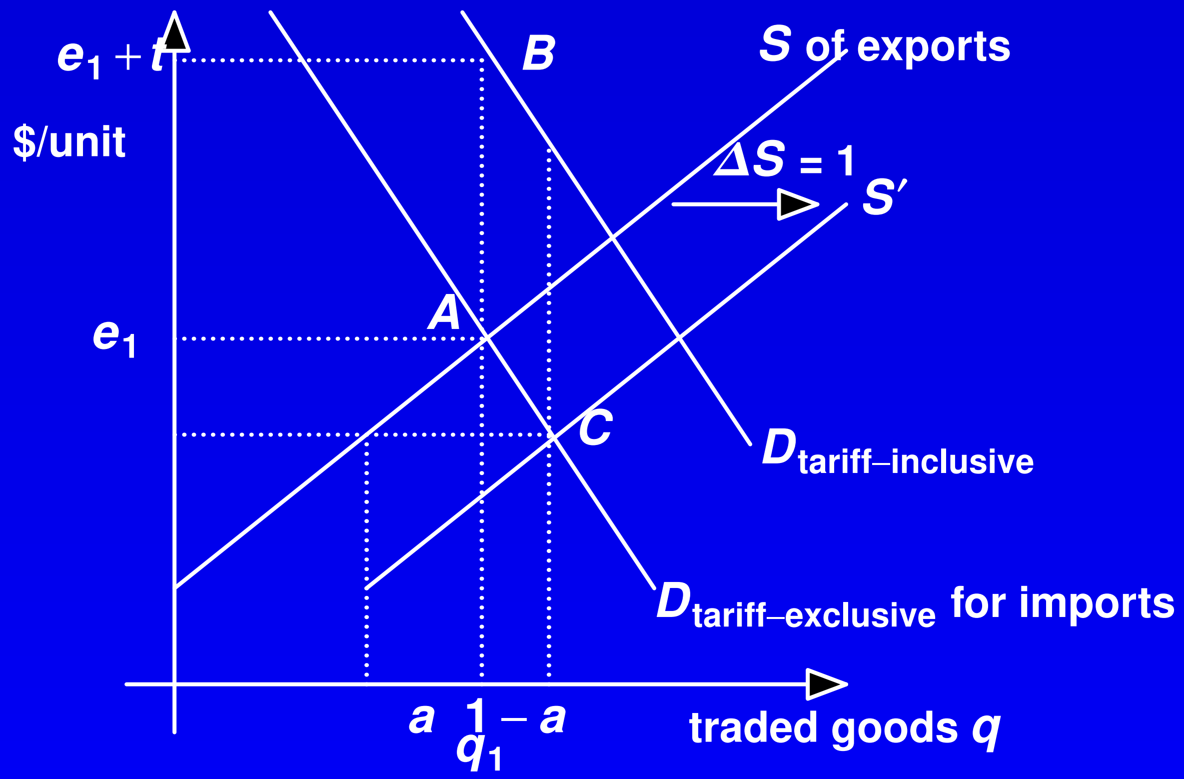
- measured in terms of foreign currency, the value of imports and exports is equal.

Foreign Exchange (cont.) —

Project now increases our supply of foreign exchange ΔS via additional exports. Let $\Delta S = 1$.



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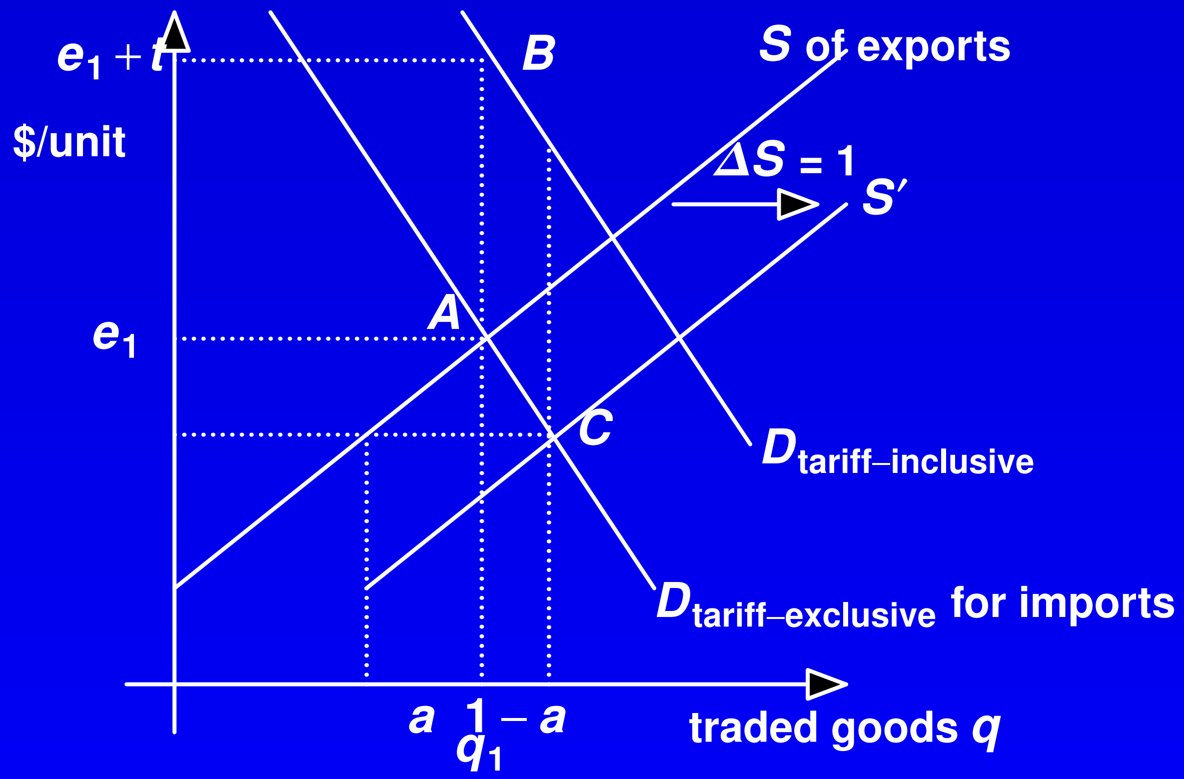

- **this situation is similar to the tax example (p.5-12)**

Foreign Exchange **(cont.) —**

•

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  + $(1 - a)$(pre-tax price of traded goods)
- shadow exchange rate will exceed market exchange rate, since exports are under-valued by the market exchange rate. — The Gregory Thesis or Dutch Disease.

Summary of Lecture 5

This lecture introduced the use of market prices — suitably adjusted to become *shadow prices* which accurately reflect the opportunity cost of the goods and services used by the project, whether produced in response to the project's demand (*incremental*) or bid away from existing uses (*displaced*) — in CBA studies.

Remember: No price change ∴ no displacement

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