Industry Supply

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1 Motivation

We have seen how to derive a firm's supply curve from its marginal cost curve. But in a competitive market there will typically be many firms, so the supply curve the industry presents to the market will be the sum of the supplies of all the individual firms. In this chapter we will investigate the industry supply curve.

2 Industry Supply in the Short-Run

In an industry with a fixed number of firms n, each firm i has its own supply curve, denoted by $S_i(p)$. The market or industry supply curve $S(p)$ is then given by:

$$S(p) = \sum_{i=1}^{n} S_i(p).$$

This means that for any given price p, the total quantity supplied in the market is the sum of the quantities supplied by each individual firm. Graphically, this is represented by a horizontal summation of the individual supply curves. At each price level, you add up the quantities that each firm is willing to supply, which gives you the industry supply.

2.1 Example

Let's consider the following 5 firm supply curves and its corresponding industry supply curve:

$$S_1(p) = \begin{cases} 1.0\,(p-2) & \text{if } p \geq 2, \\ 0 & \text{if } p < 2, \end{cases} \qquad S_2(p) = \begin{cases} 0.8\,(p-3) & \text{if } p \geq 3, \\ 0 & \text{if } p < 3, \end{cases} \qquad S_3(p) = \begin{cases} 1.2\,(p-1) & \text{if } p \geq 1, \\ 0 & \text{if } p < 1, \end{cases} \tag{1}$$

$$S_4(p) = \begin{cases} 1.0\,(p-4) & \text{if } p \geq 4, \\ 0 & \text{if } p < 4, \end{cases} \qquad S_5(p) = \begin{cases} 0.9\,(p-2.5) & \text{if } p \geq 2.5, \\ 0 & \text{if } p < 2.5. \end{cases} \tag{2}$$

Then, the industry supply curve is:

$$S(p) = S_1(p) + S_2(p) + S_3(p) + S_4(p) + S_5(p).$$

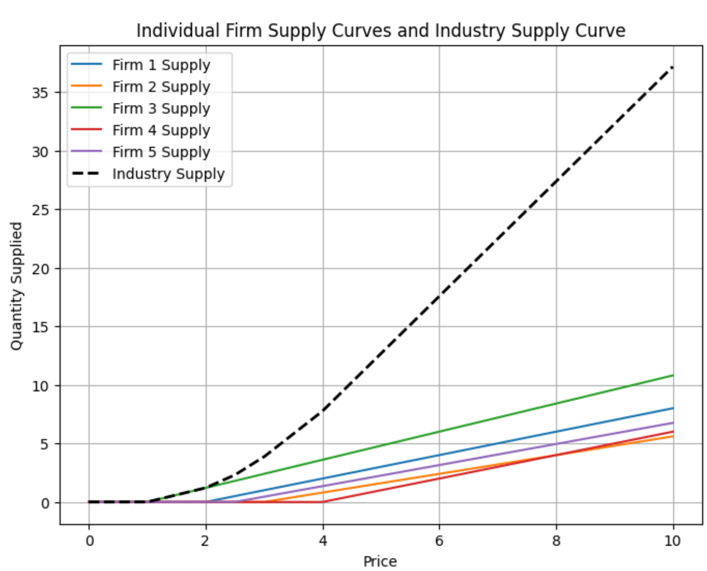
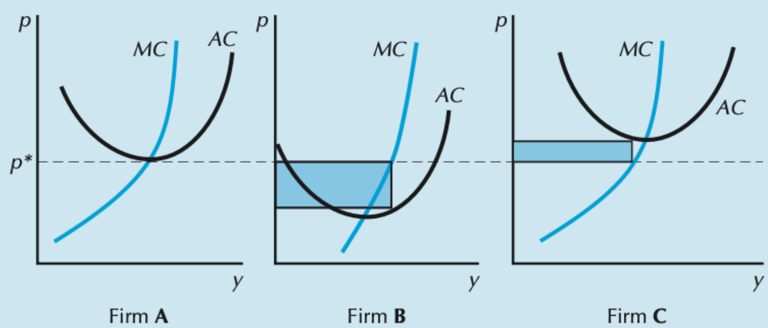


Figure 1: Industry Supply Curve

2.2 Industry Supply Equilibrium and Implications

In the short-run industry equilibrium, the market supply curve intersects the market demand curve at a price p^*. Once p^* is determined, we can analyze each firm's outcome and understand that the optimum price for the industry supply might lead to different profits or losses to the individual firms:

- **Firm A:** Operates where $p^* = \frac{c(y)}{y}$. Rearranging gives $p^* y - c(y) = 0$, meaning the firm earns zero profit.
- **Firm B:** Operates where $p^* > \frac{c(y)}{y}$, so it earns positive profits.
- **Firm C:** Operates where $p^* < \frac{c(y)}{y}$, so it incurs losses.



Short-run equilibrium. An example of a short-run equilibrium with three firms. Firm A is making zero profits, firm B is making positive profits, and firm C is making negative profits, that is, making a loss.

Figure 2: Short-Run Industry Equilibirum Point

Even if a firm like C experiences losses, it will continue operating in the short run as long as p^* exceeds its average variable cost, since producing yields a smaller loss than shutting down completely.

3 Industry Supply in the Long-Run

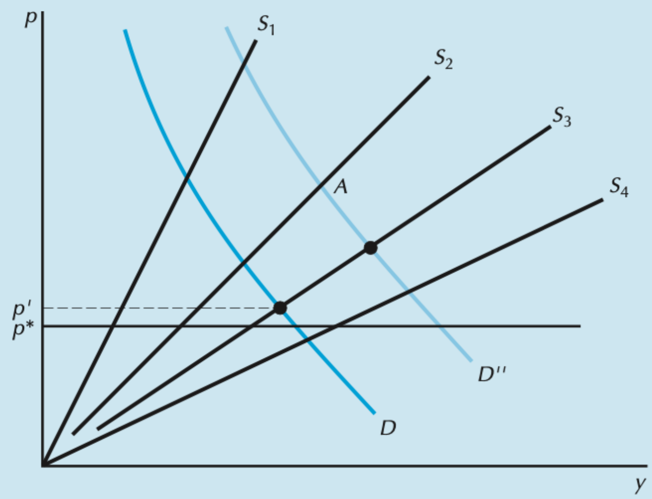
3.1 Multiple Industry Supply Curves

In the long run, firms can adjust their fixed inputs (e.g., plant size, equipment), transitioning from short-run to long-run cost curves. This flexibility allows firms to optimize production and move toward cost efficiency.

Only the portion of a firm's supply curve above its average cost matters in the long run. Firms making losses exit the industry, while those earning profits attract new entrants. This entry and exit process continues until firms earn zero economic profit (i.e., price equals average cost).

- Free Entry: In competitive industries with no restrictions, any profit opportunity invites new firms to enter, ensuring that profits are competed away over time.
- Barriers to Entry: Some industries impose legal restrictions, licenses, or other regulations that prevent new firms from entering freely. These barriers can sustain abnormal profits or losses by limiting competition.

From a libertarian anarcho-capitalist viewpoint, free entry is essential for true market efficiency and individual liberty. Any government-imposed barriers—such as licensing requirements or legal restrictions—are seen as unjustified interferences that hinder competition, distort market signals, and promote cronyism (amiguismo). In



Industry supply curves with free entry. Supply curves for $1, \ldots, 4$ firms. The equilibrium price, p', occurs at the lowest possible intersection of demand and supply such that $p' \geq p^*$.

Figure 3: Industry Supply Curves

an ideal anarcho-capitalist market, unrestricted entry and exit would ensure that only the most efficient firms survive, driving the industry to a natural equilibrium characterized by zero economic profit.

The figure 3 illustrates how free entry determines industry equilibrium when all firms share the same cost function. The lines S_1, S_2, S_3, and S_4 represent total industry supply if exactly 1, 2, 3, or 4 identical firms enter the market. Because the firms are identical, total supply scales proportionally to the number of firms. The horizontal line at p^* is the minimum break-even price, equal to the lowest average cost. If the price drops below p^*, firms incur losses in the long run and exit.

The demand curves D (representing one possible demand curve of the market) and D'' (representing a different demand in the market) show how much consumers are willing to buy at each price. Among the possible intersections, we focus on the demand curve D to illustrate the free-entry argument. The relevant free-entry equilibrium is the lowest intersection at or above p^*, which occurs at p' when three firms are in the market. Fewer than three firms (S_1 or S_2) and still considering demand curve D would yield a higher price and positive profits, attracting entry; more than three firms (S_4) would push the price below p^*, generating losses and causing exit.

3.2 Example

Suppose a firm has an explicit cost function given by

$$C(Q) = 100 + 5Q,$$

where 100\$ is the fixed cost, 5\$ is the variable cost per unit and Q is the quantity produced. Assume the owner's capital investment of \$100 could earn a 10% return elsewhere—that is, an opportunity cost of \$10 per period. In a competitive market in **long-run equilibrium**, firms earn zero economic profit, meaning that total revenue covers both the explicit costs and the opportunity cost.

- **Total Cost Including Opportunity Cost:** The total cost to consider is the sum of explicit cost and opportunity cost:
$$TC_{\text{total}}(Q) = 100 + 5Q + 10.$$
- **Determining Equilibrium Price:** Suppose the firm produces Q units and sells each at price p. In long-run equilibrium, the firm makes zero economic profit, so total revenue equals total cost including

opportunity cost:

$$pQ = 100 + 5Q + 10 \longleftrightarrow p = \frac{110}{Q} + 5.$$

For a particular output level (say, $Q = 10$ units), the equilibrium price would be:

$$p = \frac{110}{10} + 5 = 11 + 5 = 16.$$

- **Profit Calculations:**
  - Accounting Profit: The firm's accounting profit is calculated using explicit costs only:

    $$\text{Accounting Profit} = pQ - (100 + 5Q).$$

    With $Q = 10$ and $p = 16$:

    $$\text{Accounting Profit} = 16(10) - (100 + 5(10)) = 160 - (100 + 50) = 160 - 150 = 10.$$

    This \$10 represents the return on capital.
  - Economic Profit: Once we include the opportunity cost, the economic profit is:

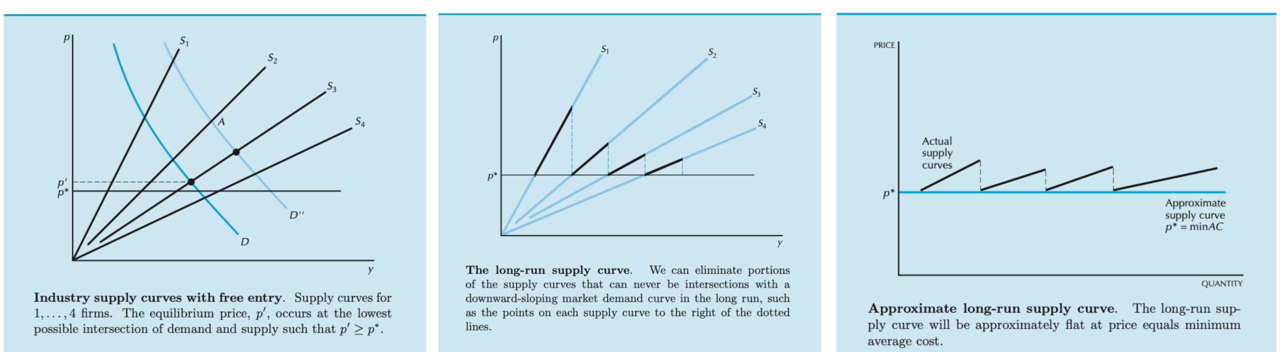
    $$\text{Economic Profit} = \text{Accounting Profit} - \text{Opportunity Cost} = 10 - 10 = 0.$$

Basically, the firm has a zero economic profit and a positive accounting profit. The firm's economic profit is zero because its total revenue just covers all explicit costs plus the normal return on capital (the opportunity cost). This is the equilibrium condition in a competitive market. At the same time, the firm still shows a \$10 accounting profit, which is the normal return the owner expects. This positive figure is why the owner remains in the business—even though, from an economic perspective, the firm is earning exactly what it could earn elsewhere (zero economic profit).

A negative economic profit indicates that the firm is not covering its opportunity cost: the owner's resources (time, money, etc.) could earn a higher return in an alternative use. In other words, the firm is underperforming relative to the broader market. Conversely, a positive economic profit means the firm is doing better than what could be earned in the next-best investment opportunity, so it is outperforming the market.

3.3 The Industtry Supply Curve

To construct the long-run supply curve first we needed to draw separate supply curves for each possible number of firms and then identifying which portions of those curves can actually occur in long-run equilibrium.



Industry supply curves with free entry. Supply curves for $1, \ldots, 4$ firms. The equilibrium price, p', occurs at the lowest possible intersection of demand and supply such that $p' \geq p^*$.

The long-run supply curve. We can eliminate portions of the supply curves that can never be intersections with a downward-sloping market demand curve in the long run, such as the points on each supply curve to the right of the dotted lines.

Approximate long-run supply curve. The long-run supply curve will be approximately flat at price equals minimum average cost.

Figure 4: Industry Supply Curve

Any point below p^*, the minimum average cost, cannot be a long-run position, because firms would incur losses and eventually exit. Moreover, even above p^*, parts of each supply curve can be ruled out by noting that any downward-sloping demand curve would intersect a supply curve with a larger number of firms at a lower price. This process leaves only small "segments" on each curve where equilibrium can occur.

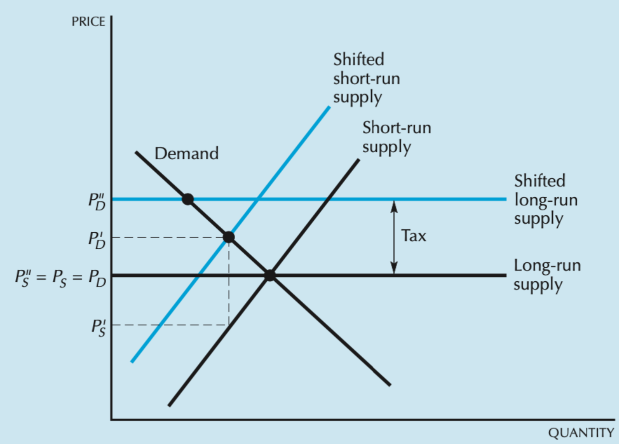
As more firms enter, the industry supply gets flatter because each firm's individual response to a price change is replicated across many firms, making total supply highly responsive to price. With enough firms, these segments become nearly horizontal at p^*, so it is a good approximation to say that the long-run supply curve is flat at the price equal to minimum average cost. In a market with free entry and exit, **any price above p^* attracts entry until profits are driven to zero**, **while any price below p^* forces exit until losses vanish**. Consequently, the industry behaves as though it has constant returns to scale: duplicating an efficient plant is equivalent to adding another identical firm, so the long-run supply curve settles at a horizontal line where price equals minimum average cost.

3.3.1 Taxation in Short & Long Run on Industry

Initially, the industry is in a long-run equilibrium with the following features:

- **Zero Economic Profit:** Each firm's price equals its minimum average cost ($p = \min AC$), so no firm has an incentive to enter or exit.
- **Horizontal Long-Run Supply Curve:** Since the industry allows free entry and exit, the long-run supply curve is flat at $p = \min AC$.

This long-run scenario is represented by the **black short-run** and long-run supply curves. The intersection of the short-run curve with the demand curve determines the optimal price equilibrium $p^* = p_D = p_S$ which matches the preferences of the suppliers (set of firms) and consumers.



Taxation in the short run and long run. In the short run, with a fixed number of firms, the industry supply curve will have an upward slope, so that part of the tax falls on the consumers and part on the firms. In the long run, the industry supply curve will be horizontal so all of the tax falls on the consumers.

Figure 5: Industry Taxation

1. Effects of Imposing the Tax in Short-Run: When a per-unit tax t is imposed on the good, we shift the short-run supply curve (with a fixed number of firms) up by t. This immediate effect occurs because each existing firm, to produce any given quantity, now needs to charge t more per unit to cover the extra cost imposed by the tax. This change is visible with the new prices:
   - **Price to Consumers Rises but by less than t.** Consumers now see a higher price P'_D. However, this increase is not the full t in the short run because the number of firms is still fixed and each tries to pass on some—but not necessarily all—of the tax to consumers. They haven't had time to adjust to the tax.

- **Price to Producers Falls below min AC.** The producers' net price P'_S is $P'_D - t$. Because they were at zero economic profit before the tax, this lower price pushes them into negative economic profit (losses). Despite losses, firms cannot instantly leave (e.g., they may have sunk costs or fixed factors they can't immediately adjust), so they stay in the market temporarily.

2. Long-Run Adjustment As time passes, firms that are now losing money (since $P'_S < \min AC$) will exit the industry if conditions remain unprofitable. Free entry and exit mean:

   - **Exit of Losing Firms** Some firms leave, reducing the total industry supply. This reduction in supply drives the market price up further for consumers.
   - **Re-Establishment of Zero Economic Profit** Eventually, enough firms exit so that the net price received by the remaining firms returns to the minimum average cost ($\min AC = P''_D$). In the long run, producers must get at least $\min AC$ to remain in the market; otherwise, they will exit.
   - **Full Tax Incidence on Consume** Because producers must again earn $\min AC$, the entire tax t is ultimately passed along to consumers in the new long-run equilibrium. Consumers end up paying $P''_D = \min AC + t$, so the long-run supply curve effectively shifts up by t.

Thus, while in the short run the tax burden is split between producers and consumers, in the long run all of the burden shifts to consumers because the only sustainable price for producers is $\min AC$, and any amount above that (i.e., the tax) has to be borne by consumers.

3.3.2 Example

Suppose a firm's total cost function is

$$C(Q) = 100 + 10Q + Q^2,$$

where:

- 100 is a fixed cost,
- $10Q$ is a linear component of variable cost,
- Q^2 captures rising marginal costs as output expands.

By definition, the **Average Cost Function** is:

$$AC(Q) = \frac{C(Q)}{Q} = \frac{100 + 10Q + Q^2}{Q} = \frac{100}{Q} + 10 + Q.$$

To find the output Q that minimizes AC, we take the derivative with respect to Q and set it to zero:

$$\frac{d\,AC(Q)}{dQ} = -\frac{100}{Q^2} + 1 = 0 \longleftrightarrow 1 = \frac{100}{Q^2} \longleftrightarrow Q^2 = 100 \longleftrightarrow Q = 10.$$

We only take the positive root since Q must be nonnegative. Plugging $Q = 10$ back into the $AC(Q)$ formula:

$$\min AC = AC(10) = \frac{100}{10} + 10 + 10 = 10 + 10 + 10 = 30.$$

Hence, **the minimum average cost** is $\boxed{30}$ when the firm produces 10 units of output, which means that:

- At $Q = 10$, the firm is operating at its most efficient scale, incurring an average cost of \$30 per unit.
- If the market is perfectly competitive with free entry and enough demand to let each firm produce 10 units, then in long-run equilibrium, the price p^* will tend toward $\min AC$ = \$30. Any price above \$30 would attract new entrants (driving price back down), and any price below \$30 would force exits (pushing price up).

3.4 Zero Profits, Zero Problem: How Consumers Benefit When Firms Break Even

In a free-entry industry, zero economic profit means that each factor of production—including the owner's time, labor, and capital—is being compensated at its opportunity cost. Positive profits attract new entrants, who compete away those profits until they reach zero, at which point there is no further incentive to enter or exit. Zero profit does not mean no one earns money; rather, it means that all inputs receive the normal returns they could get elsewhere. From an anarcho-capitalist perspective, allowing free entry and exit without state-imposed barriers ensures that entrepreneurial forces can operate unimpeded, driving resources to their most valued uses and preventing artificial monopolies or privileges that maintain profit above the competitive norm.

3.5 Restricted Industry's Entry

When an industry is constrained by a fixed factor -such as limited natural resources, special talent, or legally restricted licenses - free entry in the usual sense may not be possible. Nonetheless, any apparent "positive" profits in the long run simply reflect the fact that the fixed factor is not being valued at its true market (opportunity) cost. If you properly account for the market price of the scarce resource - like farmland or a taxi medallion - what looks like a profit disappears and becomes the rent earned by that fixed factor. In essence, competition among potential entrants will bid up the price of the scarce factor until all remaining profit is exhausted, leaving no net economic profit once that factor's rent is paid.

3.5.1 Farmers

Consider a farming example. Suppose you calculate all explicit production costs—like **seed**, **fertilizer**, **labor**, and **machinery** — and find the farmer earns \$10,000 a year in "profit." At first glance, it looks like the farmer is making positive long-run profits. However, if the farmland is scarce and can be rented to others, its true market rental value is also \$10,000 a year. Once you include that rental value (the opportunity cost of using the land), the farmer's net economic profit is zero. What appeared to be "profit" is actually rent paid to the fixed factor—farmland.

Opportunity cost always reflects the value of a resource in its next best alternative use, regardless of whether the resource is money or land. If you invest money in a business, you forgo the interest or returns you could have earned by investing elsewhere. Similarly, if you use land you already own, you forgo the rent or sale value you could obtain by letting someone else use it.

The logic is the same: the best alternative forgone—whether it's collecting interest on your capital or renting out your land—constitutes the opportunity cost. If you don't account for that cost, it may look like you're making a profit when, in fact, you could have made just as much (or more) by putting the resource to its next-best use.

3.5.2 Taxi Licenses in New York

New York City's taxi industry in 1986 had medallions selling for about \$100,000 each, while drivers themselves earned only around \$400 a week for a 50-hour shift (less than \$8 per hour). The Taxi and Limousine Commission suggested that raising fares would allow drivers to earn more and thus attract better-qualified workers. An economist would argue, however, that the scarcity of taxi medallions—of which only a fixed number exist—means any fare increase would largely be captured by the medallion owners, not by the drivers.

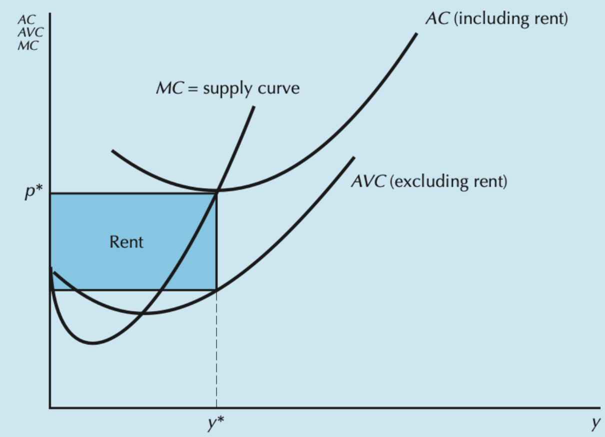
The data shows that medallion owners rented their cabs to drivers for about \$55 per day shift and \$65 per night shift. Over 320 working days and assuming two shifts per day (120\$), the annual lease income amounted to \$38,400. After paying for insurance, depreciation, maintenance, and other operating costs (about \$21,100), the medallion owner still cleared \$17,300, a 17 percent return on the \$100,000 medallion. If fares rose (imagine that now the day shift is 70\$ and night shift \$80, per day would be \$150 and per year $320 \times \$150 = \$48000$) and each cab could earn an additional \$10,000 a year. This extra \$10,000 per year of medallion income then gets "capitalized" into the medallion's market value. Since its net yearly return is now \$27,300, and buyers still look for about a 17% return, the new selling price of the medallion rises to roughly \$160,000 (a return of 17% of \$160,000 is approx \$27,000).

Since drivers' wages are determined in the labor market and they have to lease the medallion at whatever the market rate is, their take-home pay would remain roughly the same. Thus, raising fares does not improve the driver's earnings in a setting where the real bottleneck is the limited supply of medallions.

3.6 Economic Rent

Economic rent is the extra payment to a factor of production beyond what is needed to keep it in use. Mathematically, is defined as:

$$p^* y^* - c_v(y^*) - \text{ rent } = 0 \longleftrightarrow \text{ rent } = p^* y^* - c_v(y^*).$$



Economic rent for land. The area of the box represents the economic rent on the land.

Figure 6: Economic Rent

Some examples to understand better the concept:

- If it costs only \$1 per barrel to pump oil but the market price is far higher, the difference is rent arising from the limited supply of oil in the ground.
- With taxi medallions, they cost almost nothing to create but are extremely valuable because the city strictly limits how many can exist; the scarcity of medallions lets their owners collect rent.
- Farmland is another fixed resource: from the economy's perspective, all land is already there regardless of its price, so any payment to it is rent.

In each case, the market price of the final product—oil, taxi rides, or crops —determines the rent on the fixed factor. Once the rent is correctly counted as a cost of production, there are no "excess" profits left, so firms in competitive markets earn zero economic profit.

4 The Politics of Rent

In many industries, legal restrictions on entry (such as fixed numbers of taxi or liquor licenses) artificially constrain supply, creating economic rents for incumbents. Any attempt to increase the number of licenses threatens the market value of existing ones, so current license-holders have a strong incentive to lobby against liberalization. This political opposition often leads to rent seeking - substantial resources spent on legal fees, lobbying, and public relations - none of which contributes to producing more goods or services. Instead, it merely preserves the incumbents' privilege.

From an anarcho-capitalist viewpoint, these legal restrictions are coercive distortions that prevent true market competition. They block newcomers from offering services, raise prices for consumers, and encourage wasteful lobbying to maintain the status quo. In a market without government-imposed barriers, such economic rents would be competed away naturally, and resources currently spent on lobbying would instead flow into genuine production or innovation.

4.1 Farming the Government: How Subsidies Can Backfire

Historically, the U.S. government has subsidized unplanted farmland primarily to prevent overproduction and stabilize crop prices. If every farmer planted and harvested as much as possible, the resulting surplus could drive prices down so far that many farmers would not cover their costs. By paying farmers to keep a portion of their land idle, the government reduces total supply, helping to keep crop prices (and thus farm incomes) from collapsing. Environmental and conservation considerations—such as preventing soil erosion—have also been cited to justify these programs.

Before 1996, this subsidy system guaranteed a support price for certain crops, paying farmers the difference if the market price fell below that support price. To qualify, a farmer had to keep part of the land out of production. Because large farms stood to benefit the most, new rules in the 1985 Farm Bill tried to cap how much any single large farm could receive. In practice, however, this cap was often circumvented by a strategy called "farming the government".

Large farm owners would "break up" their holdings into smaller parcels and lease them to outside investors, so that each new, smaller "farm" remained under the subsidy cap. Each "farm" then received a payment for the acres left unplanted, without exceeding the cap for any single parcel. This tactic effectively preserved—or even increased—total subsidies flowing back to the original landowners, because the parcels they leased out could each claim the full amount.

A numerical example illustrates this point clearly. Imagine a single farm of 1,000 acres, with a subsidy rate of \$100 per unplanted acre and a subsidy cap of \$20,000 per farm. If the farm remains whole, the maximum it can receive is \$20,000—even though 1,000 acres left idle could theoretically collect \$100,000. By subdividing the land into five smaller farms of 200 acres each, each farm can claim \$20,000 (since 200 acres $\times$ \$100 = \$20,000), for a total of \$100,000 across all parcels. Although this maneuver meets the letter of the law, it clearly defeats the policy's goal of restricting large-farm subsidies. In the end, the government pays \$100,000 instead of \$20,000, and the original owner—through higher land rents—still captures most of the benefit.

From a free-market or libertarian viewpoint, these subsidy programs distort natural price signals and restrict individual choice. Without such intervention, surplus production would drive prices down and ultimately force farmers to become more efficient or shift to other crops. Consumers would benefit from lower prices, and uncompetitive producers would either adapt or exit the market. In reality, however, once subsidy programs are in place, large farmers and landowners have strong incentives to devise ways to maximize payments—demonstrating how well-intentioned policies can be outmaneuvered, leading to higher costs for taxpayers and minimal improvement in overall economic efficiency.

4.2 Energy Policy

4.2.1 Policy Proposal I

In 1974, OPEC, a group of oil-producing nations, coordinated a significant increase in the price of oil. Countries without their own petroleum resources could not substitute domestically produced oil and thus had no choice but to pay the higher international price. Consequently, the costs of goods and services reliant on oil—such as transportation, heating, and plastics—rose as well, leading to inflationary pressures and higher energy costs for both businesses and consumers in those import-dependent nations.

OPEC's coordinated action to raise oil prices fits the classic definition of cartel or oligopoly behavior. In an oligopoly, a small number of producers dominate the market, and by coordinating their supply decisions, they can exert significant influence over prices. OPEC member countries collectively produce a large portion of the world's oil, so restricting output allows them to push prices higher than would prevail under more competitive conditions.

- In the short run, other producers often cannot ramp up output quickly enough to offset OPEC's production cuts, which gives OPEC considerable leverage over world oil prices.
- Over the long run, however, sustained high prices can spur exploration and technological innovation in non-OPEC regions, as well as encourage consumers and firms to reduce their oil usage or switch to alternative energy sources. This natural market response can ultimately limit OPEC's ability to maintain artificially high prices indefinitely.

From a libertarian standpoint, government typically should not intervene to break up or regulate a cartel. Instead, the solution lies in market forces that, over time, can erode a cartel's power:

1. **High Prices Spur Competition:** Sustained high prices make it profitable for new producers to enter or for existing ones to expand production. This new supply can ultimately undermine the cartel's influence.
2. **Substitution and Innovation:** High prices encourage consumers and businesses to adopt more efficient technologies or switch to alternatives (e.g., renewable energy sources). As demand shifts away from the cartel's product, the cartel loses leverage.
3. **No Coercive Barriers:** Libertarians argue that, in the absence of government-imposed barriers (such as licenses or quotas), a cartel's power to maintain high prices is inherently unstable, because free entry and innovation eventually offer consumers better or cheaper substitutes.

The government devised a solution latter known as Two-Tiered Oil Pricing. In the mid-1970s, the U.S. Congress tried to stop "windfall profits" that domestic oil producers would earn from OPEC's price hike. Under the new policy, domestic oil from wells established before 1974 had to be sold at about \$5 per barrel, whereas imported oil continued to sell at around \$15 per barrel, here once again we notice the imposition by law of how to produce/sell goods. The idea was that mixing cheaper domestic oil with more expensive imported oil might push down the average price of oil and, in turn, keep gasoline prices lower for consumers, but this proposal didn't change anything at the end. We recall the difference between the oil firm producers and refiner firms which take the pumped oil and refine it to produce gasoline. This policy actually split the industry into two groups with different incentives:

- Domestic Oil Producers They were effectively forced to sell their oil at \$5 instead of \$15. While not necessarily losing money, they certainly lost the "windfall" gain they could have earned if they sold at the world price.
- Refiners These companies buy crude oil (domestic or imported) and turn it into gasoline. Naturally, refiners use the cheapest oil first, the \$5 domestic oil—before switching to \$15 imported oil once the domestic supply is exhausted. But refiners still price their gasoline based on the cost of the last barrel of crude they use, which is \$15. Hence, the market price for gasoline remains near \$15 oil's marginal cost.

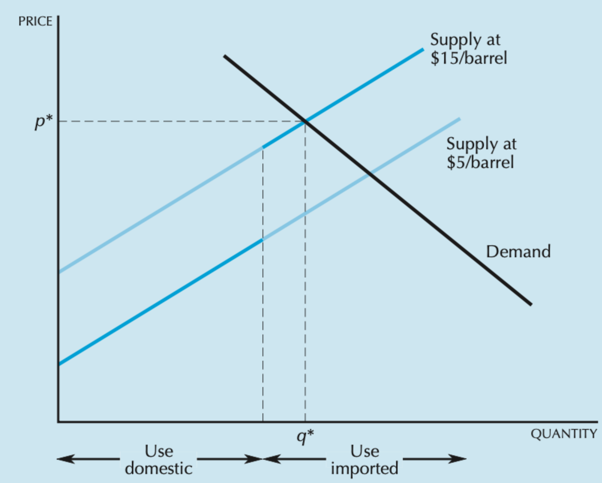
Because consumers purchase finished gasoline, not raw oil, they pay a price determined by that \$15 marginal barrel. So while refiners enjoy a profit margin on any cheap \$5 oil they obtained, consumers do not see lower gas prices. In effect, the policy transferred what would have been domestic producers' extra revenue to the refiners, rather than giving any discount to drivers at the pump. In conclusion, controlling the price of part of the oil supply (the domestic portion) without altering the marginal cost of producing gasoline has no impact on what consumers ultimately pay. Instead, it merely redistributes potential profits within the industry.

4.2.2 Policy Proposal II

After realizing that the two-tiered system alone did not reduce gas prices, the Department of Energy imposed price controls on gasoline. Each refiner now had to set its gasoline price according to the average cost of its oil inputs, which depended on how much cheap domestic oil versus expensive imported oil it could buy. Because different refiners (and different regions) had access to different amounts of domestic oil, the price of gasoline began to vary significantly across the country. Imagining that the domestic oil was \$5 per barrel and imported oil was \$15 per barrel.

- **Refiner in Texas:** Suppose this refiner can source 80% of its oil domestically and 20% from imports. Its average oil cost per barrel is $0.8 \times 5 + 0.2 \times 15 = 4 + 3 = \$7$. After adding refining overhead, it might have a total cost of, say, \$8 per "barrel equivalent" of gasoline. Under the new price-control rules, it can only charge a small markup, so its gasoline might end up at \$9.
- **Refiner in New England:** This refiner can only get 10% domestic oil, with 90% imported. Its average oil cost per barrel is $0.1 \times 5 + 0.9 \times 15 = 0.5 + 13.5 = \$14$. Adding refining overhead yields a total cost of \$15 per barrel equivalent of gasoline. Price controls let it charge only slightly above \$15, so it might sell gasoline at \$16.

Because Texas gasoline ends up far cheaper than New England gasoline, arbitrage opportunities arise: people can buy gas in Texas and resell it in New England for a profit. To stop that, the government restricted shipments of gasoline from low-price to high-price regions, creating regional shortages when demand exceeded the capped supply.



The supply curve for gasoline. Under the two-tiered oil pricing policy, the supply curve of gasoline would be discontinuous, jumping from the lower supply curve to the upper supply curve when the cheaper oil was exhausted.

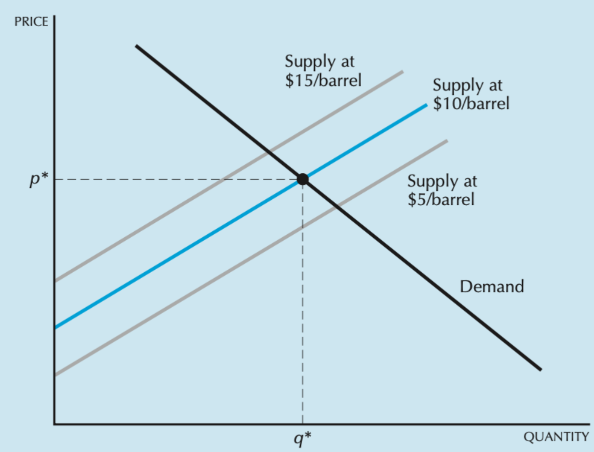
Figure 7: Proposal II

Under a free market, higher-priced regions would import gasoline from lower-priced regions until prices roughly evened out. But with strict price controls and limits on shipping, local supply could run out—leading to empty gas stations in some areas and surpluses in others. These shortages were a new phenomenon: before the policy, refiners freely shipped oil and gasoline around the country, preventing major regional price discrepancies. In a normal market, price differences would be arbitraged away, but under price controls, the government had to impose further regulations to stop reselling, causing even more distortions and gasoline shortages. Both the price control itself and the ban on arbitrage violate free-market principles. Under a truly free system, refiners and distributors could price their products as they see fit, and anyone could buy gasoline in lower-price regions and sell it in higher-price regions. By disallowing that natural market mechanism, the government not only restricts producers' freedom to set prices but also stifles the normal flow of goods that would otherwise help equalize prices across regions. The net effect is to reduce efficiency, create artificial shortages, and ultimately harm consumers who face higher prices or empty gas stations.

4.2.3 Policy Proposal III

Finally, a third solution was proposed. Under the entitlement program, the government dropped its ban on shipping gasoline between regions but kept a form of price control that tied each refiner's allowable gasoline price to its average cost of oil—calculated via a mix of cheap domestic barrels and more expensive imported barrels. Specifically, every time a refiner purchased one barrel of \$15 foreign oil, it was entitled to buy one barrel of \$5 domestic oil, bringing its blended cost to about \$10 per barrel. This scheme forced domestic producers to sell their oil (\$5) below the world market price (\$15), effectively transferring part of their potential "windfall profits" to refiners and, indirectly, to consumers.

From a libertarian perspective, the program still violated market freedom by dictating how American producers must sell their oil. Domestic producers faced an unfair constraint: they could not charge the higher world price of \$15, while foreign producers faced no such restriction. In the short run, this arrangement could indeed lower refiners' marginal costs and reduce gasoline prices for consumers, but at the expense of discouraging U.S. production. Over time, if domestic producers are systematically forced to sell oil at artificially low prices, many will exit the market or reduce output, leading to less domestic supply and making the United States increasingly dependent on foreign oil.



The entitlement program. Under the entitlement program the supply curve of gasoline would lie between the supply curve if all oil were provided at the imported price and the supply curve if all oil were provided at the domestic price.

Figure 8: Proposal III

4.3 Carbon Tax

The carbon tax proposal is a market-based way to reduce total carbon emissions to a desired target T at minimum cost, without the government having to micromanage each firm's emissions. First, we will explain the general idea then we will study an example to better understand it.

- **Each Firm Has Its Own Cost of Reductions.** Every firm can cut its carbon output, but the cost of doing so (e.g., installing cleaner technology) differs among firms. If Firm A can reduce emissions cheaply while Firm B finds it expensive, an efficient solution should make Firm A do more of the reducing, and Firm B should reduce less, but both reduce "proportionally".
- **Minimize Total Cost.** The policy goal is to reduce overall emissions by T units at the lowest total cost across all firms. Economists show that in such an optimum, the marginal cost of cutting one more unit of emissions must be equal across all firms. If Firm A's marginal cost is lower than Firm B's, then A should reduce more (and B less) until they balance out.

- **How a Carbon Tax Works.** Instead of the government telling each firm how much to cut, it imposes a tax t per unit of emissions. Each firm then decides how much to reduce on its own:
  - If a firm can cut an extra unit of emissions at a cost below t, it will do so, because that's cheaper than paying the tax.
  - If cutting an extra unit costs above t, the firm will prefer to emit and pay the tax.

  Over time, the optimal reduction is reached wheneach firm reduces emissions up to the point where its marginal cost of cutting more matches the tax rate t.

- **Reaching the Target T.** The government selects a tax rate t^* so that, when all firms make their individual decisions, the sum of the reductions equals T. The beauty of this system is that firms with cheaper reduction costs do more of the cutting, and firms with more expensive reduction costs do less—naturally achieving the least-cost outcome.

In short, a carbon tax aligns each firm's private incentives with society's goal of reducing total emissions, without the government having to specify each firm's emissions cap. By choosing the right tax rate t^*, total emissions fall to the target T at the lowest overall cost.

4.3.1 Example

Let's consider two firms, and show how a carbon tax can achieve a desired total reduction in emissions T at the lowest possible total cost. We will see why matching each firm's marginal cost of cutting emissions to the tax rate yields an efficient outcome. We suppose that each firm initially emitts 10 units of carbon, for a total of 20. The goal is to reduce overall emissions by $T = 10$ units, so the final total must be $20 - 10 = 10$.

Let x_1 and x_2 be how many units of emissions each firm cuts, with $x_1 + x_2 = 10$. Each firm can reduce emissions at some cost that increases with the number of units reduced. We use quadratic cost functions to reflect increasing difficulty as more emissions are cut:

$$\begin{aligned}
\textbf{Firm 1:}\ c_1(x_1) &= x_1^2 \implies MC_1(x_1) = 2\,x_1. \\
\textbf{Firm 2:}\ c_2(x_2) &= 0.5\,x_2^2 \implies MC_2(x_2) = x_2.
\end{aligned}$$

We want to minimize total cost,

$$\begin{aligned}
&\min_{x_1,\ x_2} \quad c_1(x_1) + c_2(x_2) = x_1^2 + 0.5\,x_2^2, \\
&\text{subject to} \quad x_1 + x_2 = 10.
\end{aligned}$$

By expressing x_2 in terms of x_1, $x_2 = 10 - x_1$, we can rewrite the total cost as:

$$\text{Total Cost} = x_1^2 + 0.5\,(10 - x_1)^2.$$

By standard calculus, we find the cost-minimizing x_1 is 3.33 (one-third of 10), and hence x_2 is 6.67. At this point, marginal costs match:

$$MC_1(3.33) = 2 \times 3.33 \approx 6.67, \quad MC_2(6.67) = 6.67.$$

So **Firm 1** cuts about 3.33 units, and **Firm 2** cuts about 6.67 units, for a total of 10. The total cost of this arrangement is minimized, and we see that it's cheaper for **Firm 2** (which has lower marginal cost early on) to cut more. Here, the carbon tax associated would be 6.67 per unit of emission.

Instead of the government dictating "**Firm 1** must cut 3.33 units, **Firm 2** must cut 6.67," it can impose a carbon tax t on every unit of carbon emitted. Each firm then decides for itself how much to cut. Suppose the government picks $t = 6.67$:

- **Firm 1** chooses x_1 to minimize
$$c_1(x_1) + t(\bar{x_1} - x_1).$$
But effectively, the firm cuts until its marginal cost equals the tax, which is minimizing the previous function:
$$c_1(x_1) + t(\bar{x_1} - x_1) \longleftrightarrow \frac{\partial[c_1(x_1) + t(\bar{x_1} - x_1)]}{\partial x_1} = 0 \longleftrightarrow MC_1(x_1) = t$$
And with the specified values:
$$MC_1(x_1) = 2x_1 = 6.67 \implies x_1 = 3.33.$$

- **Firm 2** does the same, cutting until
$$MC_2(x_2) = x_2 = 6.67 \implies x_2 = 6.67.$$

Together, they reduce $3.33 + 6.67 = 10$ units. Because each firm cuts just until its marginal cost hits the tax rate, we get the exact same allocation that we found by solving the cost-minimization problem directly. Firms with cheaper early cuts (Firm 2) do more of the reduction, while the higher-cost firm (Firm 1) does less.

Libertarian Approach on Ecology & Carbon Taxes

From a libertarian perspective, there are generally two main reactions to carbon taxes. Some libertarians oppose them outright as another form of government intervention that distorts market signals, while others view them as a more efficient, less intrusive alternative to detailed environmental regulations. Let's consider 3 possible approaches to societal worries on environment:

- **Opposition on Principle:** Strict libertarians argue that any government-imposed tax—carbon or otherwise—is an infringement on individual and economic freedom. They maintain that private property rights and voluntary market interactions should be the mechanism for dealing with pollution, rather than a centralized tax scheme.

- **Preference Over Regulation:** A more moderate libertarian stance holds that if society decides pollution needs addressing, then a carbon tax—applied uniformly and transparently—may be preferable to the patchwork of mandates, subsidies, and strict regulations. They see a carbon tax as a market-based approach that allows firms and consumers to choose how to reduce emissions, rather than having government prescribe specific technologies or quotas.

- **Property-Rights Approach:** Some libertarians contend that pollution is best tackled by strengthening private property rights and using courts to resolve harms caused by emissions. They argue that if individuals or communities could sue polluters more easily for damages, the market would price externalities without a blanket government tax.

In short, while most libertarians share a skepticism toward government intervention, there is debate within libertarian circles about whether a carbon tax can be justified as the least bad policy option—or whether it still violates the fundamental principle of voluntary exchange and property rights.

4.4 Cap and Trade

For this subsection we still study how to tax the carbon impact of firms, and compare it to the carbon tax section previously discussed.

Under a cap and trade system, the government first determines how many total emissions it is willing to allow—say 150 million tons of carbon per year—and then issues 150 million tradable licenses, **each representing the right to emit one ton**. Firms that need to emit carbon must hold enough licenses to cover their emissions, and any firm can buy or sell these licenses in a permit market. If firms collectively want to emit more than 150 million tons, the price of permits rises, prompting some firms to cut back rather than pay the higher permit cost; if firms want to emit less, the permit price falls because there is no shortage of licenses. In practice, the government sets the total number of licenses to match a desired environmental target (for example, reducing emissions from 200 million tons to 150 million). Bear in mind that these licenses usually have a fixed lifespan. Compared to a carbon tax, cap and trade fixes the overall quantity of emissions and lets the price fluctuate, while a carbon tax fixes the price of emitting (e.g., $50 per ton) and lets the total emissions fluctuate. Both systems can achieve efficient pollution cuts if designed correctly: cap and trade provides certainty about the maximum emissions level but can lead to volatile permit prices, whereas a carbon tax offers cost certainty for firms but leaves the final emissions level somewhat uncertain.