The Digital Economist

Lecture 8 -- Aggregate Supply and Price Level Determination

LONG RUN AGGREGATE SUPPLY

Aggregate Supply represents the *ability of an economy to produce goods and services*. In the **Long Run** this ability to produce is based on the level of production technology and the availability of factor inputs. This relationship can be written as follows:

$$\mathbf{Y}^*_t = f(L_t, K_t, M_t)$$

where **Y*** is an aggregate measure of **potential output** in a given economy.

In the aggregate,

- L_t represents the quantity and ability of labor input available to the production process,
- K_t represents capital, machinery, transportation equipment, and infrastructure, and
- M_t represents the availability of natural resources and materials for production.

Over time with growth in the availability of factor inputs or technological improvement, the level of potential output is expected to increase. Thus in the Long Run we define the Aggregate Supply (**AS_{LR}**) function as being influenced by those elements included in the production function defining the level of potential output but independent of the price level.

Figure 1 -- Aggregate Production

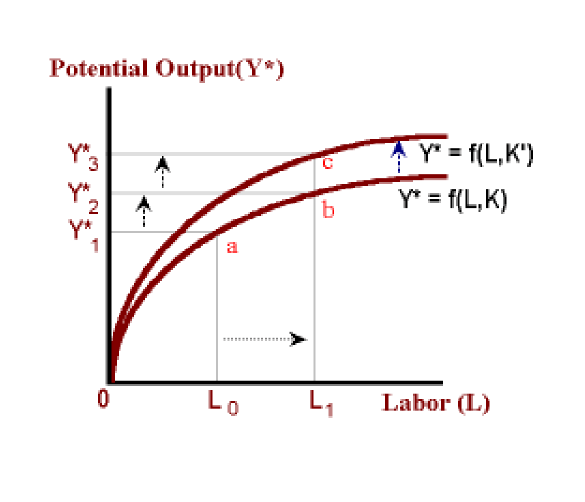
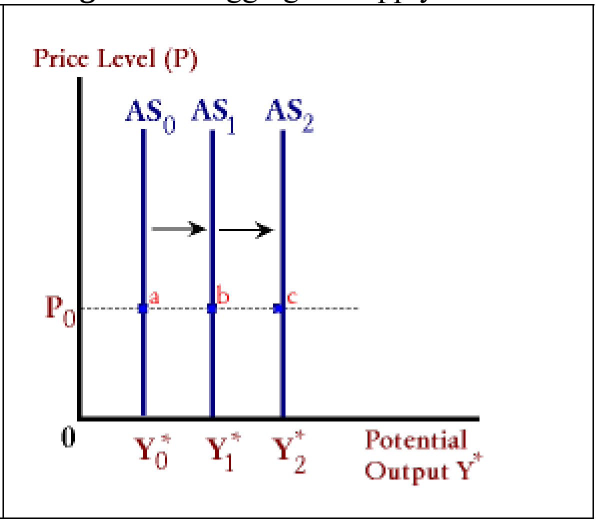


Figure 2 -- Aggregate Supply



In the above diagrams we find that in time period '1' the economy is capable of producing a level of output equal to **Y^*_1**. Growth in the amount of labor ('a' to 'b') available allows for the production of more output with existing levels of technology (**Y^*_1** to **Y^*_2**. More capital (or materials) or improvements in productivity will lead to an even greater potential to produce (**Y^*_2** to **Y^*_3**) at each-and-every price level (i.e., 'b' to 'c').

LABOR SUPPLY DECISIONS

Models of labor supply begin with the assumption that workers choose combinations of hours-worked and income towards the goal of maximizing their level of utility given the time constraint of the number of hours in the day.

In most labor supply models, work is considered to be an undesirable good. Hours not worked are called leisure hours with leisure time being the desirable good. The problem of the worker appears as follows:

maximize **U** = f(Income, Leisure)

s.t.

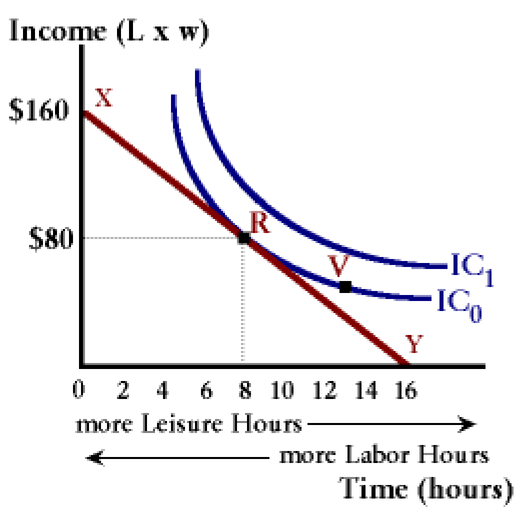
labor hours + leisure hours < 16 waking hours.

The above expression may be read as maximize utility (satisfaction) which is a function of income and leisure hours (both desirable goods) subject to the number of waking hours available in a day". The above model may be expressed in terms of labor hours 'L' as follows:

max **U** = f(**w** L, 16-L),

where '**w**' is the prevailing **real wage** rate. In order to understand the above model, we will use indifference curve analysis to examine the effects of a changing wage rate on the number of labor hours supplied. In figure 3, any point on the curve **IC_o**, represents a combination of income and leisure hours that will give the individual the same level of satisfaction. The individual would be indifferent between point '**R**' and point '**V**' on this curve.

Figure 3 -- A worker optimum



Points on the curve **IC_1** represents combinations (*or bundles*) of income and leisure that give the individual a higher level of satisfaction. The line '**XY**' represents the budget constraint imposed by the number of waking hours available in a day (note: *the horizontal intercept is equal to 16*) with a slope determined by the real wage rate '**w**'.

In any indifference curve model, equilibrium for the individual exists where an indifference curve is just tangent to the budget line. In the diagram above this occurs at point '**R**'. The economic interpretation of this tangency is that this is the point where the marginal rate of substitution 'MRS' between income and leisure time is just equal to the price of leisure time as measured by the real wage rate. This real wage represents the opportunity cost of leisure time in terms of foregone income. An increase in the real wage rate will serve to rotate the budget line upwards (holding the horizontal intercept constant) and allow for a tangency with the higher indifference curve as shown in figures 4 a & b. As wages rise, the worker is better off with the ability to earn more with each hour of work or to maintain current income levels with less work (and thus the ability to consume more leisure time).

Figure 4a -- An increase in wages (strong substitution effect)

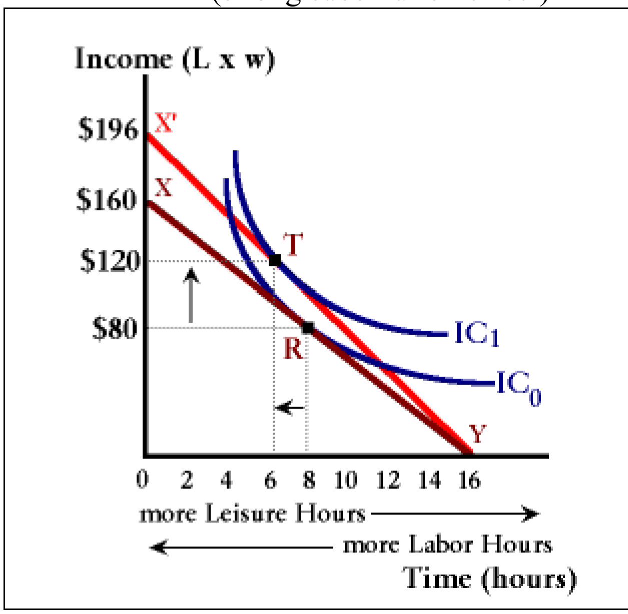
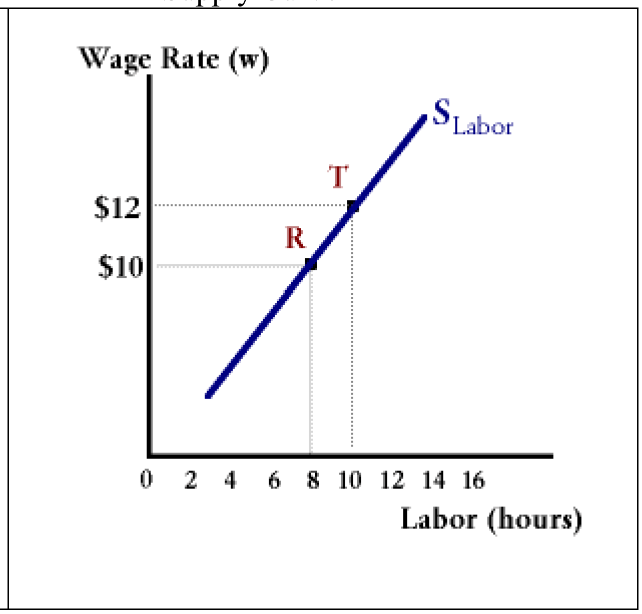


Figure 4b --Corresponding Labor Supply Curve



In figure 2a, an increase in the wage rate from $10 per hour to $12 per hour had the effect of increasing the equilibrium level of income and decreasing the number of leisure hours (work hours increased) as indicated by the solid curve **IC_1**. In this case the worker reduces the amount of leisure time from 8 hours to 6 hours (**R** to **T**).

It could have been the case that the new equilibrium point was defined by the curve **IC_1**' in figures 5 a & b. In this case the worker reduced the number of work hours upon receiving the wage increase. Both cases are theoretically possible due to the relative size of the **income** and **substitution effects**. The total change in leisure hours is called the total effect which is the summation of income and substitution effects. With a wage increase, leisure time becomes relatively more expensive (*in terms of foregone wages*) so the worker will substitute away from leisure time -- the substitution effect is negative for a wage increase.

Figure 5a -- An increase in wages (*strong income effect*)

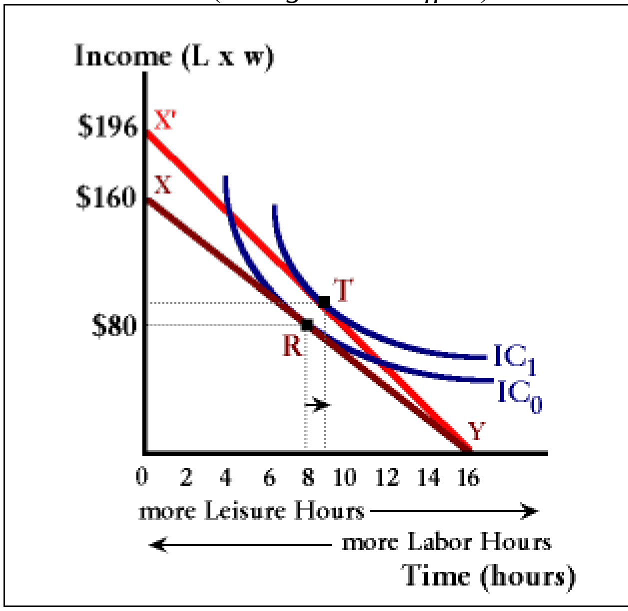
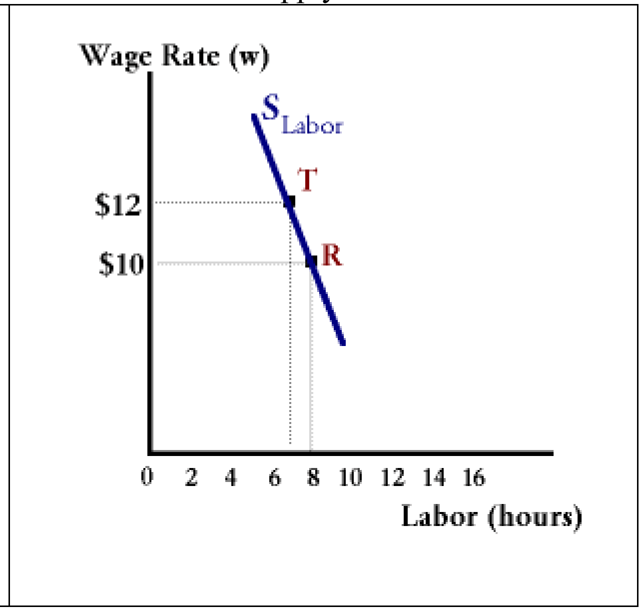


Figure 5b -- Corresponding Labor Supply Curve



Additionally, as income rises with the wage increase individuals will want to consume more leisure assuming that this good is a normal good -- the income effect for a wage increase is always positive. If the positive income effect is less than the negative substitution effect, the total effect will be negative and the worker will consume less leisure and more work. This will lead to a "normal" upward sloping labor supply curve (*the relationship between the real wage and labor hours supplied*) as seen in figure 4b. If the income effect is greater than the substitution effect, the worker will consume more leisure (a positive total effect) and less work. In this case the labor supply curve will be "backward-bending" or represent an inverse relationship between the wage rate and labor hours supplied (see Figure 5b).

Empirical studies have concluded that, when we aggregate among all workers, the labor supply curve is upward sloping and fairly steep (that is, *labor supply decisions are highly wage inelastic or insensitive to changes in the wage rate*). Stronger influences on labor supply come about with changes in population, labor force participation rates (demographic changes) and immigration flows.

LABOR MARKET EQUILIBRIUM

If we assume that labor supply is positively related to the real wage:

$$L_s = f_{[+]}(\mathbf{w})$$

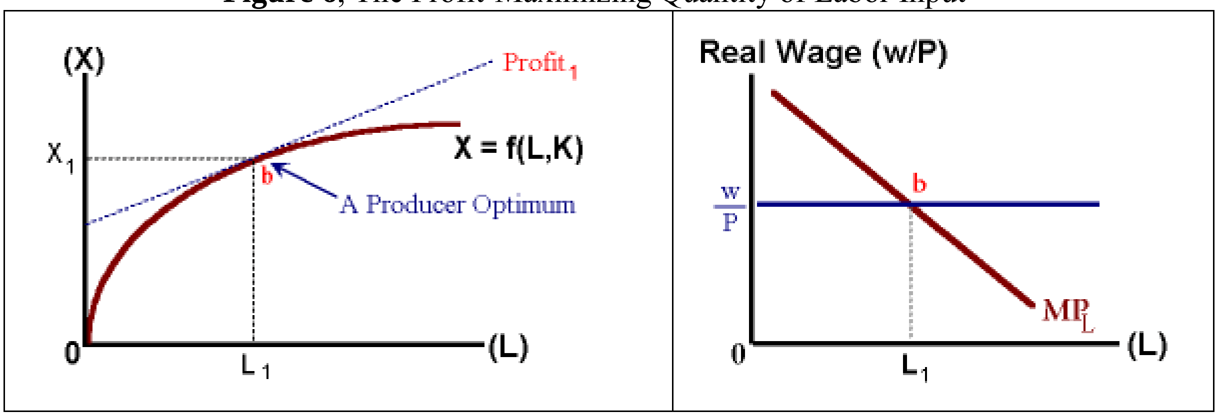
then any increase in labor demand 'L_d' will lead to higher equilibrium quantities of labor being made available to labor markets at higher real wages. However, before we discuss equilibrium conditions, we need to take a look at the determinants of labor demand.

Labor Demand

The demand for labor results from producers seeking labor input as one of several factor inputs into the production process: X = f(L,K,M).

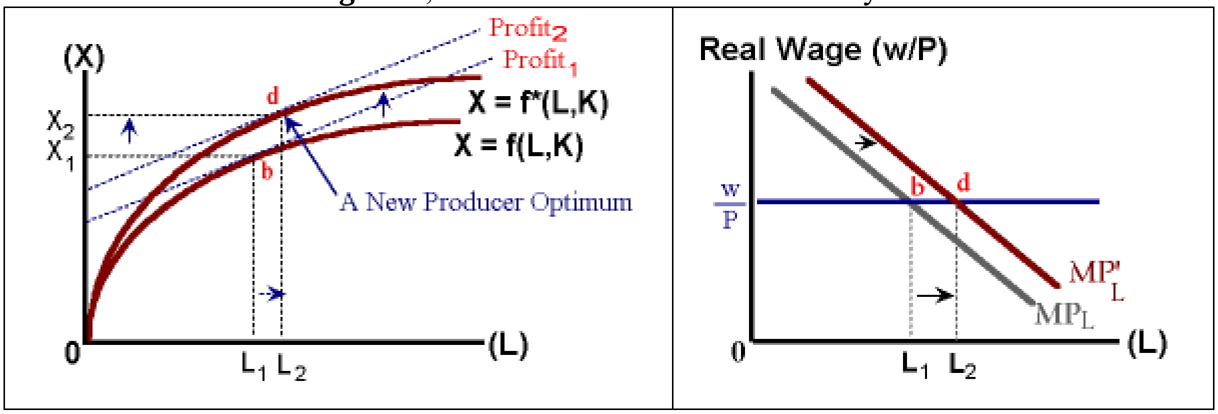
Referring back to **lecture 3**, we find that the profit maximizing firm will hire labor up to the point where the marginal productivity of the last worker hired 'MP_L' is just equal to the real wage 'w/P_x'. This is shown graphically in the diagram below left by the tangency between the production function (*slope* = MP_L) and the dotted iso-profit line (*slope* = w/P_x) or in the diagram below right by the intersection of **MP_L** and **w/P** as defined by point '**b**':

Figure 6, The Profit-Maximizing Quantity of Labor Input



Changes in labor productivity, either due to technological improvement or by the addition of more capital per worker will lead to an upward shift in the production function (more output for each unit of labor input) and an outward shift in **MP_L** (*each worker is more productive at the margin*). Holding the real wage constant will result in more labor being hired and more output being produced as shown in the diagrams below:

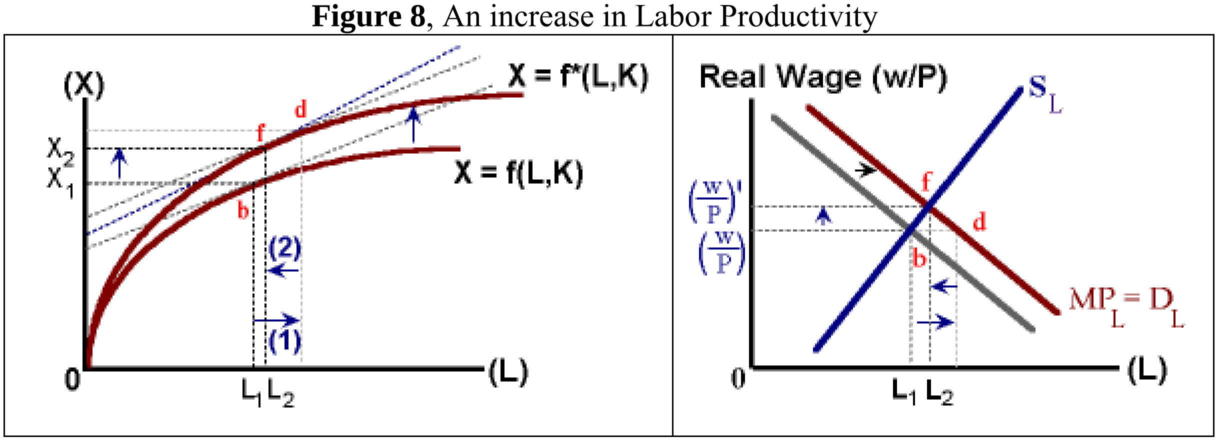
Figure 7, An Increase in Labor Productivity



In reality, this type of shock when matched with an upward sloping labor supply curve should lead to an increase in the real wage. This higher real wage is necessary to induce more workers into the labor market or to induce existing workers to work longer hours (*in both cases sacrificing leisure time*). This is shown below in figure 8. The increase in productivity shifts the production function upwards and the marginal product of labor outwards (b → d). However, this excess demand for labor leads to an increase in nominal and real wages leading to an upward movement along the new labor demand curve in the right diagram and a counter-clockwise rotation in the iso-profit line in the left diagram (d → f).

Thus a complete model of this type of shock (*an increase in productivity*) will lead to a larger equilibrium quantity of labor ($\mathbf{L_1} \rightarrow \mathbf{L_2}$) and higher real wages.

Figure 8, An increase in Labor Productivity



Other types of shocks that may affect labor markets would be in labor supply either due to changes in labor force participation rates or changes in immigration patterns. For example, a relaxation of immigration policies (i.e., *the H-visa program of the late 1990's in support of the "tech" boom*) would shift labor supply outwards putting downward pressure on the real wage. This decline in real labor costs might lead business firms to hire more labor, increasing the level of production and increasing the output of the economy.

PRICE LEVEL DETERMINATION

In the aggregate economy the price level is determined by the balance (*or imbalance*) between the *ability to produce* goods and services and the ability to spend to acquire those same goods (see Figure 6). The ability to produce is summarized by the long run Aggregate Supply (**AS_{LR}**) function based on the level of technology and availability of factor inputs. The *ability to spend* is summarized by the Aggregate Demand (**AD**) relationship that represents combinations of price and output levels for a given level of Nominal GDP. As prices rise, purchasing power falls, and thus the quantity of goods and services that can be acquired with a given nominal income declines. Aggregate Demand represents this inverse relationship between the price level and purchasing power.

$$\mathbf{AD} = \{Y^R{}_t, P_t \, \varepsilon \, \mathbf{R}^2 \mid Y^R{}_t = Y_t^{Nominal}/P_t\}$$

A supply-side shock, such as an increase in labor productivity, would shift **AS_{LR}** outward demonstrating a greater potential to produce at each and every price level. We can see this change in figure 9. This shock, over a sufficient period of time, creates an excess supply of goods ($Y^* > Y^R$) and exerts downward pressure on the price level. As prices fall, purchasing power increase reflecting an increase in the ability to spend (i.e., a movement from **A** to **B**). The net result is an increase in output and a lower aggregate price level.

Figure 9
Aggregate Supply and Aggregate Demand

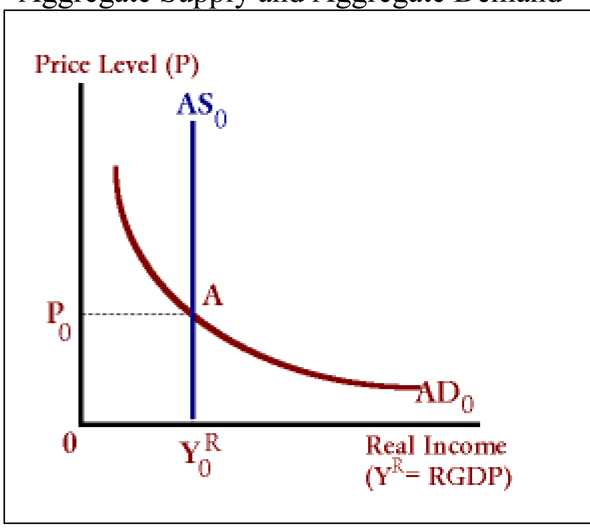
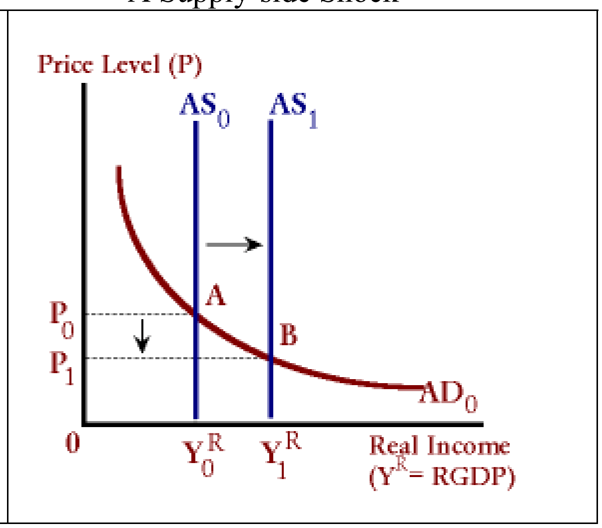
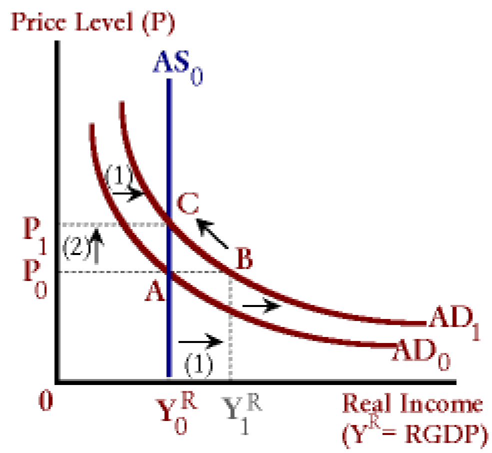


Figure 10
A Supply-side Shock



In figure 11, we have a demand-side shock perhaps the result of an increase in government spending (*expansionary fiscal policy*). This shock shifts the **AD** relation outward. Initially there is an **excess demand for goods** (**A** to **B**) evidenced by a depletion of inventories. Given that potential output has not changed, in time this excess demand will cause the price level to increase. As prices increase, purchasing power falls and the ability to spend decreases (**B** to **C**). The net result of this shock is an increase in the price level with no change in output or real spending.

Figure 11, A Demand-side Shock



Graphically the reaction of the price level to demand-side or supply-side shocks is easy to model. However the actual process of adjustment is a bit more complicated. In cases where the *ability to spend* exceeds the *ability of the economy to produce goods*, depleted inventories are only replenished through the acquisition of scarce factor inputs -- factor inputs that are fully employed elsewhere in the economy. Attempts to replenish these inventories will require attracting resources from alternative uses by bidding up wages and factor prices. It is this process of bidding for resources and the impact on the price level that requires additional discussion.

PRICE ADJUSTMENT AND THE REAL GDP / OUTPUT GAP

Given that wages are a large part of national income and thus represent the bulk of production costs, changes in prices are often strongly related to changes in wage rates.

$$\text{Costs} = f(\text{wages})$$

and

$$\text{Prices} = \alpha[\text{Costs}]$$

where 'α' is some **markup** factor ($\alpha > 1.0$) depending on the degree of competition in different industries. If business firms attempt to increase production such that, in the aggregate, production levels exceed the potential of the domestic economy, wages will be bid upward as firms attempt to attract labor from other firms. These wage increases will be passed on to the consumer via the markup in the form of higher prices. Or as:

$$Y > Y^* \rightarrow w\uparrow \quad \text{and thus } P\uparrow.$$

The above two relationships allow for the establishment of a relationship between the level of output and changes in the price level.

The Phillips Curve
In 1958 A.W. Phillips established an empirical relationship between wage inflation and the gap between the actual level of unemployment 'u' and the natural rate of unemployment 'u*' The **natural rate of unemployment** is defined as that rate where there is no upward nor downward pressure on wage rates. A rate of unemployment 'u_{high}' above this natural rate would imply slack in labor markets such that wages would be expected to fall or, at least, not rise. A rate of unemployment 'u_{low}' below the natural rate would signal tight labor markets such that wages are being bid upwards as employers attempt to fill out the ranks of their required labor force. The parameter 'β' represents that rate at which wages adjust to tightness or slack in labor markets.

$$\%\Delta w = -\beta(u-u^*)$$

if $u > u^*$ then

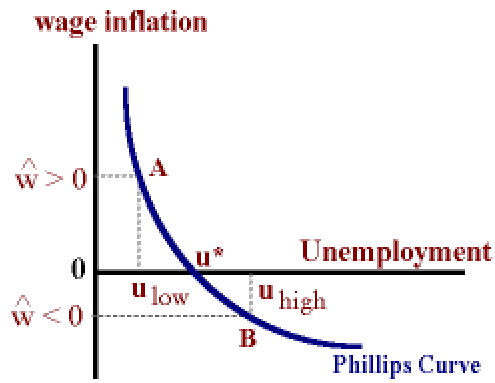
$$\%\Delta w < 0$$

and wage deflation exists.
Otherwise if $u < u^*$,

$$\%\Delta w > 0,$$

we have wage inflation.

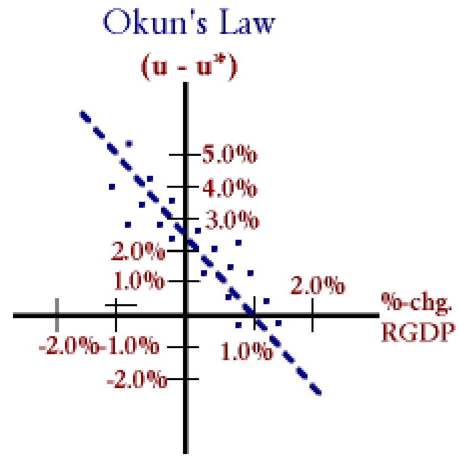
Figure 9, The Phillips Curve



Okun's Law
A third empirical relationship is **Okun's law** which states that for every percentage point 'u' exceeds 'u*', growth in Real GDP is 2.5% below the rate of growth in Potential Output in the U.S. economy.

$$\%\Delta Y^R - \%\Delta Y^* = -2.5(u - u^*)$$

Figure 10, Okun's Law



This expression can be rewritten as:

$$(u - u^*) = \Phi(\%\Delta Y^R - \%\Delta Y^*)$$

where $\Phi = -(1 / 2.5)$.

Finally given our markup equation:

$$\text{Prices} = \alpha(\text{wages})$$

and combining the following three expressions:

- $\%\Delta P = \alpha\%\Delta w$
- $\%\Delta w = -\beta(u-u^*)$ and
- $(u-u^*) = -\Phi(\%\Delta Y^R - \%\Delta Y^*)$

we have,

$$\%\Delta P = [\alpha(-\beta)(-\Phi(\%\Delta Y^R - \%\Delta Y^*)]$$

defining: $\theta = \alpha(-\beta)\Phi$,

$$\%\Delta P = \theta(\%\Delta Y^R - \%\Delta Y^*)$$

In this final expression, we find that changes in the price level are related to the difference between the ability to buy goods and services in a particular economy Y^R and the ability to produce those goods and services Y^*.

If:

$$\%\Delta Y^R_t > \%\Delta Y^*$$

then

$$\%\Delta P > 0$$

and inflationary pressure exists in the economy. If the opposite is true, we will then observe deflationary pressure in the economy.

PRICE EXPECTATIONS and SHORT RUN AGGREGATE SUPPLY

A different approach to understanding aggregate supply is in the form of the **Lucas Aggregate Supply** equation. This equation is derived from individual supply equations (over 'n' goods) for different economic agents based on actual prices and expected prices:

$$Y^i_t = Y^*_t + b(P^i_t - E[P^i_t]) \text{ -- } \textit{for } i = 1 \ldots n \textit{ goods.}$$

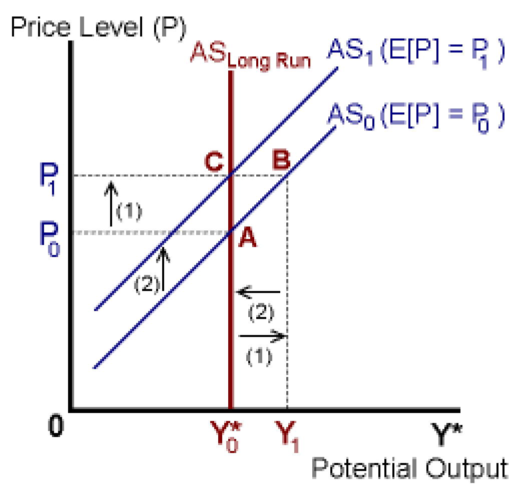
Expectations about the agent's own price are derived by that agent based on observations about the general price level: $E[P^i_t] = f(P_t)$. If the firm's actual price 'P^i_t' exceeds the expected price value $E[P^i_t]$ then this is situation is characterized by the agent as an increase in the relative price for the agent's product or services (the agent perceives that the market is placing a higher value on its product) and thus this agent will devote more resources to production such that $Y^i_t > Y^*_0$ where Y* represents some normal level of output by that agent.

Aggregating over all agents in the economy, we have a **short run** aggregate supply function that states that actual output will exceed the normal level of output ($\mathbf{Y_1} > \mathbf{Y^*_0}$ *in the diagram below*) when the actual price level exceeds the expected price level ($\mathbf{P_1} > \mathbf{P_0}$) perhaps due to some unanticipated shock to the economy or monetary system. An equation for short-run Aggregate Supply (**AS**) can be defined as:

$$\mathbf{Y_t} = \mathbf{Y^*_0} + \beta(\mathbf{P_t} - E[\mathbf{P_t}])$$

and shown in the diagram below:

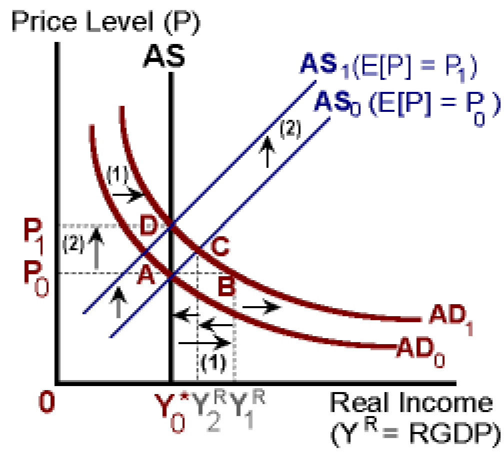
Figure 11 -- Lucas Aggregate Supply



In time these economic agents will observe that the price of their particular good has not changed <u>relative</u> to the price of other goods in the economy. These agents will discover that they have made incorrect production decisions (*i.e., overproduced*) and make the necessary corrections. This involves an upward revision of their price expectations ($P_t = E[P_t]$) and a reduction in output (**B** to **C** *in the above diagram*). Even though output temporarily exceeded the potential of the economy, in the long run the level of output will return to this potential level ($\mathbf{Y_t} = \mathbf{Y^*_0}$).

Given an unanticipated expansionary fiscal or monetary policy shock, aggregate demand will shift outward as defined in traditional demand-side models (**A** to **B** below). This increase in demand-side spending will put upward pressure on the general price level and the shift in demand leads to a movement along the upward-sloping aggregate supply schedule '$\mathbf{AS_0}$' (**A** to **C**). As prices increase, purchasing power declines (**B** to **C**). This increase in the price level is interpreted by different economic agents as an increase in the relative price for their product or service. These agents respond by increasing their level of output. As time passes, these economic agents find that the price increase represented an increase in the absolute price level rather than an increase in relative prices. They adjust their price expectations accordingly as shown by an inward shift in aggregate supply (**AS_0** to **AS_1**). Output declines, prices increase and purchasing power is further reduced. (**C** to **D**):

Figure 12, a Demand-Side Expansionary Shock



These agents were "tricked" into producing more output such that they find that they have overproduced. The response to this information about the absolute price level leads to an updating in the agents' expectation about general prices (i.e., $E[P^i_t]$ are adjusted upwards). Given this update in price expectations, the aggregate supply function shifts upwards such that over time the actual level of output **Y*** remains unchanged. However, the general price level has increased. The outward demand-side shift leads to a temporary increase in output until price expectations are updated to allow for a reactionary upward shift in aggregate supply.

In summary, the only way a change in the price level can affect supply (*production*) decisions in an aggregate economy is if the price level '**P**' exceeds that expected '**E[P]**' by individual producers. Ultimately changes in (*potential*) output are the result of changes in the available of resources or productivity (and technology).

Be sure that you understand the following concepts:

- The Aggregate Production Function
- Factor Inputs
- Aggregate Output
- Potential Output
- Long Run Aggregate Supply
- Labor Supply
- Income and Substitution Effects
- Backward-bending Labor Supply
- Real GDP
- Aggregate Demand
- Inventory Depletions / Accumulation
- Output Gap
- the Price Level
- Supply-side Shocks
- Demand-side Shocks
- the Markup
- the Rate of Unemployment
- the Natural Rate of Unemployment
- The Phillips Curve
- Okun's Law
- Lucas Aggregate Supply
- Price Expectations