Finance 581: Arbitrage and Purchasing Power Parity Conditions
Module 5: Lecture 1
[Speaker: Sheen Liu]

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>MODULE 5
>Arbitrage and
>Purchasing Power Parity Conditions

[Sheen Liu]: Managers of multinational firms, international portfolio investors, importers, exporters, must deal with the foreign exchange rates every day. They definitely want to know the answer to the fundamental question: What are the relations between exchange rates? What are the determinants of exchange rates? The economic theories that link exchange rates, price levels, and interest rates together are called the international parity conditions. These international parity conditions form the core of the financial theory that is unique to international finance. In economics and finance there is a powerful market force behind the relations between currencies and behind the international parity conditions. The force is arbitrage [*Emphasized*]. Arbitrage is the practice of taking advantages of a profit from the difference between the market prices. When used by academics, arbitrage becomes a powerful concept to derive the relations between currencies and the international parity conditions. This module will review the concept of arbitrage first then use the arbitrage argument to derive one of the international parity conditions, the purchasing power parity condition which relates exchange rates and currencies to the price levels and inflation rates of the two countries [*Emphasized*].

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>OULTINE
>- Review: Arbitrage
>- Chapter 6 Foreign Exchange Market
> - Cross Rates
> - Intermarket Arbitrage
>- Chapter 7 International Parity Conditions
> - Price and Exchange Rate

[Sheen Liu]: In this module, we'll first review the concept of arbitrage [*Emphasized*]. Some currency pairs are not actively traded to their exchange rate is determined through their relation to a widely traded third currency. So their exchange rate established this way is the cross rate [*Emphasized*]. We're using the argument of intermarket arbitrage to determine cross rates [*Emphasized*]. Next we use the arbitrage argument to justify international purchasing power parity and relative purchasing power parity [*Emphasized*]. Purchasing power parity relates exchange rates to price levels of two countries. Purchasing power parity with the

balance of payments and interest rate parity is a widely used method of forecasting exchange rates [*Emphasized*].

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> REVIEW: ARBITRAGE
> - Arbitrage is "a money machine".
>   1. Has no risk
>   2. Does require investment.

[Sheen Liu]: What is an arbitrage? An arbitrage is a transaction that makes a risk free profit at zero cost. In other words, arbitrage is a money machine. Whenever there is an arbitrage opportunity, you can make money without taking any risk and without investment [*Emphasized*]. Arbitrage must satisfy two conditions. The first is making money without taking risk and the second is making money without investment [*Emphasized*]. You may hit the jackpot in Las Vegas and make a lot of money, but it's not arbitrage. You have to take the risk of losing your money to hit jackpot. The first condition is not satisfied. You may invest your money into Treasury bill and have a risk free return on your investment. It's risk free, but it's not arbitrage because of the risk free profit coming from your investment. The second condition is not satisfied. So what's really an arbitrage? Imagine you are on the street and penniless. Once you spot and arbitrage opportunity, you can become a millionaire or billionaire after carrying out arbitrage.

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> REVIEW: ARBITRAGE
> - Arbitrage is "a money machine".
>   3. Has no risk
>   4. Does require investment.
> - Buying and selling identical financial instruments
>   - At different prices
>   - On different markets

[Sheen Liu]: So how do we arbitrage? To put it in a simple way, you buy and sell the same good at different prices on different markets [*Emphasized*]. Next slides show an example.

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> REVIEW: ARBITRAGE
> - Example: One ounce of gold costs $1000 in England and $990 in France
>   - Is there any arbitrage opportunity
>   - If yes, how to arbitrage?
> - Arbitrage procedure
>   - Borrow $990 to buy 1-oz gold in France;

- Sell the gold in England for $1000;
- Payoff the loan (assuming negligible interests);
- Profit = $1000 - $990 = $10

[*Images of gold*]

[Sheen Liu]: This is a simple example of arbitrage. One ounce of gold costs 1000 dollars in England and 990 in France. It is easy to see that there is an arbitrage opportunity. How to arbitrage: you might say buy gold in France and sell it in England. This answer is only half right. Purchasing gold requires money or investment. Well, arbitrage does not require investment. Arbitrage must satisfy two conditions: the first is making money without taking risk and the second is making money without investment. As we discussed previously, you can make risk free profit by investing in Treasury bill but that's not arbitrage. To check if there is an arbitrage opportunity, you may imagine that you start with zero money and try if you can make some money. If yes, that is an arbitrage. We start with zero money. We borrow 990 dollars to buy one ounce of gold in France and sell the gold in England for 1000 dollars [*Emphasized*]. We pay off the loan assuming that we buy and sell on the computer so the time between buying and selling is short and the interest on the loan is negligible. Then the profit is 1,000 dollars minus 990 dollars which is 10 dollars per ounce [*Emphasized*]. If we want to be ten million dollars rich, we just buy and sell one million ounces gold. This sounds too good to be true. In fact, British financier, Nathan Mayer Rothschild, did something similar to this. Rothschild was almost single-handedly financing the British army during the Napoleonic war effort, financing the shipment of bullion to the Duke of Wellington's armies across Europe. It is said that Rothschild has offices in England and continental Europe, if gold was cheaper in England and more expensive in continental Europe, he sold gold in continental Europe and bought in England and vice versa.

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REVIEW: ARBITRAGE
- Arbitrage opportunities disappear quickly and markets go back to normal.
- Law of one price
  - In normal markets, identical goods or financial instruments have one single price.
  - Helps to determine arbitrage-free prices.
- Complications
  - Different financial instruments that have the same cash flows are identical in arbitrage sense.
  - There may be multiple ways to generate the same cash flows.

[Sheen Liu]: There are a lot of people looking for an arbitrage opportunity. If one ounce of gold costs $1000 in England and $990 in France, many people rush to buy gold in France, pushing up the price. At the same time, they rush to sell gold in England pushing down the price. Consequently, the prices in England and France converge to a single price.

Arbitrage opportunities are like money lying on the street, they will quickly disappear [*Emphasized*]. Money should not be lying on the street all the time. The arbitrage opportunity should be rare. In normal markets, identical goods should have one single price this is the law of one price [*Emphasized*]. So far, arbitrage sounds simple, however it can get complicated. The financial transactions that generate the same cash flows are identical instruments [*Emphasized*]. The same cash flows can be generated through many different transactions in the financial market. The triangular arbitrage in foreign exchange market is an example we'll discuss next.

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INTERMARKET ARBITRAGE
- Some currency pairs are not actively traded, so their exchange rate is determined through their relationship to a third currency (cross rate).
    - Example: Exchange rate between Japanese yen (¥) and Mexican peso (Ps)
        - ¥110.73/$
        - Ps11.4456/$

[*Flow Chart of exchange rate between Japanese yen and Mexican peso*]

[Sheen Liu]: Some currency pairs are not actively traded, so their exchange rate is determined through their relationship to a widely traded third currency. The exchange rate established this way is the cross rate [*Emphasized*]. For example, Japanese yen and Mexican peso are not actively exchange; to have the exchange rate between them we use their exchange rate with U.S. dollars [*Emphasized*]. You may make the following exchanges: Exchange 110.73 yen for a dollar then exchange a dollar for 11.4456 Mexican pesos. This operation is equivalent to exchanging 110.73 Japanese yen for 11.4456 Mexican pesos. So the cross rate is 9.6745 Japanese yen per Mexican peso. It is also the arbitrage free exchange rate between Japanese yen and Mexican peso. We can check it quickly. One dollar exchanged for 11.4456 pesos then exchange 11.4456 pesos for 110.73 Japanese yen, finally exchange back for 1 dollar, there is no gain or losses.

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INTERMARKET ARBITRAGE
- Cross rates can be used to check on opportunities for intermarket arbitrage.
    - Assume that a bank quotes a spot rate of ¥9.8000/Ps, differing from the cross rate ¥9.6745/Ps.
    - Arbitrage profit is $0.01298 for each dollar.
    - Banks and financial institutions are able to borrow large sums of money.

[*Flow Chart of intermarket arbitrage*]

[Sheen Liu]: Cross rates can be used to check opportunities for arbitrage. Let's say a bank quotes a spot rate of 9.8 Japanese yen per peso which is different from the cross rate 9.6745 Japanese yen per peso [*Emphasized*]. There is an arbitrage opportunity here. To see it, let's borrow 1 dollar. Exchange one dollar for 11.4456 pesos, next exchange 11.4456 Mexican pesos at 9.8 yen per peso for 112.17 Japanese yen. Finally, exchange 112.17 Japanese yen at the 110.73 per dollar for 1.01298 dollars. Arbitrage profit is 1.298 cents for each dollar. You may say it's only one cent profit per dollar. If you start with 100 million dollars, you'd be able to make one million dollars profit. Banks and financial institutions are able to borrow large sums of money [*Emphasized*]. Arbitrage is not just a fairy tale; there is a group of investors and fund managers who are actively engaging in arbitrage activities. They are the arbitragers. If an exchange rate differs from the arbitrage free cross rate, the arbitrage activities push the exchange rate back to the arbitrage free cross rate.

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ABSOLUTE PURCHASING POWER PARITY (PPP)
- Example: A Big Mac in China costs 12.5 Yuan, while in US it costs $3.57. the exchange between dollar and Yuan is Yuan 6.83/$
- Arbitrage
  - Borrow $1.8302 (= $\frac{\text{Yuan } 12.5}{\text{Yuan } 6.83/\$}$);
  - Exchange $1.8302 for Yuan 12.5;
  - Buy a Big Mac in China;
  - Sell it in US for $3.57;
  - The arbitrage profit is $1.7398.
- PPP (arbitrage-free exchange rate) is
$$S = \frac{\text{Yuan } 12.5}{\$3.57} = \frac{\text{Yuan } 3.50}{\$} = \frac{p^{\text{yuan}}}{p^{\$}}$$

[Sheen Liu]: Let's look at another example of arbitrage. A Big Mac in China costs 12.5 Yuan, while in the US it costs $3.57 [*Emphasized*]. The exchange rate between dollar and Yuan is 6.83 Yuan per dollar [*Emphasized*]. You probably see the arbitrage opportunity in this situation. Let's borrow 1.8302 dollars, exchange 1.8302 dollars for 12.5 Chinese Yuan, buy a Big Mac in china, sell it in US for $3.57 [*Emphasized*]. In this case, the arbitrage profit is not trivial, it is 1.7398 dollars [*Emphasized*]. It is easy to see that to eliminate the above arbitrage opportunity, 12.5 Yuan must be exchanged for 3.57 dollars. No matter if you hold $3.57 or exchange $3.57 for Chinese Yuan, your money buys one Big Mac. Therefore, the arbitrage-free exchange rate must be 12.5 Yuan for 3.57 dollars or 3.5 Yuan per dollar. This argument can be extended to any pair of currencies. Once you convert money, a Big Mac should cost the same no matter where you go, this is another form of the Law of One Price. It refers to the international arbitrage condition for goods and services. The Law of One Price requires that goods and services should be selling for the same price in a given currency across countries. Otherwise, one can arbitrage by buying goods at a cheaper price in one country, ship them to another country where goods are more expensive, and sell them.

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PURCHASING POWER PARITY
- A primary principle of competitive markets is that prices will equalize across markets if frictions do not exist.
- The exchange rate between two currencies should equal the ratio of the countries' price levels:

$$P^\$ \times S = P^y$$
$$S = P^y/P^\$$$

$P^\$$ = price in US dollars
S = the spot exchange rate
P^y = the price in Yuan.

[Sheen Liu]: A principle of competitive markets is that prices will equalize across markets if frictions do not exist [*Emphasized*]. If Big Macs can be shipped to the US without frictions, such as transportation costs, tariffs and other frictions, the dollars that can buy a Big Mac in US will buy a Big Mac in China as well after exchanged for Chinese Yuan. In general, the exchange rate between two currencies should equal the ratio of the country's price levels [*Emphasized*]. The price of a Big Mac in US dollars is $P^\$$ [*Emphasized*]. The first equation implies that converting the dollar price into Chinese Yuan by multiplying the exchange rate between dollar and Yuan should give the Yuan price of a Big Mac in China. The second equation says that the exchange rate between Chinese Yuan and US Dollar is the ratio between the price in China and the price in US. This is the absolute purchasing power parity. The purchasing power of money is also known as its real value and indicates the amount of goods and services that can be purchased with a given amount of money. Absolute purchasing power parity says that exchanging one currency for another currency does not change the purchasing power.

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PURCHASING POWER PARITY
- If the law of one price were true for all goods and service, the purchasing power parity (PPP) exchange rate could be found from any individual set of prices.
- By comparing the prices of identical products denominated in different currencies, we could determine the absolute PPP exchange rate that should exist if markets were efficient.
- Two general conclusions can be made from these tests:
  - PPP holds up well over the very long run;
  - But poorly for shorter time periods.

[Sheen Liu]: If the law of one price were true for all goods and services, the purchasing power parity exchange rate could be found from any individual set of prices [*Emphasized*]. By comparing the prices of identical products denominated in different currencies, we could determine the absolute purchasing power parity exchange rate that should exist if there were

not frictions in the markets [*Emphasized*]. However, any of the frictions that create a deviation from the law of one price can also cause a deviation from the absolute purchasing power parity. Clearly transactions costs, such as the cost of shipping, generate deviations from the absolute purchasing power parity. Tariffs and quotas on imports and exports also create deviations. Empirical testing of purchasing power parity shows that the absolute purchasing power parity holds up well over the long run, but poorly for shorter time periods [*Emphasized*].

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RELATIVE PURCHASING POWER PARITY (RPPP)
- Example: A Big Mac in China costs 24.38 Yuan, while in US it costs $3.57. The exchange between dollar and Yuan is Yuan 6.83/$.
  - The rate of China inflation is 5%
  - The rate of US inflations is 3%
- Next year, a Big Mac
  - In China costs Yuan 25.60 (= 24.38(1+0.05))
  - In US costs $3.68 (= $3.57(1+0.03))
- Next year's arbitrage-free exchange rate should be

$$S(\text{next year}) = \frac{\text{Yuan}24.38(1+0.05)}{\$3.57(1+0.03)} = \frac{\text{Yuan}25.60}{\$3.68} = \frac{\text{Yuan}6.96}{\$}$$

$$= \frac{P^{\text{Yuan}}(1+\pi^Y)}{P^\$(1+\pi^\$)} = S\frac{1+\pi^Y}{1+\pi^\$}$$

$$\frac{S(\text{next year})}{S} = \frac{1+\pi^Y}{1+\pi^\$} = \frac{1+0.05}{1+0.03} = 1.0194$$

[Sheen Liu]: Managers and investors are interested in not only determining spot exchange rates but also forecasting future exchange rates. Let's extend the absolute purchasing power parity to next year. A Big Mac in China costs 24.38 Yuan, while in US it costs 3.57 dollars [*Emphasized*]. The exchange rate between dollar and Yuan is the price ratio which is 6.83 Yuan per dollar. The rate of China inflation is 5 percent [*Emphasized*]. The rate of US inflation is 3 percent [*Emphasized*]. Next year a Big Mac in China costs 24.38 Yuan times 1 plus 5 percent inflation rate which gives 25.60 Yuan. A Big Mac in US costs 3.57 times 1 plus 3 percent inflation which give 3.68 dollars. The law of one price requires that the next year's exchange rate much be the next year's price ratio on 25.60 Yuan and 3.68 dollars which is 6.98 Yuan per dollar [*Emphasized*]. In principle, next year, once you convert money, a Big Mac should cost the same no matter where you go. The current exchange rate, the spot rate, may not satisfy the absolute purchasing power parity. In such case, we may relax our interpretation of the relation and then rewrite the equation looking at the ratio between next year's exchange rate and spot rate [*Emphasized*]. The ratio is between the inflations of the two countries. It is 1.0194 between China inflation and US inflation. The ratio says that Chinese Yuan will be weakened by 1.94% because of higher inflation in China. The second equation tells the trend of the future exchange rate. It does require that the law of one price must hold. The ratio tells which currency will be weakened and which one will be strengthened. Even the absolute purchasing

power parity does not hold for the spot exchange rate. The ratio of the inflations between the two countries tells the trend of the future exchange rate, that is which will be weakened and which will be strengthened. This is the relative purchasing power parity.

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RELATIVE PURCHASING POWER PARITY
- If inflation in a foreign country differs from inflation in the home country, the exchange rate will adjust to maintain equal purchasing power.
- Absolute PPP is not particularly helpful in determining what the spot rate is today, but that the relative change in prices between two countries over a period of time determines the change in the exchange rate over that period.
- More specifically, with regard to Relative PPP:
  - If the spot exchange rate between two countries starts in equilibrium, any change in the differential rate of inflation between them tends to be offset over the long run by an equal but opposite change in the spot exchange rate.

$$\frac{S(\text{next year})}{S} = \frac{(1 + \pi^Y)}{(1 + \pi^\$)}$$

[Sheen Liu]: The relative purchasing power parity suggests that if inflation in a foreign country differs from inflation in the home county, the exchange rate will adjust to maintain equal purchasing power [*Emphasized*]. The logic is that inflation lowers the purchasing power of money, a change in the exchange rate to compensate for different levels of inflation should occur. Currencies in countries with high inflation will be weak according to the relative purchasing power parity, causing the purchasing power of goods in the home country versus this country to be similar. Absolute purchasing power parity is not very helpful in determining what the spot rate is today, but that the relative change in prices between two countries over a period of time determines the change in the exchange rate over that period [*Emphasized*]. More specifically, relative purchasing power parity takes market imperfections into account. Exchange rates adjust in response to differences in inflation across countries. If the spot exchange rate between two countries starts in equilibrium, any change in the differential rate of inflation between them tends to be offset in the long run by equal change in the spot exchange rate [*Emphasized*].

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PURCHASING POWER PARITY
- In an economy with many goods, purchasing power is defined in terms of a representative bundle of goods.
- Individual national currencies often need to be evaluated against other currency values to determine relative purchasing power.
  - The objective is to discover whether a nation's exchange rate is "overvalued" or "undervalued" in terms of PPP.

- This problem is often dealt with through the calculation of exchange rate indices such as the nominal effective exchange rate index.

[Sheen Liu]: In the previous example, the quantity of Big Macs one can buy with one dollar defines the purchasing power of US dollar. In an economy with many goods, purchasing power is defined in terms of a representative bundle of goods. Individual national currencies often need to be evaluated against other currency values to determine relative purchasing power [*Emphasized*]. The objective is to discover whether a nation's exchange rate is "overvalued" or "undervalued" in terms of purchasing power parity [*Emphasized*]. This problem is often dealt with through the calculation of exchange rate indices such as the nominal effective exchange rate index [*Emphasized*]. Effective exchange rate index is a weighted index of a currency value against a basket of international currencies.

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EXCHANGE RATE PASS-THROUGH
- The degree to which the prices of imported and exported goods change as a result of exchange rate changes is termed pass-through.
- Incomplete exchange rate pass-through is one reason that a country's real effective exchange rate index can deviate.
- Although PPP implies that all exchange rate changes are passed through by equivalent changes in prices to trading partners, empirical research in the 1980s questioned the long-held assumption.
- Price elasticity of demand is an important factor when determining pass-through levels.

$$\text{Price elasticity of demand} = e_d = \frac{\%\Delta Q_d}{\%\Delta P}$$

Q_d = Quantity demanded
P = Product price
- The smaller the elasticity, the higher the pass-through

[Sheen Liu]: The exchange rate pass-through is the percentage change in local currency import prices resulting from a 1 percent change in the exchange rate between the exporting and importing countries. The degree to which the prices of imported and exported goods change as a result of exchange rate changes is termed pass-through [*Emphasized*]. Incomplete exchange rate pass-through is one reason that a country's real effective exchange rate index can deviate from the absolute purchasing power parity. Although purchasing power parity implies that all exchange rate changes are passed through by equivalent changes in prices to trading partners. Empirical research questioned this long-held assumption. For example, a car manufacturer may or may not adjust the pricing of its cars sold in a foreign country if the exchange rates alter the manufacturer's cost structure in comparison to the foreign market. Pass-through can also be partial as there are many mechanisms by which companies can absorb the impact of the exchange rate changes. Price elasticity of demand is a measure of responsiveness of quantity demanded to price [*Emphasized*]. It is an important factor when determining pass-through

levels. The price elasticity of demand for any good is the percentage change of quantity of the good demanded as a result of the percentage change in the good's price. The smaller the elasticity, the higher the pass-through. In other words, if the price increase does not change much of the demand, the exchange rate change will pass-through the price.

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EXHANGE RATE PASS-THROUGH
- Example
  - Euro appreciates for 20% against US dollar.
  - The PPP implies that the dollar prices of the cars made in Germany increase by 20%.
  - Assume that price elasticity of demand is large in US.
  - German car makers may decide to increase their car prices by 14.29% (<20%)
  - German car makers absorb 5.71% (= 20% - 14.29%).
  - The pass-through is

$$\text{Pass} - \text{through} = \frac{14.29\%}{20\%} = 71\%$$

[Sheen Liu]: The example illustrates the exchange rate pass-through. Euro appreciates for 20 percent. The purchasing power parity implies that the prices of the cars made in Germany increase by 20 percent accordingly [*Emphasized*]. Let's assume that the price elasticity of demand is large in US [*Emphasized*]. That is to say, a 20 percent increase in the car price would reduce German car sales a lot. German car makers may decide to increase their car prices by less than 20 percent [*Emphasized*]. They may increase the car prices by 14.29 percent and the German car makers absorb 5.71 percent. This results in a 71 percent pass-through, that is 14.29 percent increase in dollar divided by 20 percent appreciation in euro [*Emphasized*]. This concludes module 5.