Engineering Economy

The Time Value of Money

The objective of this presentation is to explain time value of money calculations and to illustrate economic equivalence.

Money has a time value.

- *Capital* refers to wealth in the form of money or property that can be used to produce more wealth.
- Engineering economy studies involve the commitment of capital for extended periods of time.
- A dollar today is worth more than a dollar one or more years from now (for several reasons).

Return to capital in the form of interest and profit is an essential ingredient of engineering economy studies.

- Interest and profit pay the providers of capital for forgoing its use during the time the capital is being used.
- Interest and profit are payments for the *risk* the investor takes in letting another use his or her capital.
- Any project or venture must provide a sufficient return to be financially attractive to the suppliers of money or property.

Simple Interest: infrequently used

When the total interest earned or charged is linearly proportional to the initial amount of the loan (principal), the interest rate, and the number of interest periods, the interest and interest rate are said to be *simple*.

Computation of simple interest

The total interest, $\underline{I}$, earned or paid may be computed using the formula below.

$$\underline{I} = (P)(N)(i)$$

P = principal amount lent or borrowed

N = number of interest periods (e.g., years)

i = interest rate per interest period

The total amount repaid at the end of *N* interest periods is $P + \underline{I}$.

If $5,000 were loaned for five years at a simple interest rate of 7% per year, the interest earned would be

$$\underline{I} = \$5,000 \quad \text{x} \quad 5 \quad \text{x} \quad 0.07 = \$1,750$$

So, the total amount repaid at the end of five years would be the original amount ($5,000) plus the interest ($1,750), or $6,750.

Compound interest reflects both the remaining principal and any accumulated interest. For $1,000 at 10%…

Period	(1) Amount owed at beginning of period	(2)=(1)x10% Interest amount for period	(3)=(1)+(2) Amount owed at end of period
1	$1,000	$100	$1,100
2	$1,100	$110	$1,210
3	$1,210	$121	$1,331

Compound interest is commonly used in personal and professional financial transactions.

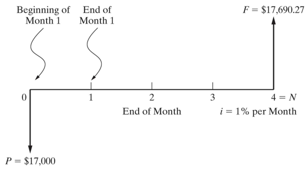
Economic equivalence allows us to compare alternatives on a common basis.

- Each alternative can be reduced to an *equivalent basis* dependent on
  - interest rate,
  - amount of money involved, and
  - timing of monetary receipts or expenses.
- Using these elements we can “move” cash flows so that we can compare them at particular points in time.

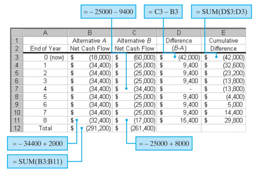
We need some tools to find economic equivalence.

- Notation used in formulas for compound interest calculations.
  - i = effective interest rate per interest period
  - N = number of compounding (interest) periods
  - P = present sum of money; *equivalent* value of one or more cash flows at a reference point in time; the present
  - F = future sum of money; *equivalent* value of one or more cash flows at a reference point in time; the future
  - A = end-of-period cash flows in a uniform series continuing for a certain number of periods, starting at the end of the first period and continuing through the last

A cash flow diagram is an indispensable tool for clarifying and visualizing a series of cash flows.



Cash flow tables are essential to modeling engineering economy problems in a spreadsheet



	A	B	C	D	E
1		Alternative *A*	Alternative *B*	Difference	Cumulative
2	End of Year	Net Cash Flow	Net Cash Flow	(*B*-*A*)	Difference
3	0 (now)	$ (18,000)	$ (60,000)	$ (42,000)	$ (42,000)
4	1	$ (34,400)	$ (25,000)	$ 9,400	$ (32,600)
5	2	$ (34,400)	$ (25,000)	$ 9,400	$ (23,200)
6	3	$ (34,400)	$ (25,000)	$ 9,400	$ (13,800)
7	4	$ (34,400)	$ (34,400)	$ -	$ (13,800)
8	5	$ (34,400)	$ (25,000)	$ 9,400	$ (4,400)
9	6	$ (34,400)	$ (25,000)	$ 9,400	$ 5,000
10	7	$ (34,400)	$ (25,000)	$ 9,400	$ 14,400
11	8	$ (32,400)	$ (17,000)	$ 15,400	$ 29,800
12	Total	$ (291,200)	$ (261,400)		

We can apply compound interest formulas to "move" cash flows along the cash flow diagram.

Using the standard notation, we find that a present amount, *P*, can grow into a future amount, *F*, in *N* time periods at interest rate *i* according to the formula below.

$$F = P(1+i)^N$$

In a similar way we can find *P* given *F* by

$$P = F(1+i)^{-N}$$

It is common to use standard notation for interest factors.

$$(1+i)^N = (F/P, i, N)$$

This is also known as the *single payment compound amount* factor. The term on the right is read "*F* given *P* at *i*% interest per period for *N* interest periods."

$$(1+i)^{-N} = (P/F, i, N)$$

is called the *single payment present worth* factor.

We can use these to find economically equivalent values at different points in time.

$2,500 at time zero is equivalent to how much after six years if the interest rate is 8% per year?

$$F = \$2,500(F/P, 8\%, 6) = \$2,500(1.5869) = \$3,967$$

$3,000 at the end of year seven is equivalent to how much today (time zero) if the interest rate is 6% per year?

$$P = \$3,000(P/F, 6\%, 7) = \$3,000(0.6651) = \$1,995$$

There are interest factors for a series of end-of-period cash flows.

$$F = A\left[\frac{(1+i)^N - 1}{i}\right] = A(F/A, i\%, N)$$

How much will you have in 40 years if you save $3,000 each year and your account earns 8% interest each year?

$$F = \$3,000(F/A, 8\%, 40) = \$3,000(259.0565) = \$777,170$$

Finding the present amount from a series of end-of-period cash flows.

$$P = A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] = A(P/A, i\%, N)$$

How much would is needed today to provide an annual amount of $50,000 each year for 20 years, at 9% interest each year?

$$P = \$50,000(P/A, 9\%, N) = \$50,000(9.1285) = \$456,427$$

Finding A when given F.

$$A = F\left[\frac{i}{(1+i)^N - 1}\right] = F(A/F, i\%, N)$$

How much would you need to set aside each year for 25 years, at 10% interest, to have accumulated $1,000,000 at the end of the 25 years?

$$A = \$1,000,000(A/F, 10\%, 25) = \$1,000,000(0.0102) = \$10,200$$

Finding A when given P.

$$A = P\left[\frac{i(1+i)^N}{(1+i)^N - 1}\right] = P(A/P, i\%, N)$$

If you had $500,000 today in an account earning 10% each year, how much could you withdraw each year for 25 years?

$$A = \$500,000(A/P, 10\%, 25) = \$500,000(0.1102) = \$55,100$$

It can be challenging to solve for *N* or *i*.

- We may know *P*, *A*, and *i* and want to find *N*.
- We may know *P*, *A*, and *N* and want to find *i*.
- These problems present special challenges that are best handled on a spreadsheet.

Finding *N*

Acme borrowed $100,000 from a local bank, which charges them an interest rate of 7% per year. If Acme pays the bank $8,000 per year, now many years will it take to pay off the loan?

$$\$100,000 = \$8,000(P/A, 7\%, N)$$

So,

$$(P/A, 7\%, N) = \frac{\$100,000}{\$8,000} = 12.5 = \frac{(1.07)^N - 1}{0.07(1.07)^N}$$

This can be solved by using the interest tables and interpolation, but we generally resort to a computer solution.

Finding *i*

Jill invested $1,000 each year for five years in a local company and sold her interest after five years for $8,000. What annual rate of return did Jill earn?

$$\$8,000 = \$1,000(F/A, i\%, 5)$$

So,

$$(F/A, i\%, 5) = \frac{\$8,000}{\$1,000} = 8 = \frac{(1+i)^5 - 1}{i}$$

Again, this can be solved using the interest tables and interpolation, but we generally resort to a computer solution.

There are specific spreadsheet functions to find *N* and *i*.

The Excel function used to solve for *N* is

NPER(*rate*, *pmt*, *pv*), which will compute the number of payments of magnitude *pmt* required to pay off a present amount (*pv)* at a fixed interest rate (*rate*).

One Excel function used to solve for *i* is

RATE(*nper*, *pmt*, *pv*, *fv*), which returns a fixed interest rate for an annuity of *pmt* that lasts for *nper* periods to either its present value (*pv*) or future value (*fv*).

We need to be able to handle cash flows that do not occur until some time in the future.

- Deferred annuities are uniform series that do not begin until some time in the future.
- If the annuity is deferred *J* periods then the first payment (cash flow) begins at the end of period *J*+1.

Finding the value at time *0* of a deferred annuity is a two-step process.

1. Use (*P/A*, *i*%, *N-J*) find the value of the deferred annuity at the end of period *J* (where there are *N-J* cash flows in the annuity).
2. Use (*P/F*, *i*%, *J*) to find the value of the deferred annuity at time zero.

$$P_0 = A(P/A, i\%, N-J)(P/F, i\%, J)$$

Sometimes cash flows change by a constant amount each period.

We can model these situations as a *uniform gradient* of cash flows. The table below shows such a gradient.

End of Period	Cash Flows
1	0
2	*G*
3	2*G*
:	:
N	*(N-1)G*

It is easy to find the present value of a uniform gradient series.

Similar to the other types of cash flows, there is a formula (albeit quite complicated) we can use to find the present value, and a set of factors developed for interest tables.

$$(P/G, i\%, N) = \frac{1}{i}\left[\frac{(1+i)^N - 1}{i(1+i)^N} - \frac{N}{(1+i)^N}\right]$$

We can also find A or F equivalent to a uniform gradient series.

$$(A/G, i\%, N) = \frac{1}{i} - \frac{N}{(1+i)^N - 1}$$

$$(F/G, i\%, N) = \frac{1}{i}(F/A, i\%, N) - \frac{N}{i}$$

The annual equivalent of this series of cash flows can be found by considering an annuity portion of the cash flows and a gradient portion.

End of Year	Cash Flows ($)
1	2,000
2	3,000
3	4,000
4	5,000

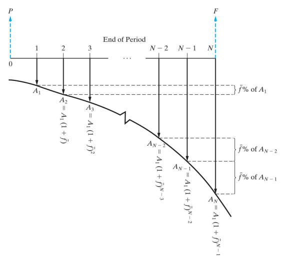
End of Year	Annuity ($)	Gradient ($)
1	2,000	0
2	2,000	1,000
3	2,000	2,000
4	2,000	3,000

$$A = \$2,000 + \$1,000(A/G, 8\%, 4) = \$3,404$$

Sometimes cash flows change by a constant rate, $\bar{f}$, each period--this is a *geometric gradient series.*

This table presents a geometric gradient series. It begins at the end of year 1 and has a rate of growth, $\bar{f}$, of 20%.

End of Year	Cash Flows ($)
1	1,000
2	1,200
3	1,440
4	1,728



We can find the present value of a geometric series by using the appropriate formula below.

If $\bar{f} \neq i$

$$\frac{A_1[1 - (P/F, i\%, N)(F/P, \bar{f}\%, N]}{1 - \bar{f}}$$

If $\bar{f} = i$

$$A_1 N(P/F, i\%, 1)$$

Where A_1 is the initial cash flow in the series.

When interest rates vary with time different procedures are necessary.

- Interest rates often change with time (e.g., a variable rate mortgage).
- We often must resort to moving cash flows one period at a time, reflecting the interest rate for that single period.

The present equivalent of a cash flow occurring at the end of period N can be computed with the equation below, where i_k is the interest rate for the k^{th} period.

$$P = \frac{F_N}{\prod_{k=1}^{N}(1+i_k)}$$

If F_4 = \$2,500 and i_1=8%, i_2=10%, and i_3=11%, then

$$P = \$2,500(P/F, 8\%, 1)(P/F, 10\%, 1)(P/F, 11\%, 1)$$

$$P = \$2,500(0.9259)(0.9091)(0.9009) = \$1,896$$

Nominal and effective interest rates.

- More often than not, the time between successive compounding, or the interest period, is less than one year (e.g., daily, monthly, quarterly).
- The annual rate is known as a *nominal* rate.
- A *nominal* rate of 12%, compounded monthly, means an interest of 1% (12%/12) would accrue each month, and the annual rate would be *effectively* somewhat greater than 12%.
- The more frequent the compounding the greater the *effective* interest.

The effect of more frequent compounding can be easily determined.

Let r be the nominal, annual interest rate and M the number of compounding periods per year. We can find, i, the effective interest by using the formula below.

$$i = (1 + \frac{r}{M})^M - 1$$

Finding effective interest rates.

For an 18% nominal rate, compounded quarterly, the effective interest is.

$$i = (1 + \frac{0.18}{4})^4 - 1 = 19.25\%$$

For a 7% nominal rate, compounded monthly, the effective interest is.

$$i = (1 + \frac{0.07}{12})^{12} - 1 = 7.23\%$$

Interest can be compounded continuously.

- Interest is typically compounded at the end of discrete periods.
- In most companies cash is always flowing, and should be immediately put to use.
- We can allow compounding to occur continuously throughout the period.
- The effect of this compared to discrete compounding is small in most cases.

We can use the effective interest formula to derive the interest factors.

$$i = (1 + \frac{r}{M})^M - 1$$

As the number of compounding periods gets larger (*M* gets larger), we find that

$$i = e^r - 1$$

Continuous compounding interest factors.

$$(P/F, \underline{r}\%, N) = e^{-rN}$$

$$(F/A, \underline{r}\%, N) = \frac{e^{rN} - 1}{e^r - 1}$$

$$(P/A, \underline{r}\%, N) = \frac{e^{rN} - 1}{e^{rN}(e^r - 1)}$$

The other factors can be found from these.

Engineering Economy

With respect to Evaluating a Single Project

The objective of Chapter 5 is to discuss and critique contemporary methods for determining project profitability.

Proposed capital projects can be evaluated in several ways.

- Present worth (PW)
- Future worth (FW)
- Annual worth (AW)
- Internal rate of return (IRR)
- External rate of return (ERR)
- Payback period (generally not appropriate as a primary decision rule)

To be attractive, a capital project must provide a return that exceeds a minimum level established by the organization. This minimum level is reflected in a firm's Minimum Attractive Rate of Return (MARR).

Many elements contribute to determining the MARR.

- Amount, source, and cost of money available
- Number and purpose of good projects available
- Perceived risk of investment opportunities
- Type of organization

The most-used method is the present worth method.

The present worth (PW) is found by discounting all cash inflows and outflows to the present time at an interest rate that is generally the MARR.

A positive PW for an investment project means that the project is acceptable (it satisfies the MARR).

Present Worth Example

Consider a project that has an initial investment of $50,000 and that returns $18,000 per year for the next four years. If the MARR is 12%, is this a good investment?

PW = -50,000 + 18,000 (P/A, 12%, 4)

PW = -50,000 + 18,000 (3.0373)

PW = $4,671.40 → This is a good investment!

Bond value is a good example of present worth.

The commercial value of a bond is the PW of all future net cash flows expected to be received--the period dividend [face value (*Z*) times the bond rate (*r*)], and the redemption price (*C*), all discounted to the present at the bond's yield rate, *i%*.

$V_N = C\ (P/F,\ i\%,\ N) + rZ\ (P/A,\ i\%,\ N)$

Bond example

What is the value of a 6%, 10-year bond with a par (and redemption) value of $20,000 that pays dividends semi-annually, if the purchaser wishes to earn an 8% return?

$V_N = \$20{,}000\ (P/F,\ 4\%,\ 20) + (0.03)\$20{,}000\ (P/A,\ 4\%,\ 20)$

$V_N = \$20{,}000\ (0.4564) + (0.03)\$20{,}000\ (13.5903)$

$V_N = \$17{,}282.18$

Capitalized worth is a special variation of present worth.

- Capitalized worth is the present worth of all revenues or expenses over an infinite length of time.
- If only expenses are considered this is sometimes referred to as *capitalized cost*.
- The capitalized worth method is especially useful in problems involving endowments and public projects with indefinite lives.

The application of CW concepts.

The CW of a series of end-of-period uniform payments A, with interest at *i%* per period, is *A(P/A, i%, N)*. As *N* becomes very large (if the *A* are perpetual payments), the (P/A) term approaches *1/i*. So, *CW = A(1/i)*.

Future Worth (FW) method is an alternative to the PW method.

- Looking at FW is appropriate since the primary objective is to maximize the future wealth of owners of the firm.
- FW is based on the equivalent worth of all cash inflows and outflows at the end of the study period at an interest rate that is generally the MARR.
- Decisions made using FW and PW will be the same.

Future worth example.

A $45,000 investment in a new conveyor system is projected to improve throughput and increasing revenue by $14,000 per year for five years. The conveyor will have an estimated market value of $4,000 at the end of five years. Using FW and a MARR of 12%, is this a good investment?

FW = -$45,000(F/P, 12%, 5)+$14,000(F/A, 12%, 5)+$4,000

FW = -$45,000(1.7623)+$14,000(6.3528)+$4,000

FW = $13,635.70 → This is a good investment!

Annual Worth (AW) is another way to assess projects.

- Annual worth is an equal periodic series of dollar amounts that is *equivalent* to the cash inflows and outflows, at an interest rate that is generally the MARR.
- The AW of a project is annual equivalent revenue or savings minus annual equivalent expenses, less its annual capital recovery (*CR*) amount.

$$AW(i\%) = \underline{R} - \underline{E} - CR(i\%)$$

Capital recovery reflects the capital cost of the asset.

- *CR* is the annual equivalent cost of the capital invested.
- The *CR* covers the following items.
  - Loss in value of the asset.
  - Interest on invested capital (at the MARR).
- The *CR* distributes the initial cost (*I*) and the salvage value (*S*) across the life of the asset.

$$CR(i\%) = I(A/P, i\%, N) - S(A/F, i\%, N)$$

A project requires an initial investment of $45,000, has a salvage value of $12,000 after six years, incurs annual expenses of $6,000, and provides an annual revenue of $18,000. Using a MARR of 10%, determine the AW of this project.

$$AW(10\%) = \underline{R} - \underline{E} - CR(10\%)$$

$$CR(10\%) = 45,000(A/P, 10\%, 6) - 12,000(A/F, 10\%, 6)$$

$$CR(10\%) = 8,777$$

$$AW(10\%) = 18,000 - 6,000 - 8,777 = \$3,223$$

Since the *AW* is positive, it's a good investment.

Internal Rate of Return

- The internal rate of return (IRR) method is the most widely used rate of return method for performing engineering economic analysis.
- It is also called the *investor's method*, the *discounted cash flow* method, and the *profitability index*.
- If the IRR for a project is greater than the MARR, then the project is *acceptable*.

How the IRR works

- The IRR is the interest rate that equates the equivalent worth of an alternative's cash *inflows* (revenue, *R*) to the equivalent worth of cash *outflows* (expenses, *E*).
- The IRR is sometimes referred to as the *breakeven interest rate*.

The IRR is the interest *i'%* at which

$$\sum_{k=0}^{N} R_k(P/F, i'\%, k) = \sum_{k=0}^{N} E_k(P/F, i'\%, k)$$

Solving for the IRR is a bit more complicated than PW, FW, or AW

- The method of solving for the *i'%* that equates revenues and expenses normally involves trial-and-error calculations, or solving numerically using mathematical software.
- The use of spreadsheet software can greatly assist in solving for the IRR. Excel uses the *IRR(range, guess)* or *RATE(nper, pmt, pv)* functions.

Challenges in applying the IRR method.

- It is computationally difficult without proper tools.
- In rare instances multiple rates of return can be found. (See Appendix 5-A.)
- The IRR method must be carefully applied and interpreted when comparing two more mutually exclusive alternatives (e.g., do not directly compare internal rates of return).

Reinvesting revenue—the External Rate of Return (ERR)

- The IRR assumes revenues generated are reinvested at the IRR—which may not be an accurate situation.
- The ERR takes into account the interest rate, ε, external to a project at which net cash flows generated (or required) by a project over its life can be reinvested (or borrowed). This is usually the MARR.
- If the ERR happens to equal the project's IRR, then using the ERR and IRR produce identical results.

The ERR procedure

- Discount all the net cash *outflows* to time *0* at ε% per compounding period.
- Compound all the net cash *inflows* to period *N* at at ε%.
- Solve for the ERR, the interest rate that establishes equivalence between the two quantities.

ERR is the *i'%* at which

$$\sum_{k=0}^{N} E_k(P/F, \varepsilon\%, k)(F/P, i'\%, N) = \sum_{k=0}^{N} R_k(F/P, \varepsilon\%, N-k)$$

where

R_k = excess of receipts over expenses in period *k*,
E_k = excess of expenses over receipts in period *k*,
N = project life or number of periods, and
ε = external reinvestment rate per period.

Applying the ERR method

For the cash flows given below, find the ERR when the external reinvestment rate is ε = 12% (equal to the MARR).

Year	0	1	2	3	4
Cash Flow	-$15,000	-$7,000	$10,000	$10,000	$10,000

Expenses $15,000 + 7,000(P/F, 12\%, 1) = 21,250$

Revenue $10,000(F/A, 12\%, 3) = 33,744$

Solving, we find

$$21,250(F/P, i'\%, 4) = 33,744$$

$$i' = 16.67\% > 12\%$$

The payback period method is simple, but possibly misleading.

- The simple payback period is the number of years required for cash *inflows* to just equal cash *outflows*.
- It is a measure of *liquidity* rather than a measure of profitability.

Payback is simple to calculate.

The payback period is the *smallest* value of θ ($\theta \leq N$) for which the relationship below is satisfied.

$$\sum_{k=1}^{\theta}(R_k - E_k) - I \geq 0$$

For *discounted* payback future cash flows are discounted back to the present, so the relationship to satisfy becomes

$$\sum_{k=1}^{\theta'}(R_k - E_k)(P/F, i\%, k) - I \geq 0$$

Problems with the payback period method.

- It doesn't reflect any cash flows occurring after θ, or θ'.
- It doesn't indicate anything about project desirability except the speed with which the initial investment is recovered.
- Recommendation: use the payback period only as supplemental information in conjunction with one or more of the other methods in this chapter.

Finding the simple and discounted payback period for a set of cash flows.

The cumulative cash flows in the table were calculated using the formulas for simple and discounted payback.

From the calculations θ = 4 years and θ' = 5 years.

End of Year	Net Cash Flow	Cumulative PW at *0%*	Cumulative PW at *6%*
0	-$42,000	-$42,000	-$42,000
1	$12,000	-$30,000	-$30,679
2	$11,000	-$19,000	-$20,889
3	$10,000	-$9,000	-$12,493
4	$10,000	$1,000	-$4,572
5	$9,000		$2,153

Engineering Economy

With respect to Depreciation and Income Taxes

The objective of Chapter 7 is to explain how depreciation affects income taxes, and how income taxes affect economic decision making.

Income taxes usually represent a significant cash outflow. In this chapter we describe how after tax liabilities and after-tax cash flows result in the *after-tax cash flow* (ATCF) *procedure*. Depreciation is an important element in finding after-tax cash flows.

Depreciation is the decrease in value of physical properties with the passage of time.

- It is an accounting concept, a *non-cash* cost, that establishes an annual deduction against before-tax income.
- It is intended to approximate the yearly fraction of an asset's value used in the production of income.

Property is depreciable if

- it is used in business or held to produce income.
- it has a determinable useful life, longer than one year.
- it is something that wears out, decays, gets used up, becomes obsolete, or loses value from natural causes.
- it is not inventory, stock in trade, or investment property.

Depreciable property is

- tangible (can be seen or touched; personal or real) or intangible (such as copyrights, patents, or franchises).
- depreciated, according to a depreciation schedule, when it is put in service (when it is ready and available for its specific use).

Straight line (SL): constant amount of depreciation each year over the depreciable life of the asset.

$$d_k = \frac{B - SV_N}{N}$$

- N = depreciable life
- B = cost basis
- d_k = depreciaton in k
- BV_k = book value at end of k
- SV_N = salvage value

Declining-balance (DB): a constant-percentage of the remaining BV is depreciated each year.

$$d_k = B(1-R)^{k-1}(R)$$

$$BV_k = B(1-R)^k$$

The constant percentage is determined by R, where $R = 2/N$ when 200% declining balance is being used, $R = 1.5/N$ when 150% declining balance is being used.

The *units-of-production* method can be used when the decrease in value of the assset is mostly a function of use, instead of time. The cost basis is allocated equally over the number of units produced over the asset's life. The depreciation per unit of production is found from the formula below.

$$\frac{B - SV_N}{(\text{Estimated lifetime production units})}$$

The *Modified Accelerated Cost Recovery System* (MACRS) is the principle method for computing depreciation for property in engineering projects. It consists of two systems, the main system called the *General Depreciation System* (GDS) and the *Alternative Depreciation System* (ADS).

When an asset is depreciated using MACRS, the following information is needed to calculate deductions.

- Cost basis, B
- Date the property was placed into service
- The property class and recovery period
- The MACRS depreciation method (GDS or ADS).
- The time convention that applies (half year)

Using MACRS is easy!

1. Determine the asset's recovery period (Table 7-2).
2. Use the appropriate column from Table 7-3 that matches the recovery period to find the recovery rate, r_k, and compute the depreciation for each year as

$$d_k = r_k B; \quad 1 \le k \le N+1$$

There are many different types of taxes.

- Income taxes are assessed as a function of gross revenues minus allowable expenses.
- Property taxes are assessed as a function of the value of property owned.
- Sales taxes are assessed on the basis of purchase of goods or services.
- Excise taxes are federal taxes assessed as a function of the sale of certain goods or services often considered nonnecessities.

We will focus on income taxes.

Taking taxes into account changes our expectations of returns on projects, so our MARR (after-tax) is lower.

$$\text{Before-tax MARR} \approx \frac{\text{After-tax MARR}}{\text{1-effective income tax rate}}$$

The after-tax MARR should be *at least* the tax-adjusted weighted average cost of capital (WACC).

$$WACC = \lambda(1-t)i_b + (1-\lambda)e_a$$

λ = fraction of a firm's pool of capital borrowed from lenders

t = effective income tax rate as a decimal

i_b = before-tax interest paid on borrowed capital

e_a = after-tax cost of equity capital

Depreciation is not a cash flow, but it affects a corporation's taxable income, and therefore the taxes a corporation pays.

Taxable income = gross income

– all expenses except capital invest.

– depreciation deductions.

Federal taxes are calculated using a set of income brackets. each applying a different tax rate on the marginal value of income. State taxes vary widely.

- Tax rates are found in Table 7-5.
- Corporations need to know their *effective tax rate*, which is a combination of federal and state taxes according to either formula below.

$$t = \text{state rate} + \text{federal rate(1-state rate)}$$
$$t = \text{federal rate} + \text{state rate(1-federal rate)}$$

The disposal of a depreciable asset can result in a gain or loss based on the sale price (market value) and the current book value

$$[\text{gain (loss) on disposal}]_N = MV_N - BV_N$$

A gain is often referred to as *depreciation recapture*, and it is generally taxed as the same as ordinary income. A loss is a *capital loss*. An asset sold for more than it's cost basis results in a *capital gain*.

After-tax economic analysis is generally the same as before-tax analysis, just using after-tax cash flows (ATCF) instead of before-tax cash flows (BTCF). The analysis is conducted using the after-tax MARR.

Cash flows are typically determined for each year using the notation below.

R_k = revenues (and savings) from the project during period *k*

E_k = cash outflows during *k* for deductible expenses

d_k = sum of all noncash, or book, costs during *k*, such as depreciation

t = effective income tax rate on ordinary income

T_k = income tax consequence during year *k*

$ATCF_k$ = ATCF from the project during year *k*

Some important cash flow formulas.

Taxable income

$$R_k - E_k - d_k$$

Ordinary income tax consequences

$$T_k = -t(R_k - E_k - d_k)$$

$$BTCF_k = R_k - E_k$$

$$ATCF_k = BTCF_k + T_k$$

$$ATCF_k = (1-t)(R_k - E_k) + td_k$$

End of Year, *k*	(*A*) Before-Tax Cash Flow (BTCF)	(*B*) Depreciation Deduction	(*C*) = (*A*) − (*B*) Taxable Income (TI)	(*D*) = −*t*(*C*) Cash Flow for Income Taxes	(*E*) = (*A*) + (*D*) After-Tax Cash Flow (ATCF)
0	Capital investment				Capital investment
1, 2, ..., N	Ordinary income is positive (or negative) in sign	Depreciation (positive in sign)	TI can be negative or positive in sign	−*t* (TI) (opposite in sign from TI)	After-tax cash flows from operations
N	Market value (MV)		MV − BV†	−*t*(MV − BV)	MV−*t*(MV−BV)

Before-Tax IRR, PW, and so on (Computed from Col. *A*, using the before-tax MARR)

After-Tax IRR, PW, and so on (Computed from Col. *E*, using the after-tax MARR)

†BV = book value at end of year *N*

Acme purchased a pump for $250,000 and expended $20,000 for shipping and installation. The addition of this pump will result in an increase in revenue of $80,000, with associated increased expenses of $10,000, each year. The pump has a GDS recovery period of five years, and Acme's effective tax rate is 41%. What is the ATCF for this project for the fourth year of service of the asset?

$$B = \$250,000 + \$20,000 = \$270,000$$

$$BTCF_4 = R_4 - E_4 = \$80,000 - \$10,000 = \$70,000$$

$$d_4 = 0.1152(\$270,000) = \$31,104$$

$$T_4 = -0.41(\$80,000 - \$10,000 - \$31,104) = \$15,947$$

$$ATCF_4 = BTCF_4 + T_4$$

$$ATCF_4 = \$70,000 - \$15,947 = \underline{\$54,053}$$

Economic value added, EVA, is an estimate of the profit-earning *potential* of proposed capital investments in engineering projects. It is the difference between a company's adjusted net operating profit after taxes (NOPAT) in a particular year and its after-tax cost of capital during that year.

$$\begin{aligned} EVA_k &= \text{(Net Operating Profit After Taxes)}_k \\ &- \text{(Cost of Capital)}_k \\ EVA_k &= NOPAT_k - i \cdot BV_{k-1} \end{aligned}$$

where,

k = an index for the year

i = after-tax MARR based on the cost of capital

and

$$\begin{aligned} NOPAT_k &= (R_k + E_k - d_k)(1-t) \\ NOPAT_k &= ATCF_k - d_k \end{aligned}$$

For Acme, what is the EVA for year 4 if their after-tax MARR is 8%?

$$\begin{aligned} NOPAT_4 &= ATCF_4 - d_4 \\ NOPAT_4 &= \$54,053 - \$31,104 = \$22,949 \end{aligned}$$

$$\begin{aligned} EVA_4 &= NOPAT_4 - i \cdot BV_3 \\ EVA_4 &= \$22,949 - (0.08)(\$77,760) \\ EVA_4 &= \underline{\$16,728} \end{aligned}$$

Engineering Economy

Chapter 8: Price Changes and Exchange Rates

The objective of Chapter 8 is to present how inflation/deflation is dealt with in engineering economy studies.

Our assumption of constant prices for goods and services is generally not the case. *General price inflation* increases the average price of goods and services over time, while *deflation* results in a decrease in average prices (certainly a more rare circumstance).

Changes in the consumer price index (CPI) and producer price index (PPI) are used as surrogate measures of inflation. The rate of change can be found, in either case, from the formula below.

$$\frac{(Index)_k - (Index)_{k-1}}{(Index)_{k-1}}(100\%)$$

The oil refinery business has been in the news a lot. The general inflation rate for this industry for the 2007 calendar year can be found using the producer price index (from www.bls.gov).

$$\begin{aligned} Est.Inflation &= \frac{(PPI)_{2007} - (PPI)_{2006}}{(PPI)_{2006}}(100\%) \\ &= \frac{267 - 241}{241}(100\%) = 11\% \end{aligned}$$

There are a lot of terms to know!

- *Actual dollars* (*A$*), also known as *current*, *nominal*, or *inflated* dollars, represent cash at the time it occurs.
- *Real dollars* (*R$*), also known as *constant* dollars, are dollars expressed in terms of the same purchasing power relative to a particular time.
- *General price inflation (or deflation) rate* (*f*), perhaps peculiar to particular business environment.

More terms to know.

- *Market (nominal) interest rate* (i_m) is the money paid for the use of capital, adjusted for anticipated general price inflation.
- *Real interest rate* (i_r) is the money paid for the use of capital, not adjusted for anticipated inflation (the *inflation-free* interest rate).
- *Base time period* (*b*) is the reference or base time period used to define the constant purchasing power of real dollars.

Actual dollars in year *k* can be converted into real dollars as of any base period by the relationship below.

$$\begin{aligned} (R\$)_k &= (A\$)_k \left(\frac{1}{1+f}\right)^{k-b} \\ &= (A\$)_k (P/F, f\%, k-b) \end{aligned}$$

It is important to use the correct dollar-type/interest-type combination. Otherwise, the results will be biased.

- When cash flow estimates are made using actual dollars, *A$*, the correct rate to use is the market interest rate, i_m (which is adjusted for inflation).
- When cash flow estimates are made using real dollars, *R$*, the correct rate to use is the real interest rate, i_r.

Relating the market interest rate and the real (inflation free) interest rate.

$$1 + i_m = (1 + f)(1 + i_r)$$

or

$$i_r = \frac{i_m - f}{1 + f}$$

Caution: Fixed and responsive annuities!

It is critical when performing engineering economic analyses that future cash flows be consistent, and perhaps converted, into either real or actual (constant) dollars, as appropriate, before performing the analysis.

Foreign exchange rates can alter purchasing power, and should be considered in analyses of multiple world economies with varying economic circumstances. As exchange rates vary, the value of goods in a particular currency will fluctuate. The rate is analogous to changes in the general inflation rate.

Let

i_{US} = rate of return in terms of a market interest rate relative to U.S. dollars

i_{fm} = rate of return in terms of a market interest rate relative to a foreign currency

f_e = annual devaluation rate between the foreign currency and the U.S. dollar (positive f_e is used when the foreign currency is devalued)

The relationship among these variables is

$$1 + i_{US} = \frac{1 + i_{fm}}{1 + f_e}$$

or

$$i_{fm} = i_{US} + f_e + f_e(i_{US})$$

and

$$i_{US} = \frac{i_{fm} - f_e}{1 + f_e}$$

The currency of the country of Albatross, the grickle, is devalued against the U.S. dollar by 8% per year. The rate of return on an investment relative to the grickle in Albatross is 12%. What is the equivalent return relative to the dollar?

$$\begin{aligned} i_{US} &= \frac{i_{fm} - f_e}{1 + f_e} \\ &= \frac{0.12 - 0.08}{1 + 0.08} \\ i_{US} &\approx 4\% \end{aligned}$$

Hedging foreign exchange risk

To hedge or not to hedge?

- **Investors can, in principle, perform any foreign exchange hedging that the corporation can. Consequently, the corporation need not devote resources to the elimination of diversifiable or hedgeable risk.**
- **Indeed, hedging might be counterproductive by harming the interests of shareholders.**

To hedge or not to hedge?

- **Similarly, a firm which takes over other firms in different industries might displease shareholders who can diversify their portfolio directly by purchasing shares themselves in those industries.**

To hedge or not to hedge?

When there are neither transactions costs, nor bankruptcy costs, shareholders with perfect information can undertake any hedging they feel necessary.

In short, a cogent argument can be made that the firm should not hedge foreign exchange risk - exposure to unexpected changes in the exchange rate.

However, the majority of international firms hedge foreign exchange risk selectively, if not completely.

To hedge or not to hedge?

- **A counterargument in favor of FOREX hedging is made by Ian Giddy*:**

Exchange-rate volatility may make earnings volatile and thus increase the probability of financial distress. If hedging reduces the nominal volatility of the firm's earnings, it will in turn reduce the expected value of the costs of financial distress (including bankruptcy) ... Some of these costs are borne by creditors, in which case a reduction in expected distress costs will reduce lenders' required rate of return. …

To hedge or not to hedge?

In addition, for a given level of debt, lower earnings volatility will entail a lower probability of a negative net worth. … Because currency matching reduces the probability of financial distress, it allows the firm to have greater leverage and therefore a greater tax shield. Thus, the greater the degree of bankruptcy-cost-hedging, the greater the value of the firm and the lower the cost of capital.(pp. 481-2).

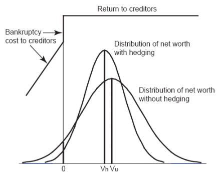
***Source: Ian H. Giddy, Global Financial Markets, © DC Heath and Company 1994, pp. 481-2.**

To hedge or not to hedge?

- **Thus, in comparison to the unhedged firm, the reduced costs of financial distress and the lowered borrowing costs may offset the costs of the hedges.**
- **Another way of putting the argument is that hedging reduces the market risk of a company. By hedging, a company's β is lower so its risk premium is lower.**
- **Thus the firm's expected net earnings would be discounted at a lower interest rate. However, expected earnings are reduced due to the costs of the hedges. Its net worth could be higher or lower.**

To hedge or not to hedge?

- The cost of hedging (according to Giddy).



- Hedging reduces the risk of bankruptcy and financial distress, but is likely to reduce the value of the firm by [V_u – V_h], the cost of hedging.

Hedging foreign exchange risk

- Hedging defined:
- A firm or an individual hedges by taking a position, such as acquiring a cash flow, an asset or a contract, that will rise (or fall) in value to offset a fall (or rise) in the value of an existing position.
- A *perfect* hedge is one eliminating the possibility of future gain or loss due to unexpected changes in the value of the existing position.

Transactions exposure

- A long position: When a firm has accounts receivable in foreign exchange at some time in the future, it is exposed to transactions exposure - losses or gains due to unexpected changes in the exchange rate.

Transactions exposure

The payoff from an unhedged long position, say accounts receivable in 90 days in euros.

- The expected exchange rate (pound price of the euro) in 90 days is given by F_{90},
- In 90 days, we will realize a spot rate, S_{90}.
- Consequently, the unanticipated change in the exchange rate or forecast error is indicated by:

$$[F_{90} - S_{90}]$$

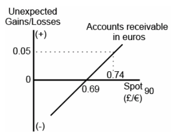
- This represents the gain (if positive) or the loss (if negative) per unit of the euro in which the firm has long foreign exchange exposure.

Transaction exposure

- If the firm is long 100,000 euros (accounts receivable, for example) the unhedged firm gains if the spot price of the euro is above the forward price upon receipt of the euros.

Payoff diagram for accounts receivable
(a long position in foreign exchange)

An unanticipated gain

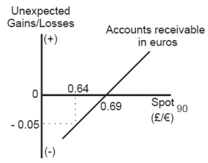


Transaction exposure

- If the spot price is less than the forward, the firm will lose: [F_{90} - S_{90}] 100,000 pounds.

Payoff diagram for accounts receivable
(a long position in foreign exchange)

An unanticipated loss

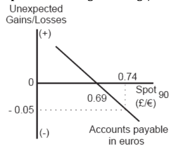


Transactions exposure

- If you are short euros (accounts payable, for example), you will lose [F_{90} - S_{90}] 100,000 pounds if the spot price is higher.

Payoff diagram for accounts payable
(a short position in foreign exchange)

An unanticipated loss

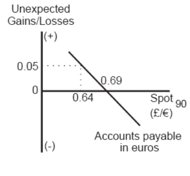


Transaction exposure

- If the spot price is lower, you will gain by not being hedged.

Payoff diagram for accounts payable
(a short position in foreign exchange)

An unanticipated gain

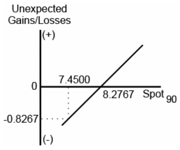


Transaction exposure

- Example: You are the owner of FU YANG FLYING EAGLE DUMPLINGS and have sold $100,000 worth of rice dumplings (*zongzi*) to a Chinese restaurant in San Francisco. You will be paid $100,000 in 90 days. Assume that the current spot exchange rate is 8.2767 yuan to the dollar. There is some risk that you may suffer a loss if you do not sell the accounts receivable in the forward market.
- Suppose, for example that the IMF and the US Treasury accomplish their goals of a yuan appreciation. You will lose in terms of yuan, should you not hedge.

Transaction exposure

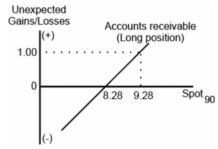
Here is the payoff diagram assuming a 10% revaluation of the yuan.



The unanticipated revaluation of the yuan has reduced the yuan value of your accounts receivable by -0.8267 yuan per dollar. Since you receive $100,000 in 90 days, their new value in yuan are only 7.45*100,000=745,000 yuan. In other words, you have lost (8.2767-7.4500)*100,000= 82,670 yuan.

Transaction exposure

An unexpected devaluation of the yuan, for example due to capital account liberalization, may increase the yuan value of your accounts receivable by 1.000 yuan per dollar. Since you receive $100,000 in 90 days, their new value in yuan are 9.28*100,000 =928,000 yuan. In other words, you might unexpectedly gain as depicted in the payoff diagram.



Hedging transaction exposure

Hedging FOREX exposure eliminates both the risk of losses, and the chance of gains from unexpected movements in the exchange rate.

There are several contractual hedges you may consider.

A forward hedge
A money market hedge
An options hedge

Here we ignore the transactions costs of the hedge, which are the commission on the forward sale and the receiving of the "bid" price of the dollar, which is lower than the "ask"

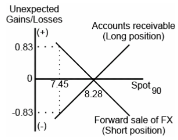
Hedging transaction exposure

1. **A forward market hedge – Sell the $100,000 forward for delivery at F90 , or 8.2767. When you receive the accounts payable, deliver the $100,000 to settle your forward contract.**

   If you sell the entire amount of your accounts receivable, you have a "perfect hedge" that eliminates all possibility of gain or loss from an unexpected change in the exchange rate.

Hedging transaction exposure

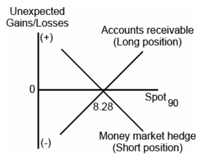
1. A forward market hedge



With a perfect hedge in the forward market you lose on one contract what you gain on the other. If the spot rate falls to 7.45 in 90 days, you lose 0.83 yuan per dollar of accounts receivable, but you gain 0.83 yuan per dollar on the forward sale contract.

Hedging transaction exposure

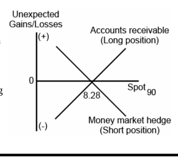
2. **A money market hedge – Borrow [$100,000/(1+ i/4)] to be repaid in 90 days. To settle the loan, you will pay interest and principal of exactly $100,000 from your receipt of accounts payable in 90 days.**



Hedging transaction exposure

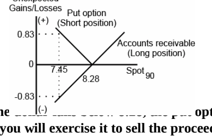
A money market hedge example: Borrow at 12% per annum for 90 days, a quarterly rate of 4%. That is, borrow [$100,000/(1.04)] =$96,153.85 for repayments in 90 days. Sell the proceeds spot to avoid acquiring a second long position in USD. To settle the loan, you pay principal of $96,153.85 and interest of $3,846.15, totaling $100,000 from your receipt of accounts payable.

Note: A money market hedge involves a loan agreement, borrowing in one currency selling the proceeds spot, keeping the loan obligation. Hedging repeated transactions is called "matching currency flows", which can be conveniently done via foreign exchange swaps.



Hedging transaction exposure

3. An options hedge: Purchase a put option with a strike or exercise price at 8.28 – at the money. You keepthe upside potential of appreciation of the dollar while eliminating downside risk for a premium, the cost of the option.



If the spot price of the ... option is "in the money" and you will exercise it to sell the proceeds from accounts receivable.

Hedging transaction exposure

Option hedge: If you were willing to accept some loss, you could instead purchase an "out of the money" put option, say at 8.20, which would be less expensive.

Hedging transaction exposure

There are other ways of avoiding exchange rate risk:

4. Currency invoicing – by selling your zongzi in yuan, you shift your foreign exchange risk to the importer. Since this passes the cost of hedging to the importer, you may have to settle for worse terms in your sale of rice dumplings.

Hedging transaction exposure

Other ways of avoiding exchange rate risk:

5. In the terms and conditions of a letter of credit, you may specify risk contingency clauses as to which party pays what amount when there is an unexpected change in the exchange rate.

Both parties can share in the exchange rate risk with a "currency contingency clause."

Operations exposure

Operating exposure measures the changes in the net present value of a firm due to unexpected changes in exchange rates.

It is a forward looking concept which re-estimates the discounted cash flow in foreign currency in terms of home currency for overseas operations following an unexpected change in the exchange rate.

Operations exposure

Parker Pen's European operations involve both the production and sale of pens in the European Community. It has a partial natural hedge in that its direct costs of production are in euros. When the dollar price of the euro rises, both expected revenues and costs in euros rise by the same percent.

Operations exposure

However, if the cash flow in euros is positive, the euro appreciation adds to earnings in dollars. When the dollar price of the euro falls, expected net earnings in euros suffer a fall in value in terms of dollars.

This is known as operating exposure.

Hedging operations exposure

However, the firm can make economic decisions in its operations to offset the effect of the change in the exchange rate on its earnings translated into dollars.

Table 4.1 illustrates the effect of an unanticipated euro devaluation from 0.7435 euros per dollar to one euro per dollar on January 1, 2007 on expected cash flows in euros and dollars from operations of Parker Pen's French subsidiary, Parker Pen, Europe, S.A.

Hedging operations exposure

An unexpected euro depreciation

Table 4.3 Parker Pens, Europe: Unexpected euro depreciation

Expected cash flow (2007)		
Cash flow from operations in euros	€	3,000,000
Existing exchange rate ($ per €)	$	1.2878
Cash flow from operations in dollars at existing exchange rate	$	3,863,490
New exchange rate ($ per €)	$	1.0000
Cash flow from operations at new exchange rate in dollars	$	3,000,000
Expected gain or loss from unanticipated change in exchange rate	$	(863,490)

With no change in the business plan, an unexpected translation loss of $863 million takes place.

Hedging operations exposure

However, management has an opportunity to adjust the business plan to offset these losses. It needs to increase its sales revenues in euros by approximately 28.9% to offset the decline in the value of the euro. The change in the business plan can involve:

- A rise in the profit margin in euros by raising prices
- A rise in revenues in euros by expanding the volume of output, or
- A combination of higher prices and increased output

Hedging operations exposure

By a combination of higher pricing and increased production in light of a depreciated euro, the new business plan could eliminate unanticipated losses from the exchange rate.

Table 4.4 Parker Pens, Europe Changes in operations to offset exchange rate exposure

Expected cash flow (2007)		
Cash flow from operations in euros	€	3,863,490
New exchange rate ($ per €)	$	1.0000
Cash flow from operations at new exchange rate in dollars	$	3,863,490
Expected gain or loss from unanticipated change in exchange rate	$	-

The key is to raise net earnings in euros by the percentage of the depreciation.

Hedging operations exposure

An unexpected euro appreciation
Table 4.5 illustrates unanticipated gains from a euro appreciation from $1.2878 to $1.500 per euro.

Table 4.5 Parker Pens, Europe : Unexpected euro appreciation

Expected cash flow (2007)		
Cash flow from operations in euros	€	3,000,000
Existing exchange rate ($ per €)	$	1.2878
Cash flow from operations in dollars at existing exchange rate	$	3,863,490
New exchange rate ($ per €)	$	1.5000
Cash flow from operations at new exchange rate in dollars	$	4,500,000
Expected gain or loss from unanticipated change in exchange rate	$	636,510

Parker Pen, Europe could expand its operations in Europe to profit from the increased euro appreciation.

diversification

Management can also diversify the firm's operations and financing in order to reduce operating exposure. Common techniques are:

1. Diversifying operations: Parker Pens, N.Y. has shifted the production or assembly of its pens to France, purchasing parts and hiring labor there. Its pens are paid for in euros on a regular basis, Parker uses the euros from its sales to pay for parts, assembly, distribution and after-sales service on a matching basis. This is a natural hedge.

diversification

Example of diversifying operations:

Japanese automobile firms have managed their foreign exchange risk by opening plants in the United States. Their dollar revenues can be used in part to pay wages, rents, salaries, and other operational expenses in dollars.

The decline in yen revenue due to dollar devaluation is offset in large part by the decline in costs when reckoned in yen. Net income, however, is still adversely affected.

Hedging operations exposure

Risk-shifting by currency invoicing

By invoicing in U.S. dollars, Parker, N.Y. could in principle shift the foreign currency exposure to the wholesale purchasers from the French affiliate.

However, the shifting of the foreign exchange exposure to the wholesale purchasers, may cost Parker Pens, N.Y. the contract since it imposes currency risk on the wholesalers. They may shift to a French source of supply that invoices in euros.

Hedging operations exposure

Risk-sharing by currency contingency clauses

In the terms and conditions of a letter of credit, a risk-sharing currency clause may pass part of the currency risk onto the foreign importer. For instance, if the pound declines by more than 10% between today and settlement for exports of a Boeing aircraft, the British airline may agree in advance to pay 5% more pounds for the plane at settlement.

Thus, at settlement, the British airline pays 5% more in pounds and Boeing, receives 5% less in dollars if the pound declines 10%.

Hedging operations exposure

Leads and lags in currency payments

A firm can purchase dollars with pesos before they depreciate, then pay its dollar liability early.

Similarly, it can delay paying its "soft" currency liabilities by lagging the payment so as to purchase the soft currency after it loses value.

That is, it delays its payment, waiting to purchase the peso at a lower rate.

Hedging operations exposure

Reinvoicing centers

A reinvoicing center manages operating exposure in one center. Manufacturing affiliates ship goods directly to distribution affiliates, but invoice the reinvoicing center who then receives title to the goods and invoices the distribution affiliate in a separate currency.

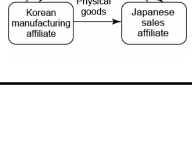
Transactions exposure thus resides in the reinvoicing center. The invoicing center thus centralizes the net exposure to each currency.

A reinvoicing center could also transfer profits from a high tax affiliate to a low tax affiliate, i.e. practice aggressive transfer pricing.

Hedging operations exposure

A reinvoicing center

The diagram depicts the flow of invoices and payments to a reinvoicing center that centralizes and nets foreign exchange exposure.



Hedging operations exposure

Matching currency flows - Natural hedges: A firm that has an ongoing inflow of foreign currency as accounts receivable, can borrow the same currency so as to have a matching accounts payable (interest and principal) as a natural hedge.

Hedging operations exposure

A foreign currency swap

One counterparty borrows under specific terms and conditions in one currency while the other counterparty borrows under different terms and conditions in a second currency. Each party borrows according in the currency of their comparative advantage.

The two counterparties then agree to service each other's debt.

Hedging operations exposure

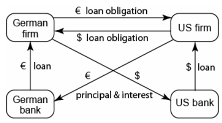
A foreign currency swap

For instance, a German firm borrows euros, a US firm borrows dollars, and they exchange the interest and principal payments, agreeing to service each other's debt.

The swap enables both firms to have lower borrowing costs in foreign currency.

Hedging operations exposure

A foreign currency swap:



A U.S. firm may have euro receipts from its exports and a German firm may have dollar receipts from its exports. Each borrows in its currency of comparative advantage, and swap the loan obligation.

Hedging operations exposure

A foreign currency swap:

A currency swap is a way of managing foreign exchange risk. Each firm pays principal and interest in the foreign currency in which their export receipts are denominated.

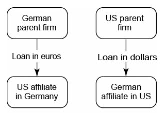
The loan payment is thus an offsetting matching currency flow – ongoing export receipts in foreign currency are used to pay ongoing interest and principal on the foreign currency loan.

Swap dealers usually intermediate currency swaps to avoid the problem of double coincidence of loan wants.

Hedging operations exposure

Back-to-back or parallel loans

Indirect financing can be done by a German firm lending euros to the US affiliate in Germany and simultaneously a US firm lending dollars to the German affiliate in the United States.



Hedging operations exposure

Back-to-back or parallel loans

The firms do not go through a swap dealer, so they do not pay the bid-ask spreads. They also benefit from lowered interest rates. In short, they save intermediation costs and benefit from comparative advantage in lending.

At the same time, the parallel loan hedges their foreign exchange risk.

Hedging operations exposure

Back-to-back or parallel loans

Naturally, there is counterparty risk, but the right of offset exists. In case of default by one of the counterparties, the other has the right to stop servicing the defaulting party's original debt.

Conclusion

A firm's free cash flow from overseas operations is subject to exchange rate risk.

By changing economic variables, purchasing contracts, or seeking offsetting matching currency flows, a firm can hedge against exchange rate losses.

Relationships among Inflation,Interest Rates, and Exchange Rates

Chapter Objectives

- To explain the purchasing power parity (PPP) and international Fisher effect (IFE) theories, and their implications for exchange rate changes; and
- To compare the PPP, IFE, and interest rate parity (IRP) theories.

Purchasing Power Parity (PPP)

- When a country's inflation rate rises relative to that of another country, decreased exports and increased imports depress the high-inflation country's currency.
- Purchasing power parity (PPP) theory attempts to quantify this inflation – exchange rate relationship.

Interpretations of PPP

- The absolute form of PPP is an extension of the law of one price. It suggests that the prices of the same products in different countries should be equal when measured in a common currency.
- The relative form of PPP accounts for market imperfections like transportation costs, tariffs, and quotas. It states that the rate of price changes should be similar.

Rationale behind PPP Theory

Suppose U.S. inflation > U.K. inflation.

$\Rightarrow \uparrow$ U.S. imports from U.K. and
$\downarrow$ U.S. exports to U.K.

$\Rightarrow$ Upward pressure is placed on the £.

This shift in consumption and the £'s appreciation will continue until

❶ in the U.S.: $\text{price}_{\text{U.K. goods}} \geq \text{price}_{\text{U.S. goods}}$

❷ in the U.K.: $\text{price}_{\text{U.S. goods}} \leq \text{price}_{\text{U.K. goods}}$

Derivation of PPP

Assume that PPP holds.

Over time, inflation occurs and the exchange rate adjusts to maintain PPP:

$P_h \rightarrow P_h(1 + I_h)$

where P_h = **home country's price index**
I_h = **home country's inflation rate**

$P_f \rightarrow P_f(1 + I_f)(1 + e_f)$

where P_f = **foreign country's price index**
I_f = **foreign country's inflation rate**
e_f = **foreign currency's % Δ in value**

Derivation of PPP

PPP holds $\Rightarrow P_h = P_f$ and

$$\mathbf{P_h(1 + I_h) = P_f(1 + I_f)(1 + e_f)}$$

Solving for e_f: $e_f = \dfrac{(1 + I_h)}{(1 + I_f)} - 1$

$I_h > I_f \Rightarrow e_f > 0$ i.e. foreign currency appreciates

$I_h < I_f \Rightarrow e_f < 0$ i.e. foreign currency depreciates

Example: Suppose $I_{\text{U.S.}}$ = 9% and $I_{\text{U.K.}}$ = 5% .

Then $e_{\text{U.K.}} = \dfrac{(1 + .09)}{} - 1 =$

3.81%

Simplified PPP Relationship

When the inflation differential is small, the PPP relationship can be simplified as

$$e_f \cong I_h - I_f$$

Example: Suppose $I_{\text{U.S.}}$ = 9% and $I_{\text{U.K.}}$ = 5% .

Then $e_{\text{U.K.}} \cong 9 - 5 = 4\%$

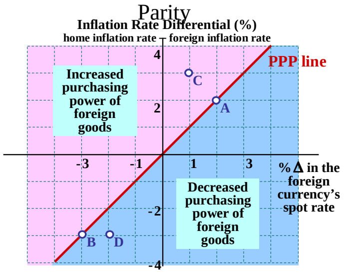
U.S. consumers: $\Delta P_{\text{U.S.}} = I_{\text{U.S.}} = 9\%$

$\mathbf{\Delta P_{\text{U.K.}} = I_{\text{U.K.}} + e_{\text{U.K.}} = 9\%}$

U.K. consumers: $\Delta P_{\text{U.K.}} = I_{\text{U.K.}} = 5\%$

$\mathbf{\Delta P_{\text{U.S.}} = I_{\text{U.S.}} - e_{\text{U.K.}} = 5\%}$

Graphic Analysis of Purchasing Power Parity



Testing the PPP Theory

Conceptual Test

- Plot actual inflation differentials and exchange rate % changes for two or more countries on a graph.
- If the points deviate significantly from the PPP line over time, then PPP does not hold.

Testing the PPP Theory

- Empirical studies indicate that the relationship between inflation differentials and exchange rates is not perfect even in the long run.
- However, the use of inflation differentials to forecast long-run movements in exchange rates is supported.
- A limitation in the tests is that the choice of the base period will affect the result.

Why PPP Does Not Occur

PPP does not occur consistently due to:

❶ confounding effects

- Exchange rates are also affected by differences in inflation, interest rates, income levels, government controls and expectations of future rates.

❷ a lack of substitutes for some traded goods

PPP in the Long Run

- PPP can be tested by assessing a "real" exchange rate over time.
  - The real exchange rate is the actual exchange rate adjusted for inflationary effects in the two countries of concern.
- If the real exchange rate follows a random walk, it cannot be viewed as being a constant in the long run. Then PPP does not hold.

International Fisher Effect (IFE)

- According to the Fisher effect, nominal risk-free interest rates contain a real rate of return and anticipated inflation.
- If all investors require the same real return, differentials in interest rates may be due to differentials in expected inflation.
- Recall that PPP theory suggests that exchange rate movements are caused by inflation rate differentials.

International Fisher Effect (IFE)

- The international Fisher effect (IFE) theory suggests that currencies with higher interest rates will depreciate because the higher nominal rates reflect higher expected inflation.
- Hence, investors hoping to capitalize on a higher foreign interest rate should earn a return no higher than what they would have earned domestically.

International Fisher Effect (IFE)

Investors Residing in	Attempt to Invest in	I_h	I_f	e_f	i_f	Return in Home Currency	I_h	Real Return Earned
Japan	Japan	3%	3%	0%	5%	5%	3%	2%
	U.S.	3	6	-3	8	5	3	2
	Canada	3	11	-8	13	5	3	2
U.S.	Japan	6	3	3	5	8	6	2
	U.S.	6	6	0	8	8	6	2
	Canada	6	11	-5	13	8	6	2
Canada	Japan	11	3	8	5	13	11	2
	U.S.	11	6	5	8	13	11	2
	Canada	11	11	0	13	13	11	2

Derivation of the IFE

- According to the IFE, $E(r_f)$, the expected effective return on a foreign money market investment, should equal r_h, the effective return on a domestic investment.
- $r_f = (1 + i_f)(1 + e_f) - 1$
  - i_f = interest rate in the foreign country
  - e_f = % change in the foreign currency's value
- $r_h = i_h$ = interest rate in the home country

Derivation of the IFE

- Setting $r_f = r_h$: $(1 + i_f)(1 + e_f) - 1 = i_h$
- Solving for e_f : $e_f = \frac{(1 + i_h)}{(1 + i_f)} - 1$
- $i_h > i_f \Rightarrow e_f > 0$ i.e. foreign currency appreciates
  $i_h < i_f \Rightarrow e_f < 0$ i.e. foreign currency depreciates

Example: Suppose $i_{U.S.} = 11\%$ and $i_{U.K.} = 12\%$.
Then $e_{U.K.} = \frac{(1 + .11)}{(1 + .12)} - 1 = -.89\%$

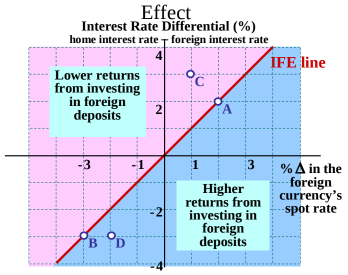
Derivation of the IFE

- When the interest rate differential is small, the IFE relationship can be simplified as

$$e_f \cong i_h - i_f$$

- If the British rate on 6-month deposits were 2% above the U.S. interest rate, the £ should depreciate by approximately 2% over 6 months. Then U.S. investors would earn about the same return on British deposits as they would on U.S. deposits.

Graphic Analysis of the International Fisher Effect



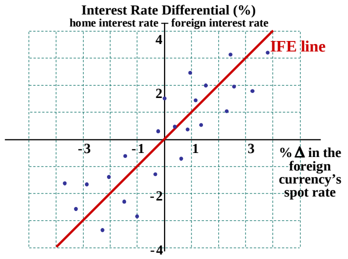
Graphic Analysis of the IFE

- The point of the IFE theory is that if a firm periodically tries to capitalize on higher foreign interest rates, it will achieve a yield that is sometimes above and sometimes below the domestic yield.
- On average, the yield achieved by the firm would be similar to that achieved by another firm that makes domestic deposits only.

Tests of the IFE

- If actual interest rates and exchange rate changes are plotted over time on a graph, we can see whether the points are evenly scattered on both sides of the IFE line.
- Empirical studies indicate that the IFE theory holds during some time frames. However, there is also evidence that it does not hold consistently.

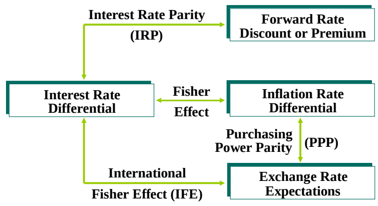
Tests of the International Fisher Effect



Why the IFE Does Not Occur

- Since the IFE is based on PPP, it will not hold when PPP does not hold.
- In particular, if there are factors other than inflation that affect exchange rates, exchange rates may not adjust in accordance with the inflation differential.

Comparison of the IRP, PPP, and IFE Theories



Comparison of the IRP, PPP, and IFE Theories

Interest rate parity

Forward rate premium p
Interest rate differential $i_h - i_f$

$$p = \frac{(1+i_h)}{(1+i_f)} - 1 \cong i_h - i_f$$

Purchasing power parity

% Δ in spot exchange rate e_f
Inflation rate differential $I_h - I_f$

$$e_f = \frac{(1+I_h)}{(1+I_f)} - 1 \cong I_h - I_f$$

International Fisher effect

% Δ in spot exchange rate e_f
Interest rate differential $i_h - i_f$

$$e_f = \frac{(1+i_h)}{(1+i_f)} - 1 \cong i_h - i_f$$