

Lecture 4

- Basis Relationships
- Absence of Arbitrage
- Cash and Carry Arbitrage
- Covered Interest Arbitrage

Basis Relationships

Generally, basis is the difference between two prices

- ▣ Study of basis relationships was important in analysis of derivative securities prior to the financial futures 'revolution' (see Lecture 1)
- ▣ Hieronymous, *The Economics of Futures Trading* (1977) is an excellent example of the traditional approach

Types of Basis

Reading RSD, p.191-200

- Location Basis, e.g., the Vancouver-Thunder Bay Canola basis (see Fig. 3.6-7)
- Quality Basis, e.g., Columbian-Brazilian coffee basis (see Fig. 3.5)
- Maturity Basis and Delivery Basis

Figure 3.7 Cash Prices for Canadian Grain

GRAIN

BY PARRISH and HEIMBECKER

(Prices quoted in tonnes)

Domestic 1 CW 13.5 wheat, Thunder Bay, 187.24, Export 1 CW 13.5 wheat, St. Lawrence, 235.86, Export 1 CW durum, St. Lawrence, 289.28.

Domestic milling wheat — CIF Bayports: 1 CW durum wheat 270.21, 1 CW 14.5 wheat 236.23, 1 CW 13.5 wheat 208.24, 2 CW 13.5 wheat 200.93, 1 CW 12.5 wheat 206.93; 2 CW 12.5 wheat 198.38.

FEEDING GRADES

Sample wheat DGC 119.20; 3 CW oats 140.50; 1 CW barley 112.00, 1 feed screening 108.00.

ONTARIO GRAIN

Approximate bid price track shipping point.

2 white oats 115.00; Ontario feed oats 90.00; Ontario barley 95.00; 2 winter wheat milling 169.58, 2 soybeans 273.10, 2 rye 100.00; 2 yellow corn 129.82; 3 yellow corn 128.63.

WINNIPEG CASH PRICES

Feed oats: 1 cw 106.40; 2 cw 106.40; 3 cw 104.40; mixed grain oats; 94.40.

Feed barley (Thunder Bay): 1 cw 94.90; 2 cw 92.90; mixed grain barley 84.90.

Rye: 1 cw 112.60; 2 cw; 110.60; 3 cw 82.60.

Flax: 1 cw 271.60; 2 cw 269.60; 3 cw 236.60.

Canola: In store Thunder Bay No. 1 Canada 473.60; In store Vancouver No. 1 Canada 481.30.

Feed Wheat: 3 red spring: 109.70; Can Feed: 103.70.

WHEAT BOARD

Export wheat, St. Lawrence: 1 cw 13.5 pct; 235.86; 1 cw 11.5 pct; 225.26; 2 cw 13.5 pct; 230.26; 2 cw 11.5 pct; 220.26; 3 cw 220.26; 1 durum 294.37; 2 durum 289.53; 3 durum 284.53.

Malting barley (domestic), Thunder Bay: Special Select 6-row; 169.00; Select 6-row 166.50; Special Select 2-row; 176.00; Select 2-row 173.50.

Source: Globe and Mail, Monday, August 8, 1994.



Figure 3.6 Cash Prices for Oil

OIL PRICES

Monday August 8, 1994.			
CRUDE GRADES	Mon	Fri Yr. Ago	
OFFSHORE-d			
European "spot" or free market prices			
Arab lt.	h16.25	16.55	13.95
Arab hvy.	h15.05	15.35	11.55
Iran, lt.	h17.30	17.60	14.90
Forties	h17.95	18.15	16.60
Brent	h17.85	18.15	16.50
Bonny lt.	h18.05	18.35	16.95
Urals-Medit.	h17.05	18.55	14.85

DOMESTIC-f

Spot market

W. Tex. Int Cush			
(1775-1875) (Sep)	h19.40	19.30	17.55
W.Tx.sour, Midl (1550-1740) ..	h18.50	18.40	15.65
La. sw. St.Ja (1750-1870)	h19.50	19.35	17.80
No. Slope del USGULF	hn17.75	17.65	15.80

Open-market crude oil values in Northwest Europe around 17:50 GMT in dlrs per barrel, for main loading ports in country of origin for prompt loading, except as indicated.

REFINED PRODUCTS

Fuel Oil, No. 2 NY gal.	g.4975	.4905	.4790
Diesel Fuel, 0.05 S.			
NY harbor low sulfur	g.5100	.5010	n.a.
Gasoline, unded, premium			
NY gal.	g.7110	.7145	.6145
Gasoline, unded, reg.			
NY gal.	g.5915	.5880	.5345
Propane, Mont Belvieu,			
Texas, gal.	g na	.3040	.3065

Butane, normal, Mont Belvieu,

Texas, gal.	g na	.3540	.3615
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RAW PRODUCTS

Natural Gas

Henry Hub, \$ per mmbtu .	g1.57 1/2	1.65	n.a.
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a-Asked, b-Bld, c-Corrected, d-as of 11 a.m. EST in North-west Europe, f-As of 4 p.m. EST, Refiners' posted buying prices are in parentheses, g-Provided by Telerate Systems, h-Dow Jones International Petroleum Report, n.a.-Not available, z-Not quoted, n-Nominal, r-Revised.

Source: *Wall Street Journal*, Monday, August 8, 1994.



Fig 3.5

CASH PRICES

Monday, August 8, 1994.
(Closing Market Quotations)
GRAINS AND FEEDS¹

	Mon	Fri Yr. Ago	
Barley, top-quality Mpls., bu	2.30-.50	2.50	2.35
Bran, wheat middlings, KC ton	63.-65.0	63.-65.0	53.00
Corn, No. 2 yel. Cent. Ill. bu	bp2.11	2.09½	2.23½
Corn Gluten Feed, Midwest, ton ..	88.-95.0	88.-95.0	78.00
Cottonseed Meal,			
Ciksdle, Miss. ton	140-142½	140.00	172.50
Hominy Feed, Cent. Ill. ton	60.00	60.00	58.00
Meat-Bone meal, 50% pro. Ill. ton ..	192.50	192.50	n.a.
Oats, No. 2 milling, Mpls., bu	1.39¼-44¼	1.38½-43½	1.61¼
Sorghum, (Milo) No. 2 Gulf cwt ...	4.30	4.26	4.36
Soybean Meal,			
Cent. Ill., 44% protein-ton	164-168	163½-67½	206.00
Soybean Meal,			
Cent. Ill., 48% protein-ton	177-181	176½-80½	218.00
Soybeans, No. 1 yel Cent.-Ill. bu ..	bp5.60	5.58	6.57½
Wheat,			
Spring 14%-pro Mpls. bu	3.77¼-82¼	3.77¼-82¼	4.91¼
Wheat, No. 2 sft red, St. Lou. bu ...	bp3.17½	3.17½	3.02½
Wheat, No. 2 hard KC, bu	3.54¼	3.54¼	3.24¼
Wheat, No. 1 sft wht, del Port Ore	3.51	3.52	3.41

FOODS

Beef, Carcass, Equiv. Index Value,			
choice 1-3,550-700lbs.	103.60	103.75	111.60
Beef, Carcass, Equiv. Index Value,			
select 1-3,550-700lbs.	95.85	96.40	108.05
Broilers, Dressed "A" NY lb	x.5330	.5373	.5690
Broilers, 12-Cty Comp Wtd Av .....	.5385	.5379	.5985
Butter, AA, Chgo., lb. ....	.75½	.75½	.78
Cocoa, Ivory Coast, smetric ton ...	g1.627	1.667	1.176
Coffee, Brazilian, NY lb.	n1.74	1.97	.64½
Coffee, Colombian, NY lb.	n1.84	c2.05	.80½
Eggs, Lge white, Chgo doz. ....	.60-.65	.60-.65	.69½
Flour, hard winter KC cwt	9.40	9.40	9.95
Hams, 17-20 lbs, Mid-US lb fob ....	.53	.53	.63½
Hogs, Iowa-S. Minn. avg. cwt	43.25	43.25	48.00
Hogs, Omaha avg cwt	44.00	43.50	47.50
Pork Bellies, 12-14 lbs Mid-US lb ...	.42-.44	.39-.42	.47½
Pork Loins, 14-18 lbs. Mid-US lb ...	1.16-.17	1.16-.17	1.11
Steers, Tex.-Okla. ch avg cwt	70.50	z	76.75
Steers, Feeder, Okl Cfy. av cwt ...	89.50	88.50	97.50
Sugar, cane, raw, world, lb. fob ...	.1187	.1196	.0949

FATS AND OILS

Coconut Oil, crd, N. Orleans lb. ...	xxn.29¼	.29½	.22½
Corn Oil, crd wet mill, Chgo. lb. ...	n.25	.25	.21
Corn Oil, crd dry mill, Chgo. lb. ...	n.28¼	.28¼	.21½
Grease, choice white, Chgo lb.	n.16¼	.16¼	.14
Lard, Chgo lb.	n.18¼	.18¼	.15½
Palm Oil, ref. bl. deod. N. Orf. lb. ...	n.30	.28	.20
Soybean Oil, crd, Decatur, lb. ....	.2454	.2468	.2354
Tallow, bleachable, Chgo lb.	n.18¼	.18¼	.15¼
Tallow, edible, Chgo lb.	n.19	.19	.16

FIBERS AND TEXTILES

Burlap, 10 oz 40-in NY yd	n.2750	.2750	.2400
Cotton 1 1/16 str lw-md Mphs lb ...	.6985	.7087	.5423
Wool, 64s, Staple, Terr. del. lb.	2.30	2.30	1.37

METALS

Aluminum			
Ingot lb. del. Midwest	q.69-.71	.69-.71	.56½
Copper			
cathodes lb.	p1.11	1.11	.90
Copper Scrap, No 2 wire NY lb	h.87½	.87½	.65½
Lead, lb.	q.36988	.38150	.33½
Mercury 76 lb. flask NY	q200.00	200.00	185.00
Steel Scrap 1 hvy mlt Chgo ton	135.-138.	135.-138.	112.50
Tin composite lb.	q3.4652	3.4752	3.3252
Zinc Special High grade lb.	p.46500	.46500	.44750

MISCELLANEOUS

Rubber, smoked sheets, NY lb. ...	n.66¼	.65	.43¼
Hides, hvy native steers lb., fob ...	.89	.89	.79

PRECIOUS METALS

Gold, troy oz			
Engelhard indust bullion	378.89	379.59	363.00
Engelhard fabric prods	397.83	398.57	402.15
Handy & Harman base price	377.60	378.30	381.70
Handy & Harman fabric price ..	379.10	379.80	z
London fixing AM 377.70 PM ...	377.60	378.30	381.70
Krugerrand, whol	a384.00	384.50	385.50
Maple Leaf, troy oz.	a390.00	390.50	397.00
American Eagle, troy oz.	a390.00	390.50	397.00
Platinum, (Free Mkt.)	406.00	410.50	394.50
Platinum, indust (Engelhard)	408.00	411.00	396.00
Platinum, fabric prd (Engelhard) ...	508.00	511.00	496.00
Palladium, indust (Engelhard) ...	152.00	152.00	141.00
Palladium, fabric prd (Engelhard) ...	167.00	167.00	156.00
Silver, troy ounce			
Engelhard indust bullion	5.140	5.175	4.730
Engelhard fabric prods	5.551	5.589	5.108
Handy & Harman base price	5.130	5.160	4.720
Handy & Harman fabric price ...	5.156	5.186	z
London Fixing (in pounds)			
Spot (U.S. equiv. \$5.1130)	3.3165	3.3670	3.1260
3 months	3.3590	3.4100	3.1705
6 months	3.4085	3.4605	3.2140
1 year	3.5225	3.5835	3.2920
Coins, whol \$1,000 face val	a3,643	3,673	3,397

a-Asked. b-Bid. bp-Country elevator bids to producers.
c-Corrected. d-Dealer market. e-Estimated. f-Dow Jones International Petroleum Report. g-Main crop. ex-dock, warehouses, Eastern Seaboard, north of Hatteras. h-Reuters. i-f.o.b. warehouse. k-Dealer selling prices in lots of 40,000 pounds or more. f.o.b. buyer's works. n-Nominal. p-Producer price. q-Metals Week. r-Rail bids. s-Thread count 78x54. x-Less than truckloads. z-Not quoted. xx-f.o.b. tankcars.

Source: Wall Street Journal, Monday, August 8, 1994.



Basis Definitions

- **The Basis:** $F(t, T) - S(t)$
- **The Futures Basis:** $F(t, T) - F(t, N)$

Notice that as t changes, then the carrying charges embedded in the basis will decline due to the reduction in $(T-t)$ while the carrying charges in the futures basis will not decline because $(T-N)$ does not change

More on the Futures Basis

- ▣ **Definitions Applicable to the Futures Basis**

- ▣ Contango: $F(t, T) - F(t, N) > 0$

Example: Gold

- ▣ Backwardation: $F(t, T) - F(t, N) < 0$

Example: Tbonds

Do not confuse this with the Normal
Backwardation Hypothesis for the **Yield** curve

More Basis Definitions

- **The Future Basis:** $F(0, T) - S(T)$
also could be $F(1, T) - S(1)$

Unlike the other types of basis, there is no agreed upon terminology for this basis.

This basis has to do with the accuracy of the forward/futures price as a predictor of the future spot price. (Reading RSD, p.165-171)

Absence of Arbitrage

- What is an arbitrage?

An *arbitrage* opportunity is defined here as: ***a riskless trading strategy that generates a positive profit with no net investment of funds.***

Key words: riskless and trading strategy.

No Arbitrage Condition

- A fundamental *theoretical* requirement of pricing in financial markets is that there is

NO ARBITRAGE OPPORTUNITIES

In terms of the profit function, this condition is expressed as $\pi_{arb} < 0$ (can also be a weak inequality)

Some Possible Confusions

- Do not confuse the **No Arbitrage Condition** where $\pi_{arb} < 0$ with the profit function for a speculative trade where $\pi(1) > 0$ is the desired result.
- The arbitrage profit function is time dated as $B_{arb}(0)$ to reflect all variables in the profit function being known at $t=0$ (needed for riskless trading)

Types of Arbitrage

- The type of arbitrage that is most important in the analysis of derivative securities is the *cash and carry arbitrage*.
- Other types of arbitrage include:
 - Triangular Arbitrage* (RSD, p.237)
 - Geographical Arbitrage* – price of goods in different locations differ only by the cost of purchasing and transporting, e.g., cement.

History of Arbitrage

- On the history of the concept and definition of arbitrage see Poitras, *Early History of Financial Economics 1478-1776*, p.243-7.
- The word arbitrage has a Latin root, e.g., 'arbitrio' in Italian and initially referred to trading strategies aimed at profiting from differences in exchange rates.
- Arbitrage was active in 16th C. Antwerp and has roots in antiquity.

Cash and Carry Arbitrage

- ▣ Reading: RSD, p.213-220.
- ▣ The Cash and Carry Arbitrage is the fundamental arbitrage applicable to derivative securities traded on **storable commodities**.
- ▣ Key Point: there are two arbitrages for any derivative contract – the **short arbitrage** and the **long arbitrage**.

What are Perfect Capital Markets?

Various presentations of perfect capital markets are available, with different versions emphasizing elements that are of importance to the argument at hand. One particularly complete set is provided in Haley and Schall (1979).

A.1 Costless capital markets: No capital market transactions costs (including commissions and bid/offer spreads), no government restrictions which interfere with capital market transactions, and the costless ability to make financial assets infinitely divisible.

A.2 Neutral Taxes: There are no personal or corporate taxes.

A.3 Competitive Markets: There are many perfect substitutes for all securities of a firm at any point in time and there is no discrimination in the pricing of these securities such that any security can be acquired at the same market price by all investors. In addition, firms and investors are price takers in investing, borrowing and lending activities.

A.4 Equal Access: Investors and firms can borrow, lend and issue claims on the same terms. This assumption requires that borrowing and lending rates be equal.

A.5 Homogeneous Expectations: All capital market participants have the same expectations about relevant random variables.

A.6 No Information Costs: Firms and individuals have the same available information and this information is acquired at zero cost.

A.7 No Costs of Financial Distress: Firms and individuals incur no costs of financial distress or bankruptcy such as legal costs and disruption of operations. This assumption does not rule out the possibility of bankruptcy.

The Case of Gold

- The short and long arbitrages are referenced to the position in the spot commodity
- The long gold arbitrage (RSD, p.216) involves borrowing money to buy gold and simultaneously selling the gold for forward delivery
- Solving the profit function for the long arbitrage gives:
$$F(0, T) < S(0) \{1 + r(0, T)\}.$$

Figure 4.1: Profit Function for a Long Gold Cash-and-Carry Arbitrage

<i>DATE</i>	<i>Cash Position</i>	<i>Futures Position</i>
$t=0$	Borrow $\$[Q_G S(0)]$ at interest rate $r(0,T)$ and buy Q_G ounces of gold at $S(0)$ for storage until $t=T$	Short Q_G units at $F(0,T)$
-- The cash gold position provide no pecuniary return between $t=0$ and $t=T$		
$t=T$	Deliver the Q_G units against the maturing futures contract and use the proceeds to repay the maturity value of the loan, $\$[Q_G S(0)]\{1 + r(0,T)\}$	

In this case, the profit function can be specified:

$$\pi(0) \leq \{F(0,T) - S(0)(1 + r(0,T))\} Q_G$$

More on the Gold Arbitrage

- The long arbitrage provides an *upper bound* on gold forward prices while the short arbitrage provides a *lower bound*
- Solving the profit function for the short arbitrage:
$$F(0, T) > S(0) \{1 + i(0, T)\}$$

Notice that $i(0, T)$ is an investing rate and $r(0, T)$ is a borrowing rate

Figure 4.2: Profit Function for a Short Gold Cash-and-Carry Arbitrage

<i>DATE</i>	<i>Cash Position</i>	<i>Futures Position</i>
$t=0$	Borrow Q_G ounces and sell at $S(0)$. Invest the funds received at interest rate $i(0, T)$	Long Q_G ounces at $F(0, T)$
$t=T$	Take delivery of the Q_G units against the maturing futures contract, pay with the proceeds of the investment, $\$[Q_G S(0)] \{1 + i(0, T)\}$, returning the Q_G units to settle the short position	

In this case, the profit function can be specified:

$$\pi(0) = \{S(0)(1 + i(0, T)) - F(0, T)\} Q_G$$

Cash and Carry Arbitrage Condition for Gold

- Under perfect markets assumptions, lending and borrowing rates will be equal ($i = r$) and the short and long arbitrage restrictions reduce to the cash and carry arbitrage condition for gold:

$$F(0, T) = S(0) \{1 + r(0, T)\}$$

Gold forward/ futures prices will be in contango.
Examine the NYMEX/COMEX prices on CME website (also RSD, Fig. 4.1, p.217)

Solving for the Gold Futures-Futures Condition

- In the case of gold, if

$$F(t, T) = S(t) \{1 + r(t, T)\} \text{ and } F(t, N) = S(t) \{1 + r(t, N)\}$$

Then dividing $F(t, T)$ by $F(t, N)$ gives:

$$F(t, T) = F(t, N) \{1 + r(t, T-N)\}$$

Where:

$$1 + r(t, T-N) = \{1 + r(t, T)\} / \{1 + r(t, N)\}$$

For example if 0 to T is 6 months and 0 to N is 3 months, then $1 + r(t, T-N)$ is a 3 month interest rate that starts at N and matures at T

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Futures Options

Trade Date: Monday, 22 May 2017 (Final)

All market data contained within the CME Group website should be considered as a reference only and should not be used as validation against, nor as a complement to, real-time market data feeds. Settlement prices on instruments without open interest or volume are provided for web users only and are not published on Market Data Platform (MDP). These prices are not based on market activity.

Month	Open	High	Low	Last	Change	Settle	Estimated Volume	Prior Day Open Interest
MAY 17	1251.7	1255.3B	1251.7	1255.3B	+8.0	1260.7	14	23
JUN 17	1257.5	1262.6	1251.6	1260.5	+7.8	1261.4	206,134	184,463
JLY 17	1259.0	1263.3	1253.3	1262.0	+7.8	1263.0	450	1,045
AUG 17	1260.0	1265.8	1254.8	1263.8	+8.0	1264.8	45,561	151,864
OCT 17	1262.2	1269.2	1259.2	1267.3	+8.1	1268.2	1,448	7,169

2017 Metals Options Expiration Calendar

About Gold

Gold futures are hedging tools for commercial producers and users of gold. They also provide global gold price discovery and opportunities for portfolio diversification. In addition, they:

- Offer ongoing trading opportunities, since gold prices respond quickly to political and economic events
- Serve as an alternative to investing in gold bullion, coins, and mining stocks

Things to know about the contracts:

- Physically delivered
- Block-trade eligible
- American-style options

Solving for the General Futures-Futures Condition with Implied carry ($ic(t, T)$)

- Gold is unusual in having **no carry return**, either pecuniary or a non-pecuniary convenience yield
- More generally, the relationship between spot and futures/forward prices has both **carry cost** ($cc(t, T)$) and a **carry return** ($cr(t, T)$) $\rightarrow ic(t, T) = cc(t, T) - cr(t, T)$

- ***This produces the general results:***

$$F(t, T) = S(t) \{1 + ic(t, T)\}$$

$$F(t, T) = F(t, N) \{1 + ic(t, T-N)\}$$

METALS AND PETROLEUM

COPPER-HIGH (CMX) — 25,000 lbs.; cents per lb.

Aug	108.60	108.60	108.25	108.30	+	1.65	116.00	75.30	159
Sept	107.25	109.10	107.25	108.60	+	1.75	116.90	74.90	25,595
Oct				108.75	+	1.65	115.05	75.20	623
Nov	109.00	109.00	108.90	108.95	+	1.60	112.80	77.75	513
Dec	107.70	109.40	107.70	108.95	+	1.50	115.20	75.75	12,617
Ja96	108.80	108.80	108.80	108.70	+	1.45	111.30	76.90	341
Feb				108.45	+	1.40	111.30	87.85	245
Mar	107.90	108.50	107.80	108.25	+	1.40	113.70	76.30	2,492
Apr				107.90	+	1.35	110.40	90.10	143
May	106.70	107.90	106.70	107.55	+	1.35	111.40	76.85	1,062
June				107.15	+	1.30	107.30	106.70	100
July	107.05	107.05	107.05	106.75	+	1.30	112.50	78.00	814
Sept				105.95	+	1.30	110.05	79.10	621
Dec				105.15	+	1.30	109.00	88.00	853
Mr96				104.15	+	1.30	105.00	99.20	134

Est vol 12,000; vol Fri 10,861; open int 46,371, -1,025.

GOLD (CMX) — 100 troy oz.; \$ per troy oz.

Aug	377.00	377.80	376.40	376.70	-	.60	415.00	341.50	1,107
Oct	379.80	380.00	379.10	379.30	-	.60	417.00	344.00	10,661
Dec	382.60	383.10	381.90	382.30	-	.60	426.50	343.00	91,590
Fb95	386.00	386.30	385.70	385.70	-	.60	411.00	363.50	11,195
Apr				389.00	-	.60	425.00	385.50	6,497
June	392.10	392.20	392.10	392.30	-	.60	430.00	351.00	10,014
Aug				395.90	-	.60	412.50	380.50	4,191
Oct				399.50	-	.60	413.30	401.00	1,077
Dec	403.30	403.30	403.30	403.20	-	.60	439.50	358.00	4,807
Fb95				407.00	-	.60	424.50	412.50	1,249
Apr				410.90	-	.60	430.00	418.30	1,141
June				414.90	-	.60	447.00	370.90	2,865
Dec				427.40	-	.60	447.50	379.60	2,696
Ju97				440.20	-	.60	456.00	436.00	1,168
Dec				453.20	-	.60	477.00	402.00	1,392
Ju98				466.80	-	.80	489.50	483.90	1,553
Dec				480.30	-	1.00	505.00	468.00	1,388

Est vol 14,000; vol Fri 25,886; open int 154,591, +394.

SILVER (CMX) — 5,000 troy oz.; cents per troy oz.

Aug				510.3	-	4.0	558.0	525.0	0
Sept	512.0	514.5	510.5	511.3	-	4.0	590.5	376.5	73,304
Dec	519.0	521.5	517.5	518.3	-	4.0	597.0	380.0	29,258
Mr95	529.0	529.0	526.0	526.0	-	4.0	604.0	416.5	6,751
May				531.3	-	4.0	606.5	418.0	3,834
July	539.0	539.0	539.0	536.9	-	4.0	610.0	403.0	3,279
Sept	545.0	545.0	545.0	542.8	-	4.0	615.0	493.0	647
Dec	553.0	553.0	553.0	552.0	-	4.0	628.0	434.0	2,114
JI96				574.4	-	4.0	630.0	524.0	943
Dec	596.0	596.0	596.0	592.0	-	4.0	670.0	454.0	1,238
JI97				618.5	-	4.0	655.0	588.0	483
Dec				639.2	-	4.0	695.0	502.0	307
Dec98				688.5	-	4.0	731.0	694.0	107

Est vol 14,000; vol Fri 16,133; open int 122,386, -1,126.



Covered Interest Arbitrage

- The cash and carry arbitrage for currencies is given a special name: ***covered interest arbitrage***.
- Covered interest arbitrage is based on the notion that, ***in markets where arbitrage is active and unrestricted, securities that differ only by currency of denomination should exhibit fully hedged returns that are approximately equal***

History and Background

- Historically, forward trading of currencies was usually bundled together with a loan to form a **bill of exchange** – money is borrowed (lent) in one location, in a given currency, and repaid (redeemed) in another location using a different currency. Reading: Poitras (2000, ch.7)
- Reading on covered interest arbitrage:
History, RSD, p.224-6; Arbitrage Trades, **RSD, p.226-40.**
(those unfamiliar with CIP go over example on p.227-8).

A Stylized Example of Covered Interest Arbitrage

Patrick Yamada, a trader in the foreign exchange department of Sanwa Bank, Singapore office, specializes in arbitraging U.S. dollars against Deutschemarks. He observes the following rates at 9:10 am Singapore time:

Spot rate: $\text{DM}1.8200 = \$1.0000$

Three Month Forward Rate: $\text{DM}1.8000 = \$1.0000$

Yamada can borrow or invest U.S. dollars for three months at 9% per annum or Deutschemarks for three months at 5% per annum. He has a borrowing limit of \$5,000,000 or the equivalent in DM.

- a) Ignoring transactions costs, how can Yamada make a riskless arbitrage profit? Assume that Yamada desires to take any profits in dollars.
- b) If the dollar three month interest rate on US dollars were 10%, instead of 9%, all other factors remaining the same, would Yamada still make a profit using the strategy outlined in a)? If not, is there another set of transactions which would provide an arbitrage profit?
- c) If the transactions costs in a) or b) were above \$7000 and were to be paid out of final proceeds, would this change the strategies described in a) or b)?



Solution to Yamada's Stylized Arbitrages

a) Yamada can make an arbitrage profit by doing a *long (DM)* covered interest arbitrage. The arbitrage is short because it involves borrowing in US and investing in DM. This arbitrage involves the following sequence of transactions which will all be executed at 9:10 am Singapore time:

Borrow \$5,000,000 for three months. In three months time, the amount owing on this borrowing will be: $(\$5 \text{ mil})(1 + (.09/4)) = \$5,112,500$

Exchange the \$5 mil. at the spot exchange rate to get $(\$5 \text{ mil})(1.82) = 9.1 \text{ mil DM}$.

Invest the 9.1 mil. DM for three months. In three months time, the investment will mature to a value: $(9.1 \text{ mil})(1 + (.05/4)) = 9,213,750 \text{ DM}$

Sell the maturing value of the DM investment for US dollars using a three month forward exchange contract. At the quoted forward exchange rate of 1.8, the DM investment will produce $(9,213,750/1.8) = \$5,118,750$

In three months time, the DM investment will mature and the proceeds delivered on the forward exchange contract. The proceeds of the forward contract will be used to settle the maturing three month loan producing an arbitrage profit of $\$5,118,750 - \$5,112,500 = \$6250$.

b) If the US interest rate is 10%, instead of 9%, then the cost of the US\$ borrowing would be $(5 \text{ mil})(1 + (.1/4)) = \$5,125,000$. Because this exceeds the covered return which could be received on the DM investment, the short arbitrage would not be profitable. However, in the absence of transactions costs, it would now be possible to do the *long* arbitrage, which would involve borrowing in DM and investing in the US. In this case the profit would be $\$5,125,000 - \$5,118,750 = \$6250$.

c) The presence of a \$7000 transaction cost would prevent either the long or the short arbitrage from being executed. This illustrates the point that covered interest arbitrage only provides upper and lower boundaries on the available combinations of interest rates and exchange rates that are consistent with absence of arbitrage at a specific point in time.

NOTE: In actual practice, the presence of transaction costs dictates that the spot and forward transactions will combined into one transaction, a foreign exchange swap.



Figure 4.4 Selected Foreign Exchange Rates

	CROSS RATES								
	Canadian dollar	U.S. dollar	British pound	German mark	Japanese yen	Swiss franc	French franc	Dutch guilder	Italian lira
Canada dollar	—	1.3797	2.1289	0.8735	0.013610	1.0362	0.2550	0.7777	0.000875
U.S. dollar	0.7248	—	1.5430	0.6331	0.009864	0.7510	0.1648	0.5637	0.000634
British pound	0.4697	0.6481	—	0.4103	0.006393	0.4867	0.1198	0.3653	0.000411
German mark	1.1448	1.5795	2.4372	—	0.015581	1.1863	0.2919	0.8903	0.001002
Japanese yen	73.48	101.37	156.42	64.18	—	76.14	18.74	57.14	0.064291
Swiss franc	0.9651	1.3315	2.0545	0.8430	0.013135	—	0.2461	0.7505	0.000844
French franc	3.9216	5.4106	8.3486	3.4255	0.053373	4.0635	—	3.0498	0.003431
Dutch guilder	1.2858	1.7741	2.7374	1.1232	0.017500	1.3324	0.3279	—	0.001125
Italian lira	1142.86	1576.80	2433.03	998.29	15.554286	1184.23	291.43	888.80	—

Mid-market rates in Toronto at noon, Aug. 8, 1994. Prepared by the Bank of Montreal Treasury Group.

		\$1 U.S. in Cdn.\$ =	\$1 Cdn. in U.S.\$ =			Cdn. \$ per unit	U.S. \$ per unit
U.S./Canada spot		1.3797	0.7248	Fiji	Dollar	0.9548	0.6920
1 month forward		1.3808	0.7242	Finland	Markka	0.2662	0.1929
2 months forward		1.3818	0.7237	France	Franc	0.2550	0.1848
3 months forward		1.3827	0.7232	Greece	Drachma	0.00578	0.00419
6 months forward		1.3862	0.7214	Hong Kong	Dollar	0.1786	0.1294
12 months forward		1.3973	0.7157	Hungary	Forint	0.01258	0.00912
3 years forward		1.4457	0.6917	Iceland	Krona	0.01972	0.01429
5 years forward		1.4917	0.6704	India	Rupee	0.04397	0.03187
7 years forward		1.5622	0.6401	Indonesia	Rupiah	0.000636	0.000461
10 years forward		1.6547	0.6043	Ireland	Punt	2.1068	1.5270
Canadian dollar	High	1.3083	0.7644	Israel	N Shekel	0.4531	0.3284
in 1994:	Low	1.3990	0.7148	Italy	Lira	0.000875	0.000634
	Average	1.3712	0.7293	Jamaica	Dollar	0.04415	0.03200
				Jordan	Dinar	1.9852	1.4388
				Lebanon	Pound	0.000824	0.000597
				Luxembourg	Franc	0.04245	0.03077
				Malaysia	Ringgit	0.5345	0.3874
				Mexico	N Peso	0.4074	0.2953
				Netherlands	Guilder	0.7777	0.5637
				New Zealand	Dollar	0.8340	0.6045
				Norway	Krone	0.1999	0.1449
				Pakistan	Rupee	0.04519	0.03275
				Philippines	Peso	0.05276	0.03824
				Poland	Zloty	0.0000603	0.0000437
				Portugal	Escudo	0.00859	0.00623
				Romania	Leu	0.0008	0.0006
				Russia	Ruble	0.000661	0.000479
				Saudi Arabia	Riyal	0.3679	0.2667
				Singapore	Dollar	0.9164	0.6642
				Slovakia	Koruna	0.0437	0.0317
				South Africa	Rand	0.3821	0.2770
				South Korea	Won	0.001719	0.001246
				Spain	Peseta	0.01062	0.00770
				Sudan	Dinar	0.0445	0.0322
				Sweden	Krona	0.1787	0.1295
				Switzerland	Franc	1.0362	0.7510
				Taiwan	Dollar	0.0524	0.0380
				Thailand	Baht	0.0553	0.0401
				Trinidad, Tobago	Dollar	0.2475	0.1794
				Turkey	Lira	0.0000441	0.0000320
				Venezuela	Bollivar	0.00812	0.00589
				Zambia	Kwacha	0.002090	0.001515
				European Currency Unit		1.5701	1.2105
				Special Drawing Right		1.9950	1.4460

Country	Currency	Cdn. \$ per unit	U.S. \$ per unit
Britain	Pound	2.1289	1.5430
1 month forward		2.1294	1.5421
2 months forward		2.1297	1.5412
3 months forward		2.1297	1.5402
6 months forward		2.1320	1.5380
12 months forward		2.1385	1.5304
Germany	Mark	0.8735	0.6331
1 month forward		0.8739	0.6329
3 months forward		0.8751	0.6329
6 months forward		0.8787	0.6339
12 months forward		0.8891	0.6363
Japan	Yen	0.013510	0.009864
1 month forward		0.013550	0.009836
3 months forward		0.013728	0.009928
6 months forward		0.013873	0.010008
12 months forward		0.014211	0.010170
Algeria	Dinar	0.0436	0.0316
Antigua, Grenada and St. Lucia	E.C. Dollar	0.5119	0.3711
Argentina	Peso	1.38205	1.00170
Australia	Dollar	1.0213	0.7402
Austria	Schilling	0.12403	0.08990
Bahamas	Dollar	1.3797	1.0000
Barbados	Dollar	0.6933	0.5025
Belgium	Franc	0.04245	0.03077
Bermuda	Dollar	1.3797	1.0000
Brazil	Real	1.509519	1.094092
Bulgaria	Lev	0.0258	0.0187
Chile	Peso	0.003281	0.002378
China	Renminbi	0.1604	0.1162
Cyprus	Pound	2.8744	2.0833
Czech Rep	Koruna	0.0490	0.0355
Denmark	Krona	0.2220	0.1609
Egypt	Pound	0.4076	0.2954

The U.S. dollar closed at \$1.3772 in terms of Canadian funds, down \$0.0095 from Friday. The pound sterling closed at \$2.1201, down \$0.0182.

In New York, the Canadian dollar closed up \$0.0050 at \$0.7261 in terms of U.S. funds. The pound sterling was down \$0.0026 to \$1.5394.

see:

Mail, Monday, August 8, 1994.

[o first page](#)



Exchange Rates and the Domestic Country

- To implement the **covered interest parity condition** it is necessary to identify which country is the domestic and which is the foreign. (See RSD, Fig. 4.2)
- Observe that FX rates can be quoted in ratio form either as $\text{\$/US}/\text{\$/C} = .7497$ or $\text{\$/C}/\text{\$/US} = 1.3339$ – the currency on top in the FX ratio is the domestic currency
- Note: different methods are used to quote the FX rate (e.g., in East Asia the convention is reversed).

Figure 4.9 Money Market Interest Rates

MONEY RATES

ADMINISTERED RATES

Bank of Canada	5.70%
Canadian prime	7.25%

MONEY MARKET RATES

(for transactions
of \$1-million or more)

3-mo. T-bill(when-issued)	5.58%
1-month treasury bills	5.21%
2-month treasury bills	5.40%
3-month treasury bills	5.50%
6-month treasury bills	6.10%
1-year treasury bills	7.20%
10-year Canada bonds	9.03%
30-year Canada bonds	9.18%
1-month banker's accept.	5.46%
2-month banker's accept.	5.56%
3-month banker's accept.	5.61%
Commercial Paper (R-1 Low)	
1-month	5.60%
2-month	5.68%
3-month	5.73%
Call money	5.25%

Supplied by Dow Jones
Telerate Canada

UNITED STATES

NEW YORK (AP) — Money
rates for Monday as reported by
Telerate Systems Inc:

Telerate interest rate index:
4.820

Prime Rate: 7.25

Discount Rate: 3.50

Broker call loan rate: 6.00

Federal funds market rate:

High 4.375, low 4.3125, last
4.3125

Dealers commercial paper:

30-180 days: 4.48-5.15

Commercial paper by fi-
nance company: 30-270 days:
4.43-4.71

Bankers acceptances dealer
indications: 30 days, 4.45; 60
days, 4.64; 90 days, 4.77; 120
days, 4.86; 150 days, 5.05; 180
days, 5.12

Certificates of Deposit Pri-
mary: 30 days, 3.40; 90 days,
3.85; 180 days, 4.23

Certificates of Deposit by
dealer: 30 days, 4.47; 60 days,
4.67; 90 days, 4.80; 120 days,
4.91; 150 days, 5.12; 180 days,
5.21

Eurodollar rates: Overnight,
4.25-4.375; 1 month, 4.50-4.5625;
3 months, 4.8125-4.875; 6
months, 5.25-5.3125; 1 year,
5.75-5.8125

London Interbank Offered
Rate: 3 months, 4.75; 6 months,
5.1875; 1 year, 5.5625

Treasury Bill auction results:
average discount rate: 3-month
as of Aug. 8: 4.43; 6-month as of
Aug. 8: 4.93

Treasury Bill, annualized rate
on weekly average basis, yield
adjusted for constant maturity,
1-year, as of Aug. 1: 5.51

Treasury Bill market rate, 1-
year: 5.29-5.27

Treasury Bond market rate,
30-year: 7.53

The Short Arbitrage Condition

- The **short** condition refers to borrowing in the domestic currency and lending offshore, fully covering the currency exposure.

The arbitrage profit function for the short arbitrage:

$$B_s(0) = F(0, 1)\{Q/S(0)\}(1+r^*) - Q(1+r) < 0$$

Here, r is a borrowing rate and r^* is a lending rate.

Figure 4.5: Short Covered Interest Arbitrage Trade

At $t=0$

US asset	Exchange Market	Foreign (Canadian) asset
Borrow $\$Q$ for 1 year at $r(0,1)$	Buy $\$Q/S(0)$ Canadian dollars, spot	Invest $\$Q/S(0)$ for 1 year at $r^*(0,1)$
	Sell $(\$Q/S(0))(1+r^*(0,1))$ Canadian dollars forward at $F(0,1)$	

At $t=1$ Use the funds from the maturing foreign asset to settle the forward exchange position by paying the foreign currency and receiving US dollars. Use these dollars to settle the US dollar loan.

where: $F(0,1)$ = the 1 year forward exchange rate in US direct terms; $S(0)$ = the spot exchange rate in US direct terms; $r(0,1)$ = the domestic (US) interest rate on a 1 year zero coupon security (quoted on a 365 day basis); $r^*(0,1)$ = the foreign (Canadian) one year interest rate (quoted on a 365 day basis).

The Long Arbitrage Condition

- The long arbitrage involves borrowing offshore and investing domestic, fully covering the currency exposure.

- The long arbitrage condition is:

$$B_L(0) = Q (1+y) - F(0,1)\{Q/S(0)\}(1+y^*) < 0$$

Here y is an investing rate and y^* is a borrowing rate.

Foreign Exchange Swaps

- The discussion of covered interest arbitrage assumes that the trader will do a spot exchange transaction and (simultaneously) a forward exchange transaction to cover the future currency exposure
- As discussed in Lecture 2 (see RSD, Fig. 1.4) in practice, to reduce transactions costs, these two trades are done as one trade known as a **foreign exchange swap**.

Figure 4.7: Short Forward-Forward Arbitrage

At $t=0$

US (Domestic) Market

Borrow $\$Q(1+r^*(0,N))$
at $r(0,T)$

Invest $Q\$(1+r^*(0,N))$
at $r(0,N)$

Exchange Market

Sell US\$ forward
 $Q\$(1+r^*(0,N))(1+r(0,N))$
at $F(0,N)$

Buy US\$ forward
 $(\$Q/F(0,N))(1+r(0,N))(1+r^*(0,T))$
at $F(0,T)$

Foreign Market

Borrow $(\$Q/F(0,N))(1+r(0,N))$
at $r^*(0,N)$

Invest $(\$Q/F(0,N))(1+r(0,N))$
at $r^*(0,T)$

At $t=N$

The US investment will mature to give $\$Q(1+r^*(0,N))(1+r(0,N))$ that is used to deliver on the forward position that matures at $t=N$. The amount of foreign currency received will be $(\$Q/F(0,N))(1+r^*(0,N))(1+r(0,N))$ which is the amount owing on the foreign borrowing maturing at $t=N$. *The cash flows at $t=N$ all cancel.*

At $t=T$

The T period foreign investment will mature to $(\$Q/F(0,N))(1+r(0,N))(1+r^*(0,T))$. This amount is delivered against the forward contract to obtain US\$ which can be used to settle the loan. The resulting US\$ cash flow will have to be less than or equal to the maturing value of the US\$ T period loan in order to ensure absence of arbitrage opportunities.



Covered Interest Parity

- Observing that the long (short) arbitrage condition bounds the forward rate above (below), imposing perfect market assumptions produces the **covered interest parity condition**:

$$F(0, T) = \frac{1 + r(0, T)}{1 + r^*(0, T)} S(0)$$

- Exercise: Solve this equation for $r(0, T)$ on the lhs to provide a more revealing connection to the terminology ‘covered interest parity’.

Solving for the Covered Parity Condition

The solution demonstrates that the domestic interest rate ($r(0, T)$) is equal to the fully hedged foreign rate interest rate ($r^*(0, T)$) where the second term on rhs is the cost of hedge

$$F(0, T) = \frac{1 + r(0, T)}{1 + r^*(0, T)} S(0) \quad \rightarrow \quad \frac{F(0, T)}{S(0)} = \frac{1 + r(0, T)}{1 + r^*(0, T)}$$

$$\frac{F(0, T)}{S(0)} - 1 = \frac{1 + r(0, T)}{1 + r^*(0, T)} - 1 \quad \rightarrow \quad \frac{F(0, T)}{S(0)} - 1 = \frac{1 + r(0, T)}{1 + r^*(0, T)} - \frac{1 + r^*(0, T)}{1 + r^*(0, T)}$$

$$\frac{F(0, T)}{S(0)} - 1 = \frac{r(0, T) - r^*(0, T)}{1 + r^*(0, T)} = \frac{F(0, T) - S(0)}{S(0)}$$

$$\rightarrow \quad r(0, T) = r^*(0, T) + (1 + r^*(0, T)) \frac{F(0, T) - S(0)}{S(0)}$$

What is the $ic(0,T-N)$ for CIP?

$$\begin{aligned} F(0,T) &= \frac{1 + r(0,T-N)}{1 + r^*(0,T-N)} F(0,N) = \left(1 + \frac{1 + r(0,T-N)}{1 + r^*(0,T-N)} - 1 \right) F(0,N) \\ &= \left(1 + \frac{1 + r(0,T-N)}{1 + r^*(0,T-N)} - \frac{1 + r^*(0,T-N)}{1 + r^*(0,T-N)} \right) F(0,N) \\ &= \left(1 + \frac{r - r^*}{1 + r^*(0,T-N)} \right) F(0,N) = (1 + \theta) F(0,N) \end{aligned}$$



Contango versus Backwardation in Currency Future and Forwards

For $F(0, T) = (1 + \theta) F(0, T)$

If $r(0, T-N) > r^*(0, T-N)$ then $\theta > 0$ and futures price term structure is in contango for CME futures prices (where US is the domestic)

Example: US rates are above Yen rates

If $r(0, T-N) < r^*(0, T-N)$ then $\theta < 0$ and futures price term structure is in backwardation

Example: US rates are below Aussie rates

Japanese Yen Futures Settlements

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Month	Open	High	Low	Last	Change	Settle	Estimated Volume	Prior Day Open Interest
JUN 17	90265	90570	89965	90335	+205	90520	140,731	204,641
JLY 17	90405	90695B	90110A	90485A	+200	90650	392	29,400
AUG 17	90245	90805B	90220A	90595A	+200	90760	162	10,000
SEP 17	90645	90945B	90355A	90730A	+205	90900	3,668	8,290
OCT 17	-	-	-	-	+205	91020	0	0
DEC 17	90865	91285	90800A	91145A	+200	91310	10	28,000
MAR 18	-	91685B	91310A	91660A	+205	91765	0	7,000
JUN 18	-	92160B	91795A	92160B	+195	92230	0	21,000
SEP 18	-	-	92390A	92395B	+200	92755	0	0
DEC 18	-	-	-	-	+200	93290	0	0
MAR 19	-	-	-	-	+205	93830	0	0
JUN 19	-	-	-	-	+205	94385	0	0
SEP 19	-	-	-	-	+200	95020	0	0
DEC 19	-	-	-	-	+200	95665	0	0

[first page](#)

Australian Dollar Futures Settlements

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Month	Open	High	Low	Last	Change	Settle	Estimated Volume	Prior Day Open Interest
JUN 17	.7458	.7473	.7422	.7430	-.0031	.7432	88,031	125,431
JLY 17	.7440	.7469B	.7420A	.7425A	-.0031	.7429	56	498
AUG 17	.7445	.7466B	.7418A	.7422A	-.0031	.7426	14	319
SEP 17	.7450	.7463B	.7413	.7419B	-.0030	.7423	953	2,958
OCT 17	-	-	-	-	-.0030	.7421	0	0
DEC 17	.7413	.7449B	.7409A	.7413	-.0030	.7415	78	158
MAR 18	-	-	.7412A	.7412A	-.0030	.7408	0	0
JUN 18	-	-	-	-	-.0030	.7402	0	14
SEP 18	-	-	-	-	-.0030	.7396	0	0
DEC 18	-	-	-	-	-.0029	.7391	0	0
MAR 19	-	-	-	-	-.0029	.7385	0	0
JUN 19	-	-	-	-	-.0028	.7379	0	0
SEP 19	-	-	-	-	-.0028	.7370	0	0
DEC 19	-	-	-	-	-.0028	.7360	0	0

Last Updated: Wednesday, 31 May 2017 06:00 PM

[About This Report](#)

[first page](#)



Sample Midterm Question #1c)

- On March 1, 1990 the spot and 3 month forward rates for the Canadian dollar (per US dollar) were \$1.1922 and \$1.2072 respectively. What "risk-free" discount rate on U.S. dollar instruments would be consistent with the interest-rate-parity theorem if the 3 month (annualized) risk-free rate on Canadian dollar instruments was 13.10%?
- Use the CIP equation to solve. Remember that US discount rates have to be converted from the true yield (this is BUS 315).

What interest rate for the CIP equation?

- Examine Money Rates in RSD, Fig. 4.4 and the money rate handouts from WSJ and Fin. Post. Observe there are a number of possible money market interest rates that could be used in the CIP formula: **treasury bills, commercial paper, eurodollars and bankers' acceptances.**
- Midterm Question #1b) asks which of these rates is most appropriate. (Review from BUS 315, also RSD, p.238-9)

See Slides in lecture 4 .zip file for Board of Governors BofG_interest-rate.pdf) and Bank of Canada (419_bofc_wfs.pdf) information on money market and other fixed income markets (too big to get on slides).

Money Market Securities

- In deciding which rate is appropriate, consider the execution of the covered interest arbitrage trades.
- Treasury bills – the actively quoted securities are issued by **federal governments** – is it possible to borrow in this market?
- Commercial paper – unsecured liabilities issued by **corporations** – two types: corporate paper and financial paper

Money Market Securities (cont'd)

- Corporate commercial paper is typically a program-based borrowing that has an allowable maximum borrowing limit and involves a dealer making markets in the security.
- Though there is some flexibility in altering amounts outstanding, commercial paper is not a security that can be used to rapidly access large amounts of funds for arbitrage.

Money Market Securities (cont'd ..)

- Bankers' acceptances are a secured liability issued by financial institutions, secured by an underlying goods transaction. (Mexican pancho example in class used to illustrate.)
- Like commercial paper, it is difficult to rapidly increase the amount of bankers' acceptances outstanding to exploit arbitrage opportunities.

Eurodollars and CIP

- What entities are the most important in the market for spot and forward exchange? The large international banking institutions, e.g., Citibank, Lloyds Bank, RBC, JPM Chase, etc.
- Where do these entities go to borrow (lend) large sums of funds at short notice? The **eurodeposit** market. The key US\$ **borrowing** rate in this market is LIBOR: the (L)ondon (I)nter(b)ank (O)ffer (R)ate → SOFR (see readings on webpage).

More on Eurodollars

- A eurodollar deposit is an unsecured, non-negotiable liability issued in the (Eurodeposit) interbank market by an international financial institution.
- Access to the interbank market is restricted to large international financial institutions that regularly operate in this market.
- Do not confuse the “Euro” currency with the Eurodeposit market – the borrowing rate in Euros is **Euribor**.

Sample Midterm Question #1d)

- The covered interest arbitrage discussion on RSD, p.231-40 (and the associated covered interest parity condition) assumes that money market securities are being used.
- Key features of money market securities: **zero coupon; maturities of one year and less.**
- Where the forward rate is for more than one year then the arbitrage involves coupon securities (RSD, p.245-51)