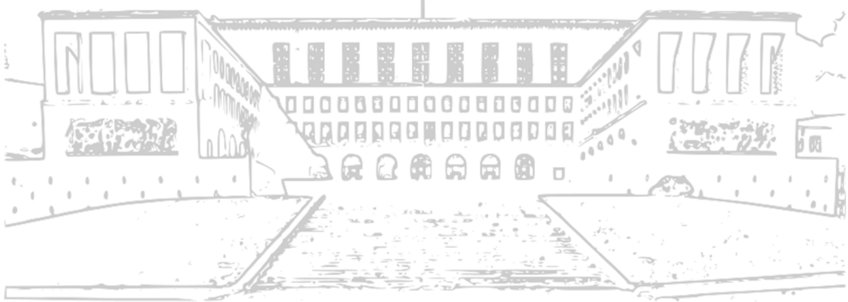
FINANCIAL MARKETS AND INSTITUTIONS

INTEREST RATES

A.Y. 2016/2017

Prof. Alberto Dreassi – adreassi@units.it



DEAMS
University of Trieste

AGENDA

- Measures
- Real and nominal IR
- IR and returns
- Demand/supply and liquidity preference
- Models of asset pricing
- Risk and IR
- Term structure

MEASURES OF IR

- Timing, kind and amount of cash-flows differ
- Comparability requires present (discounted) value, since today's value of a future cash-flow is smaller (could be invested, gives up current consumption, exposes to risks, …):

$$PV = \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t}$$

- Or, with only one CF at maturity *n*:

$$PV = \frac{CF}{(1+i)^n}$$

- This derives from future value's calculation (depending on maturity):
  - Simple interest rates (M<1y): $FV = PV \cdot (1 + i \cdot n)$
  - Compound interest rates (M>1y): $FV = PV \cdot (1+i)^n$

MEASURES OF IR

Types of credit market instruments:

- Simple/balloon loan: principal is repaid entirely at maturity with interests
- Fixed-payment (fully amortised) loan: repayment occurs periodically and represents interests and a portion of principal
- Coupon bond: repayments of interests occur periodically, whereas principal (face/par/nominal value) is repaid entirely at maturity
- Discount (zero-coupon) bond: no coupons are paid, therefore the present (purchase) value is under its face value, that is repaid entirely at maturity

Variations exist (f.i. variable IR, adjustable maturities, different amortisation plans, etc.)

MEASURES OF IR

Different measures of value for IR exist, however a common tool is the yield to maturity:

- the IR that balances the PV of future cash-flows with its current value
- For simple loans, YTM equals the simple interest rate
- For ZC bonds: $i_{YTM} = \sqrt[n]{\frac{NV}{CV}} - 1$
- For fixed-payment loans and coupon bonds, calculation is more complex (usually solved through *goal-seek* and similar spreadsheet functions):

$$CV_{FP} = \sum_{t=1}^{n} \frac{FP}{(1+i_{YTM})^t}$$

$$CV_{CB} = \sum_{t=1}^{n} \frac{C}{(1+i_{YTM})^t} + \frac{NV}{(1+i_{YTM})^n}$$

- Note that the greater the YTM, the smaller the current value, meaning that increases in IR reduce the value of a debt instrument

MEASURES OF IR

What if we do not have a maturity date?

- this debt instrument is called perpetuity (or consol)
- only interest cash-flows are periodically paid
- some algebra on previous equations leads to:

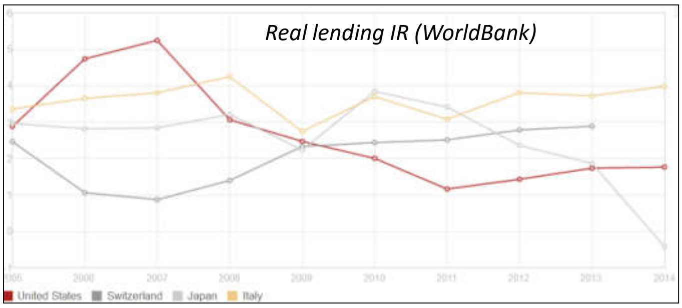
$$CV_P = \frac{C}{i_{YTM}} \Rightarrow i_{YTM} = \frac{C}{CV_P}$$

- if we compare the coupon to the price of a regular coupon bond (current yield), it proxies the interest rate especially for long-term bonds, that get similar to perpetuities

$$i_{cy} = \frac{C}{P_t}$$

REAL AND NOMINAL IR

- YTM is a nominal measures of IR (inflation is not considered)
- Inflation influences the future goods and services that can be bought in the future with a nominal amount of money
- Ex-ante real IR are adjusted for the expected change in price level to reflect the effective cost of borrowing $i_r = i - \pi^e$
- Ex-post real IR, instead, consider actual changes in inflation and can measure performances after a financial transaction expires
- Effective real IR should also consider taxation (on both lenders and borrowers)



NEGATIVE IR???

- Paying to lend money?
  - Central banks: ECB -0.2% on deposits in 9/2014 (but also DEN, SWE, CH)
  - Governments: DE from -0.4% to 0 for 1m-8y bonds (but also NED, SWE, DEN, CH, AUT), with FIN and DE issuing bonds with negative IR from inception on 2/2015
  - Corporations: Nestlé for its 4y € bonds in 2/2015, f.i.
- Should be good if you are a borrower?
  - Maybe, unless people keep money at home
  - Maybe, unless this shrinks profitability of commercial banks
  - Maybe, until this triggers a currency war
- Does it make any sense?
  - Real IR mostly do, considering negative inflation (deflation)
  - Storing money, building wealth reserves, accessing settlement services: all cost
  - A number of bonds give access to CB lending, increasing their demand
  - Taxation applies on nominal interest rates

IR AND RETURNS

- Rate of return: payments to the owner of a security plus the change in its value as a fraction of its purchase price
- IR and RoR are related but usually differ because of capital gains:

$$RoR = \frac{C + P_{t+1} - P_t}{P_t} = \frac{C}{P_t} + \frac{P_{t+1} - P_t}{P_t} = i_c + g$$

- If holding period equals time to maturity, return equals yield to maturity only for ZCs: reinvestment risk
- The bigger the time to maturity, the bigger the effect on capital gains due to changes in IR: longer term bonds are more volatile (interest-rate risk)
- Increasing IR produces capital losses, decreasing IR produces gains
- Despite capital gains and losses are unrealised, they represent missed opportunities to earn greater rates of return (opportunity cost)
- If holding period is longer than time to maturity, this is another source for reinvestment risk (uncertainty over future IR)

IR AND RETURNS

- Bonds with the same time to maturity bear different interest-rate risk
- Duration (effective maturity): weigthed average lifetime of a debt instruments' cashflows
- For ZCs time to maturity equals effective maturity (no intermediate CF)
- Other instruments are seen as a portfolio of ZCs, weighted by their proportion over the portfolio (a useful additive property)

$$DUR = \frac{\sum_{t=1}^{n} \frac{CF_t}{(1+i)^t} \cdot t}{\sum_{t=1}^{n} \frac{CF_t}{(1+i)^t}}$$

- Longer terms and smaller coupons mean bigger duration
- Increases in interest rates decrease duration
- For small changes in IR, duration is a good proxy of interest rate risk

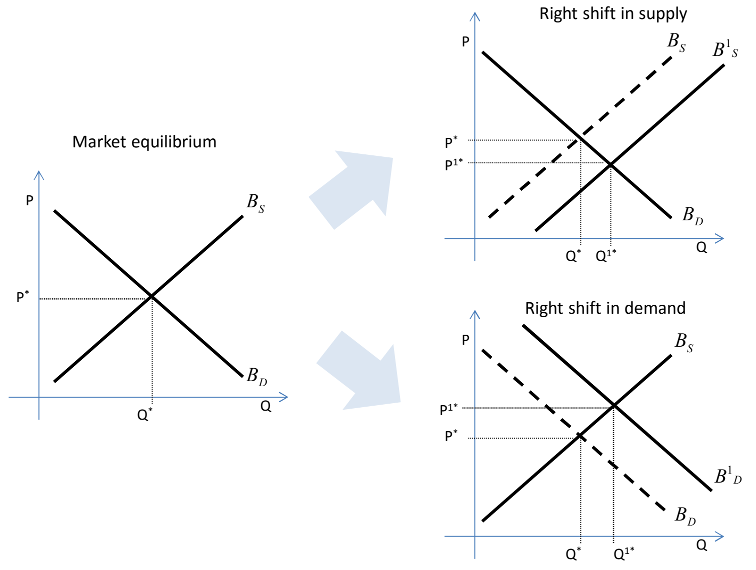
$$\%\Delta P = \frac{(P_{t+1} - P_t)}{P_t} = -DUR \cdot \frac{\Delta i}{(1+i)}$$

DEMAND AND SUPPLY FRAMEWORK

Reasons for changes in interest rates:

- Bonds' demand:
  - (+) Wealth owned by an individual
  - (+) Expected return relative to other assets
  - (–) Expected future interest rates
  - (–) Expected future inflation
  - (–) Risk (uncertainty in return) relative to other assets
  - (+) Liquidity (how quickly and cheaply turned into cash) relative to other assets
- Bonds' supply:
  - (+) Profitability of investments made with loan proceedings
  - (+) Expected inflation, leading to cheaper borrowing
  - (+) Government deficits, leading to greater issues of public debt

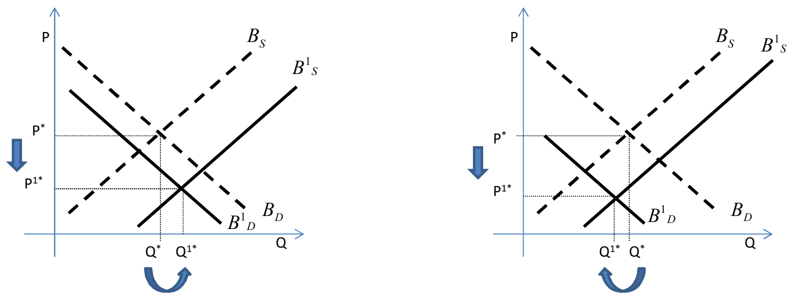
DEMAND AND SUPPLY FRAMEWORK



DEMAND AND SUPPLY FRAMEWORK

Changes in IR due to inflation:

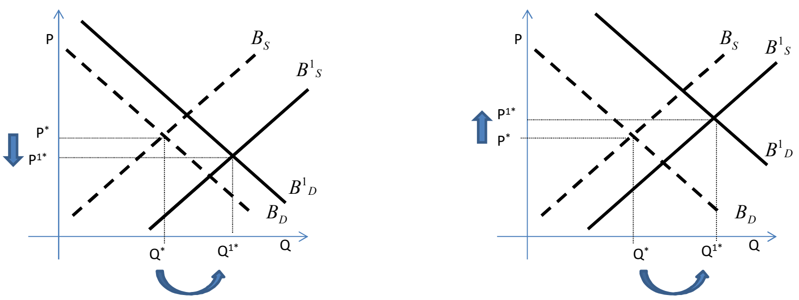
- An increase in expected inflation affects simultaneously demand (decrease of expected return) and supply (cheaper borrowing)
- IR will increase (prices fall)
- Effect on quantity is not readily predictable



DEMAND AND SUPPLY FRAMEWORK

Changes in IR due to business cycles:

- An economic expansion affects simultaneously demand (increase of wealth) and supply (greater expected returns on investments)
- Quantity will increase
- IR can increase or decrease (usually, increase – and decrease during recessions)



LIQUIDITY PREFERENCE FRAMEWORK

- Adds to the general model by focusing on bonds and money
- Assumptions:
  - Only risky bonds with return *i* and safe but costly money (opportunity cost) exist to store wealth
  - Money supply is fixed by the CB
- The bigger *i*, the smaller the quantity of money demanded because of its opportunity cost
- Demand for money changes:
  - (+) because of changes in income, meaning more wealth and more frequent uses of money
  - (+) because of changes in inflation, meaning that people care of wealth in real terms
- Supply of money changes (+) when CB changes its quantity
- When income rises, IR rise (prediction holds – consider business cycles)
- When inflation rises, IR rise (prediction holds – consider links between nominal and real IR)

LIQUIDITY PREFERENCE FRAMEWORK

When CBs increase the money supply, IR should decline, but evidence is mixed:

- Increase in money supply has an immediate liquidity effect reducing IR, but influences other variables
- It stimulates economy, increasing income (income effect) and IR, but it takes time to have effects (wages, investments, …)
- It increases prices (price-level effect) and IR, but it takes time to adjust prices of goods and services
- It increases expected inflation (expected-inflation effect) and IR, with speed of effects depending on people’s speed of adjusting expectations
- Expected inflation persists as long as price levels keep rising

LIQUIDITY PREFERENCE FRAMEWORK

When CBs increase the money supply, IR should decline, but evidence is mixed:

- Net effect not always predictable:
  - If the liquidity effect is dominant, hence after a sharp reduction in IR their recovery sets a final value smaller than the original
  - If the liquidity effect is insufficient, hence after a sharp reduction in IR their recovery leads to a final higher value
  - If the liquidity effect is marginal, since people adapt their expectations on inflation, hence the initial reduction in IR does not take place and final IR are higher immediately and grow thereafter

MODELS OF ASSET PRICING

Portfolios allow diversification:

- Holding different risky assets reducing the overall investor's risk: less risk with the same expected return, or greater expected return for the same risk
- Beneficial if investor is risk-adverse and returns on different assets are less than perfectly correlated
- The smaller the correlation, the bigger the diversification benefit
- Return on a portfolio (mean/variance):

$$R_P = x_1 R_1 + x_2 R_2 + \ldots + x_n R_n$$
$$E(R_P) = x_1 E(R_1) + x_2 E(R_2) + \ldots + x_n E(R_n)$$
$$\sigma_P^2 = E[R_P - E(R_P)]^2 = x_1 \sigma_{1,P} + x_2 \sigma_{2,P} + \ldots + x_n \sigma_{n,P}$$

- Marginal contribution of asset *i* to portfolio's risk: $x_i \frac{\sigma_{i,P}}{\sigma_P^2}$; depends on the sensitivity of return's changes to portfolio's value
- General measure of risk towards market portfolio: $\beta_i = \frac{\sigma_{i,M}}{\sigma_M^2}$

MODELS OF ASSET PRICING

Return of asset *i* (and mean and variance) can be rewritten:

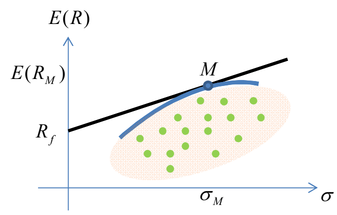
- $R_i = \alpha_i + \beta_i R_M + \varepsilon_i$
  $E(R_i) = \alpha_i + \beta_i E(R_M)$
  $\sigma_i^2 = \beta_i^2 \sigma_M^2 + \sigma_\varepsilon^2$
- Therefore, risk is influenced by a systematic risk (market riskiness and asset's *i* sensitivity to it, can not be eliminated through diversification) and a non-systematic risk (relative to the specific asset *i*, can be eliminated through diversification)

- $R_P = \frac{1}{n}\sum_{i=1}^{n}\alpha_i + \frac{1}{n}\sum_{i=1}^{n}\beta_i R_M + \frac{1}{n}\sum_{i=1}^{n}\varepsilon_i = \overline{\alpha} + \overline{\beta} R_M + \frac{1}{n}\sum_{i=1}^{n}\varepsilon_i$
  $\sigma_P^2 = \overline{\beta}^2 \sigma_M^2 + \frac{1}{n}\overline{\sigma}_\varepsilon^2$

MODELS OF ASSET PRICING

Capital Asset Pricing Model (CAPM)

- Aims at building efficient portfolios in terms of expected return and standard deviation
- Assuming free borrowing and lending at a risk-free IR and same expectations for all investors: only one market portfolio (M)
- The expected return of an asset (or portfolio) is the risk free IR plus the market price of risk times the marginal contribution of it to the risk of the portfolio:
  $E(R_i) = R_f + \beta_i[E(R_M) - R_f]$
- Expected returns are greater when systematic risks are greater (security market line)



Models of Asset Pricing

Arbitrage Pricing Theory (APT):

- Elaborates on unrealistic assumptions of CAPM
- Considers several sources of systematic risk (*k*-factor model):

$$R_i = \beta_i^1 F1 + \beta_i^2 F2 + ... + \beta_i^k Fk + \varepsilon_i$$

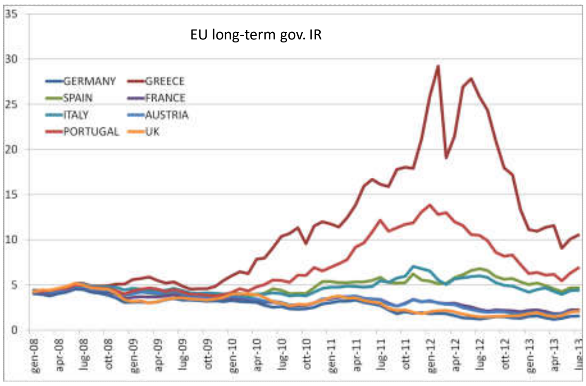
$$E(R_i) = R_f + \beta_i^1[E(R_{F1}) - R_f] + \beta_i^2[E(R_{F2}) - R_f] + ... + \beta_i^k[E(R_{Fk}) - R_f]$$

- Each risk factor has the same market premium for all securities
- Each security has a different sensitivity to each risk factor
- Over-/under-valued assets are arbitraged and brought back to predicted values
- Keeps the close link between expected return and systematic risk
- Most known:
  - 3-factor model (Fama/French), considering the market risk premium, the size effect between smaller and bigger firms, the lower or higher level of book-to-market ratios
  - 4-factor model (Carhart), adds "momentum" (historical positive track record of returns)

Risk and IR

IR differ also for bonds with equal duration because of default risk:

- government bonds were considered risk-free, yet only few of them now are really like that
- the higher the risk the bigger the risk premium (spread)
- specialised firms (rating agencies) provide judgment over borrowers' default-risk (investment grade VS junk/high yield bonds)
- IR differ also for liquidity risk (adding to the risk premium)



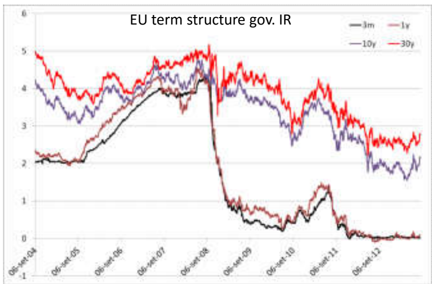
Source: ECB

- Finally, some bonds have tax incentives (municipal bonds, Italy's gov., …)

Term Structure of IR

IR differ also based on bonds' maturity:

- Differences in IR can be plotted at different maturities to derive the term structure of IR (yield curve)
- Usually yield curves are upward-sloping, meaning that longer maturities are charged with higher IR
- Flat or even downward-sloping or inverted yield curves are rare



Source: ECB

- Different maturities move similarly
- When short-term IR are high, inversion is more likely
- Inverted yield curves seem to anticipate recessions ('81, '91, 2000, '07), steep upward curves are associated with economic booms

Term Structure of IR

Three theories for explaining the term structure of IR:

Expectations theory

- If bonds at different maturities are perfect substitutes, their expected return must be equal
- $$(1+i_{n,0})^n = (1+i_{1,0})(1+i^e_{1,1})\cdot\ldots\cdot(1+i^e_{1,n-1}) \rightarrow i_{n,0} \approx \frac{i_{1,0}+i^e_{1,1}+\ldots+i^e_{1,n-1}}{n}$$
- Predicts flat curves, whereas instead are usually upward-sloping

Market segmentation theory

- Bonds at different maturities are not substitutes and each has a specific market, as well as each investor has a preferred maturity
- Together with interest-rate risk aversion, explains why longer investments require a risk premium
- Does not explain why IR move together along time
- Does not explain why with high short-term IR inversion is more likely

Term Structure of IR

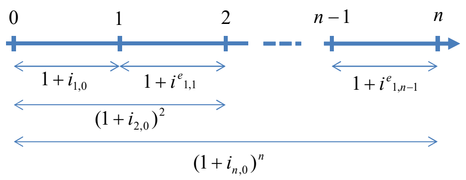
Liquidity premium theory

- Combines the other two in a comprehensive way
- Adds to expectations theory a liquidity premium for longer term bonds that is subject to market (demand, supply) conditions for that segment
- Bonds are substitutes as long as investors' preferences are compensated with a term (liquidity) premium that is always positive and grows as maturity gets longer
- $$i_{n,0} \approx \frac{i_{1,0} + i^{e}_{1,1} + \ldots + i^{e}_{1,n-1}}{n} + l_{n,0}$$
- Explains inverted term structures: when future expectations on short-term IR are of a wide fall, so that their average is not balanced even by a positive liquidity premium (more likely when short-term rates are high)
- Support empirical evidence that:
  - Term structure is a predictor of business cycles and inflation
  - Term structure is less reliable for intermediate movements

Term Structure of IR

Forward and spot rates:

- Term structures represent different useful IR



- Expected future IR are forward rates, in contrast to current IR at different maturities, called spot rates
- Knowing spot IR we can derive market expectations

F.i.: $i^{e}_{1,1} = \frac{(1+i_{2,0})^2}{1+i_{1,0}} - 1$ or, generalising: $i^{e}_{1,k} = \frac{(1+i_{k+1,0})^{k+1}}{(1+i_{k,0})^k} - 1$

- Including liquidity premiums: $i^{e}_{1,k} = \frac{(1+i_{k+1,0}-l_{k+1,0})^{k+1}}{(1+i_{k,0}-l_{k,0})^k} - 1$

EXAMPLES

1. A selling agent needs a car for his/her job. It is worth 20,000 € today and will allow to earn 15,000 € every year for three years. A three-year loan to buy the car is available at 50% annual interest rate, paid in fixed installments:

-Is it worth it?

-Is the charged IR 'ethical'?

a) Loan's installment: $R = 20{,}000 \cdot \alpha_{3\neg 50\%} = 14{,}210.53$

b) Financial and economic plan:

	0	1	2	3
Inflow		15,000.00	15,000.00	15,000.00
Outflow		-14,210.53	-14,210.53	-14,210.53
Net flow		789.47	789.47	789.47
Loan	20,000.00	15,789.47	9,473.68	0.00
Earnings		15,000.00	15,000.00	15,000.00
Interests		-6,000.00	-4,736.84	-2,842.11
Profit/loss		9,000.00	10,263.16	12,157.89

EXAMPLES

2. What is the present value of:

a) zero-coupon bond due in 3y for 2,000 with a YTM of 5%

b) bond due in 5y for 3.000 with an annual coupon of 3% and a YTM of 6%

c) perpetuity of 100 with YTM of 8%

a) $PV = \frac{2{,}000}{(1+5\%)^3} = 1{,}727.68$

b) $PV = \sum_{t=1}^{5} \frac{90}{(1.06)^t} + \frac{3{,}000}{(1.06)^5} = 2{,}620.89$

c) $PV = \frac{100}{8\%} = 1{,}250$

EXAMPLES

3. What is the price effect on the following bonds of market IR increasing from 4% to 4.25%?

a) zero-coupon bond due in 3y for 2,000 with a YTM of 5%

b) bond due in 5y for 3.000 with an annual coupon of 3% and a YTM of 6%

c) a portfolio made of 40% of the bond sub-a) and 60% of the bond sub-b)

d) what if IR drop from 4% to 3% on all three alternatives?

a) $DUR = 3 \quad \%\Delta P \approx -3 \cdot \frac{0.25\%}{1+4\%} = -0.72\%$

b) $DUR = \left(\sum_{t=1}^{5} t \cdot \frac{90}{1.04^t} + 5 \cdot \frac{3{,}000}{1.04^5} \right) \bigg/ \left(\sum_{t=1}^{5} \frac{90}{1.04^t} + \frac{3{,}000}{1.04^5} \right) = 4.71 \quad \%\Delta P \approx -4.71 \cdot \frac{0.25\%}{1+4\%} = -1.13\%$

c) $DUR = 3 \cdot 40\% + 4.71 \cdot 60\% = 4.03 \quad \%\Delta P \approx -4.03 \cdot \frac{0.25\%}{1+4\%} = -0.97\%$

d) $\%\Delta P_1 \approx -3 \cdot \frac{-1\%}{1+4\%} = 2.88\% \quad \%\Delta P_2 \approx -4.71 \cdot \frac{-1\%}{1+4\%} = 4.53\% \quad \%\Delta P_3 \approx -4.03 \cdot \frac{-1\%}{1+4\%} = 3.87\%$

EXAMPLES

4. Extract from The Economist, 29th June 2013

" […] Bankers in the rich world have moaned incessantly […] about how low interest rates are squeezing [their profits]. Now […] long-term interest rates have risen […] and changes in short-term rates seem closer than they once did […]. Rising rates may restore banks' profitability but too sudden an increase may damage their health."

Why?

"[…] The immediate threat to banks is a fall in the market value of assets that banks hold. […] A hypothetical three-percentage-point increase in yields across all bond maturities could result in losses to all holders of government bonds equivalent to 15-35% of GDP in countries such as France, Italy, Japan and Britain."

Is that all?

"But simply looking at holdings of government bonds probably understates the risk […] since they hold many other fixed-income assets that would also fall in value."

Is there anything else?

" […] A third risk to banks from higher rates is that more of their customers will struggle to repay their loans."

So?

" […] keeping rates low for long is dangerous. So is letting them rise too quickly."

EXAMPLES

5. On 2nd October 2013, the following spot interest rates on AAA Euro-area government bonds were recorded (by maturity):

M	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y
IR_spot	0.06%	0.22%	0.44%	0.69%	0.96%	1.22%	1.47%	1.70%	1.90%	2.09%

a) What are the expected one-year IRs?

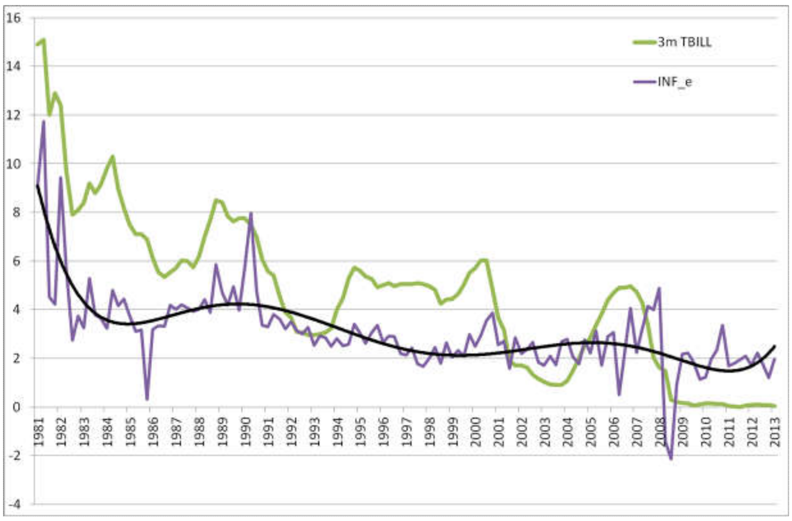
b) What would be the expected IR on a three and five years bond issued in 1, 2 and 3 years from now?

M	1y	2y	3y	4y	5y	6y	7y	8y	9y	10y
IRspot_t	0.06%	0.22%	0.44%	0.69%	0.96%	1.22%	1.47%	1.70%	1.90%	2.09%
IRfwd_1		0.38%	0.88%	1.44%	2.05%	2.53%	2.98%	3.32%	3.51%	3.82%

	1y	2y	3y
3y bond	0.90%	1.46%	2.01%
5y bond	1.46%	1.98%	2.47%

EXAMPLES

6. The following graph compares US 3-months TBILL rates with expectations on inflation. Is there consistency with our demand/supply framework?



EXAMPLES

7. The following graph compares US 3-months TBILL rates with expectations on GDP growth. Is there consistency with our demand/supply framework?