Capital Budgeting

- Capital budgeting is the process a firm uses to choose which available projects to invest in
  - this involves determining expected cash flows for the projects and discounting them at an appropriate cost of capital
  - in this lecture we will discuss how to correctly evaluate a project and understand:
    - how to think about projects for valuation purposes
    - how to estimate the cash flows for a project from market projections
      - how to turn forecasts of revenues and costs into cash flows
        » creating forecasted cash flows
Valuing a Project

Thinking about a new project

- should it matter for valuation whether the project will be its own firm or part of an existing firm?
  
  NO!
  
  - we know from before that one property of PV is value additivity
  
  - assume the firm considering the project is asset A and the new project is asset B
  
  - value additivity tell us
    
    \[ PV(A+B) = PV(A) + PV(B) \]
  
  - the impact of the value of the project on the value of the firm is simply the value of the project alone
  
  - for simple standalone projects we the value of the project to the firm will be the same as the value of the project on its own

Valuing a Project

Thinking about a new project

- should the characteristics of the firm investing in the project affect the required rate of return (cost of capital) for the project?
  
  NO!
  
  - from the CAPM the required rate of return for project i is
    
    \[ r_i = r_f + \beta^MKT \times (E[R_M] - r_f) \]
  
  - the only part of the required return which is project specific (related to project i) is the beta which depends only on the returns of the project assets and the market portfolio
  
  - risk free rate and market premium are the same for all
  
  - nothing depends on the characteristics of the investor
  
  - the cost of capital is only a function of the project
    
    - the required rate of return be a function of the assets being invested in not who is investing or how the investment is financed
Cash Flows

- Determining the cash flows from a risky project is the most difficult task in capital budgeting
  - it involves understanding several issues
    - market size and demand conditions
    - competitive environment, both present and future
    - demand curves and elasticities
    - cost structures and cost sensitivities
    - potential future opportunities
  - many of these things are uncertain
    - as a result we carefully attempt to form an estimate of what the future cash flows will be
  - let’s look at some general rules for estimating cash flows

Estimating Cash Flows

- What we want to discount in capital budgeting are the incremental expected cash flows
  - this suggests some important rules
    1. cash flows, not accounting income, are what is relevant
      - need to adjust earnings for non-cash expenses
    2. always estimate cash flows in each state of the world on an incremental basis
      - measure only new cash flows created by project
    3. deal with uncertainty in cash flows by taking expected cash flows, not the most likely cash flows
  - let’s consider each of these separately
Use Cash Flows Not Income

- Cash flow is: cash in - cash out
  - cash flow differs from earnings as measured by financial statements in that:
    - earnings reflect certain non-cash items
      - these items are called accruals and are charges or receipts recorded now for revenues and expenses neither received nor paid in that period
      - a common example is depreciation
        - rather than expense capital expenditures when they occur, accountants amortize them over the specified life of the asset
    - earnings do not reflect when cash is received or when it is paid
      - earnings reflect sales that have not been collected (accounts receivable) and expenses that have not been paid (accounts payable)
      - cost of goods sold involves inventory costs that may have been paid for in earlier periods
        - this leads to timing differences between earnings and cash flows that can affect PV calculations

The Basics of Measuring Cash Flow

- The cash flow of a project requires us to measure the cash available to investors each period
  - in a simple setup this depends only on
    - Revenues (Sales) -- income from sales of goods/services
    - Cash costs (expenses) –
      - Cost of Goods Sold (COGS) - these are the actual cash costs incurred to produce the goods/services created that period
      - Other cash costs - these are other costs actually incurred such as administrative, advertising and other selling costs
    - Depreciation - this is a special charge that allows the firm to recover the initial cost of the investment
      - this is a “non-cash” expense that must be adjusted for when measuring actual cash flows
        - it reduces taxes, but not actual cash flow
    - Taxes - this is the part of “profits” that goes to the government
      - we only focus on income taxes as other taxes are part of COGS
Depreciation

Some rules for depreciation

- depreciation is a nominal accounting charge for the original capital investment
  - it is a non-cash expense meant to reflect a portion of the cost of the original investment in the asset
    - accountants do not recognize capital expenditures as expenses
      » instead they use depreciation as an accrual charge
  - depreciation is important to account for because it reduces taxable income but not the cash flow
    - it prevents collection of taxes on the return on the initial investment
- assets are depreciated over different numbers of years depending on their useful life
  - straight line depreciation is the simplest form
    - there are also forms of accelerated depreciation that
      » compensate for fact that depreciation is not adjusted for inflation
      » allow greater tax savings earlier in the asset’s life

Calculating Depreciation

Example of straight line depreciation

- if an asset’s life is 10 years and it can be fully depreciated, the annual depreciation allowance = initial investment / 10
- generally, if an asset can be depreciated over some period T, down to some specified residual value, the annual depreciation charge is
  \[
  (1/T) \times (\text{purchase price} - \text{residual value})
  \]
  - the residual value is often estimated by the firm (or tax law)
    - it may differ from the asset’s salvage value or market price
    - if the market price is different from the residual value, the difference is taxable (either as a gain or as a loss)
- example: the firm pays $10m for an asset with a 6 year life and $0.5m residual value
  - annual depreciation charge = \((1/6) \times (10m - 500,000) = $1.583m\)
  - this is the annual amount of tax shield
    » if they sell the asset in year 6 for $1m, then they must pay tax on the difference ($1m - $0.5m)
Measuring Cash Flows

- Given this information, we can calculate cash flows (CF) in either of two ways

\[
CF = \text{Revenues} - \text{cash costs} - \text{actual taxes}
\]

where:
- actual taxes are \((\text{Revenues} - \text{cash costs} - \text{depreciation}) \times \tau\)
- cash costs = \(\text{COGS} + \text{other cash costs (expenses actually paid)}\)
- \(\tau = \text{effective corporate tax rate}\)

- this is the same as

\[
CF = (\text{Revenues} - \text{cash costs} - \text{deprec}) \times (1 - \tau) + \text{deprec}
\]

- alternatively, we can express cash flows as

\[
CF = (\text{Revenues} - \text{cash costs}) \times (1 - \tau) + (\tau \times \text{depreciation})
\]

- any of these methods will give you the same answer for the available cash flow

Free Cash Flows (FCF)

- Free cash flows differ from cash flows in that some cash is reinvested in the project or project is sold
  - typically money must be put back into project to keep it operating
  - capital expenditures
    - some of the cash flow from the project is re-invested to replace worn out equipment or to purchase new equipment allowing the firm to grow
    - these are the maintenance and replacement expenditures
  - working capital
    - some of the earnings from the project must be retained to provide additional working capital for the project
      - this is the cash needed to cover imbalances in receipts and payments
        - investors get these monies back when projects ends
  - after tax proceeds from asset disposal
    - investors recapture after tax value when disposing of assets
More on Working Capital

- What is working capital?
  - working capital is the money needed to fund short term assets necessary to operate the project
    
    \[
    \text{Working Capital} = \text{Cash} + \text{Inventory} + \text{Accts Rec}
    \]
  - net working capital (NWC) is difference between this amount and the amount financed through short term debt (payables)
    
    \[
    \text{Net Working Capital} = \text{Cash} + \text{Invent} + \text{Accts Rec} - \text{Accts Payable}
    \]
  - it is the funds the firm needs to finance its inventory and accounts receivable less the funds they save by creating accounts payable
  - as a project’s sales grow, its working capital needs grow, thus working capital is like an investment in the project’s operations
    - except that these funds are released when the operation closes
  - so for FCF we are interested in the change in NWC
    
    \[
    \Delta \text{NWC} = \Delta \text{Cash} + \Delta \text{Invent} + \Delta \text{Accts Rec} - \Delta \text{Accts Payable}
    \]

Forecasting Cash Flows

- We want to forecast a measure of the free cash flows (FCF) available to the investor’s in the firm
  
  \[
  FCF_t = \text{Sales}_t - \text{Cash Costs}_t - \text{Actual Taxes}_t - \text{Cap Ex}_t - \Delta \text{NWC}_t + \text{After-tax CF from Assets Disposal}_t
  \]
  - we often begin cash flow analysis with projections of sales and costs provided by a market analyst
    - these are provided by market analysts and other economic experts
      - forecasts of futures prices, costs and quantities as well as taxes and working capital
    - this often starts in the form of a pro forma income statement with some basic balance sheet info which then gets used in creating cash flow forecasts
  - let’s consider the case of a new iced tea product called Honest Tea
Project: Honest Tea

Project details
- $10m to purchase plant, and equipment
  - 6 years of production
  - depreciation assumptions
    - depreciation is straight line over 6 years practical life
      » residual value of fixed assets is $500,000 at end of year 6
    - annual depreciation charge: 1/6 ($10m - 0.5m) = $1.583m
  - salvage value for assets at end of year 6
    - expected salvage value of assets $1.5m
      » this is the amount you expect to be able to sell the assets for when you are done (note: there may be a tax issue here)
- working capital
  - working capital is cash basis to keep company running
    - working capital is $500,000 for year 1 and grows with sales
- cost of capital for the project is 15%

Honest Tea Projections

Pro forma asset statement and income statement
- gives basic information for cash flow analysis
  - all values in nominal terms (000s)

<table>
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<td>(2) E(Salvage Value of Assets)</td>
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<td>(2) COGS</td>
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<td>24,000</td>
<td>18,000</td>
<td>12,000</td>
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<tr>
<td>(3) Other costs</td>
<td>3,200</td>
<td>4,800</td>
<td>6,600</td>
<td>7,200</td>
<td>3,600</td>
<td>2,400</td>
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<tr>
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<td>1,583</td>
<td>1,583</td>
<td>1,583</td>
<td>1,583</td>
<td>1,583</td>
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<tr>
<td>(5) Pre-tax profit (1 - 2 - 3 - 4)</td>
<td>-2,383</td>
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<td>2,526</td>
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<td>1,406</td>
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<tr>
<td>(7) Reported Earnings (5 – 6)</td>
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<td>-249</td>
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<td>4,691</td>
<td>4,431</td>
<td>2,611</td>
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Final Year Cash Flow Issues

- In year 6, there are two CF events going on
  - first there are the results from operations
    - sales of tea and the cost of operating generating cash flow from operations
  - second there is the cash flow from the disposal of the fixed assets
    - we assume that we will be able to sell these assets for $1,500
    - these assets still have an undepreciated book value of $500 at the end of year 6 (residual value)
      - this is still a tax deductible expense
      - we only pay taxes (receive tax credits) on the cash flow from selling a fixed asset relative to the depreciated value
    - cash flow from asset disposal at time t is then
      \[
      CF_{\text{Disp}} = E(Salvage Value)_t - \left(\frac{E(Salvage Value)_t - \text{Book Value}_t}{x \text{ tax rate}}\right)
      \]
    - in this case: \(1,500 - \left(\frac{1,500 - 500}{35}\right) = 1,150\)
    - for simplicity we often consider this a negative Capital Expenditure

Free Cash Flow Calculations

- \(FCF = \text{Sales} - \text{COGS} - \text{other cash costs} - \text{actual taxes} - \text{chg in working capital} - \text{capital expenditures}\)

\[
\begin{array}{lccccccc}
\text{Period} & \text{0 (today)} & \text{1 (EOY)} & \text{2} & \text{3} & \text{4} & \text{5} & \text{6} \\
(1) Sales & 6,000 & 15,000 & 26,000 & 40,000 & 30,000 & 20,000 \\
(2) COGS & 3,600 & 9,000 & 15,600 & 24,000 & 18,000 & 12,000 \\
(3) Other costs & 3,200 & 4,800 & 6,600 & 7,200 & 3,600 & 2,400 \\
(4) Taxes paid ((I/S (6)) & -834 & -134 & 776 & 2,526 & 2,386 & 1,406 \\
(5) CF from Operations & 34 & 1,334 & 3,024 & 6,274 & 6,014 & 4,194 \\
(6) \Delta in NWC & 500 & 750 & 917 & 1,167 & -833 & -833 & 0 & -1,667 \\
(7) Capital Expenditures & 10,000 & 750 & 917 & 1,167 & -833 & -833 & 0 & -1,667 \\
(8) Free Cash Flow & -10,500 & -716 & 417 & 1,857 & 7,107 & 6,847 & 4,194 & 2,817 \\
\end{array}
\]

PV Calculations

\[
\begin{array}{l}
(9) PV of CFs at 15\% & -10,500 & -622 & 315 & 1,221 & 4,064 & 3,404 & 1,813 & 1,215 \\
(10) NPV = & 912 \\
\end{array}
\]

After tax salvage value for fixed assets is entered as a negative capital expenditure
Alternative Method to get FCF

FCF = (Sales - cash costs)*(1-tax) + (tax * depreciation) - chg in working capital - capital expenditures

<table>
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<td>7,200</td>
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<td>(4) Operating Income (4=1-2-3)</td>
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<td>(5) Taxes on OP Inc (4 x 35%)</td>
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<td>3,080</td>
<td>2,940</td>
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<td>(6) Depreciation x tax rate</td>
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<td>554</td>
<td>554</td>
<td>554</td>
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<tr>
<td>(7) CF from Operations (4-5+6)</td>
<td>34</td>
<td>1,334</td>
<td>3,024</td>
<td>6,274</td>
<td>6,014</td>
<td>4,194</td>
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<td>(8)Δ in NWC</td>
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<td>-333</td>
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<td>(9) Capital Expenditures</td>
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<td>-1,150</td>
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<td>(10) Free Cash Flow (10=7-8-9)</td>
<td>-10,500</td>
<td>-716</td>
<td>417</td>
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<td>(11) PV at 15%</td>
<td>-10,500</td>
<td>-622</td>
<td>315</td>
<td>1221</td>
<td>4064</td>
<td>3,404</td>
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<td>(12) NPV = 912</td>
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<td></td>
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<td>1813</td>
<td>1,218</td>
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PV Calculations

After tax salvage value for fixed assets is entered as a negative capital expenditure

More Careful Treatment of FCF

- Previous examples had negative tax payments
  - negative taxes are tax advantages
  - the previous treatment is only relevant if firm has income from other projects against which to apply the losses
    - or taxes paid in previous few years
  - government does not reimburse taxes on losses using cash
    - they provide a tax loss credit for use at alternative time
      - these credits can be applied against taxes paid in previous years or carried forward for use at such time when tax liability becomes positive
  - to correctly measure the actual cash flows we must account for the timing of actual taxes paid
    - tax losses (negative taxes) need to be carried forward until such time as actual tax liability exists for them to be used
      - the tax losses are nominal amounts and do not grow over time
    - thus, waiting to be able to use them reduces their time value and lowers the NPV of the project
FCF with Tax Loss Carryforwards

- Carefully delineate exactly when taxes are paid
  - no taxes are actually paid in years 1 and 2 as project produces losses (no taxable income)
  - no taxes paid in year 3 as tax losses from previous year are sufficient to offset taxes due
  - remainder of tax losses carried forward and used in year 4

<table>
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<tr>
<th>Period</th>
<th>0 (today)</th>
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FCF with Tax Loss Carryforwards

- Use the first definition of FCF
  - use actual taxes paid at time they are paid
    - this reduces the NPV of the project through the loss of time value on the tax losses (having to wait to use them)

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<td>26,000</td>
<td>40,000</td>
<td>30,000</td>
<td>20,000</td>
<td></td>
</tr>
<tr>
<td>(2) COGS</td>
<td>3,600</td>
<td>9,000</td>
<td>15,600</td>
<td>24,000</td>
<td>18,000</td>
<td>12,000</td>
<td></td>
</tr>
<tr>
<td>(3) Other costs</td>
<td>3,200</td>
<td>4,800</td>
<td>6,600</td>
<td>7,200</td>
<td>3,600</td>
<td>2,400</td>
<td></td>
</tr>
<tr>
<td>(4) Actual Taxes Paid (6C above)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,334</td>
<td>2,386</td>
<td>1,406</td>
<td></td>
</tr>
<tr>
<td>(5) Cash Flow from Operations</td>
<td>-800</td>
<td>1,200</td>
<td>3,800</td>
<td>6,466</td>
<td>6,014</td>
<td>4,194</td>
<td></td>
</tr>
<tr>
<td>(6) Δ in NWC</td>
<td>500</td>
<td>750</td>
<td>917</td>
<td>1,167</td>
<td>-833</td>
<td>-833</td>
<td>0</td>
</tr>
<tr>
<td>(7) Capital Expenditures</td>
<td>10,000</td>
<td>-1,150</td>
<td>-1,150</td>
<td>-1,150</td>
<td>-1,150</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8) Free Cash Flow (5 = 6 - 6 - 7)</td>
<td>-10,500</td>
<td>-1,550</td>
<td>283</td>
<td>2,633</td>
<td>7,299</td>
<td>6,847</td>
<td>4,194</td>
</tr>
</tbody>
</table>

PV Calculations

(9) PV at 15%  
(10) NPV = -10,500 -1,348 214 1,731 4,173 3,404 1,813 1,218

\[ \text{NPV} = \text{706} \]
Other Issues in Determining FCF

- Important issues in identifying relevant cash flows
  - include opportunity costs in addition to cash costs
    - be sure all resources are charging at least cost of next best use
      - for example, if you own the land you will use for a plant, be sure to charge the project the rental cost of the land
      - nothing is free if it has an opportunity cost
  - use the expected value if there is uncertainty about future values
    - if there is uncertainty about values at a future due to different possible states of the world, you need to specify the uncertainty and take the expected value
      - specify the plausible states of the world and place probabilities on each of them
        - use the expected value formula across these states to determine the expected value for the amount

- consider only incremental cash flows
  - measure just CF that would not be there if project not taken
    - cash flows that would occur even if the project is not undertaken are not relevant to the valuation of the project
      - examples might include market study costs or engineering/legal assessment fees
    - spilt milk principle: past expenses or losses and sunk costs are not relevant for marginal investment decision making
      - what is past is past => look forward on incremental cash flow differences between pre and post project cash flows
        - do not keep on with a bad project just because you have invested a lot of money in it already
        - look at the project on a forward basis of new investments and resulting cash flows
  - in finance, the value of an investment is a function of the future expected incremental cash flows from that investment discounted at the opportunity cost for the riskiness of the CFs
Other Issue in Capital Budgeting

- Important issues in capital budgeting
  - it is important that we understand how the project works
    - this requires rolling up your sleeves and getting inside the project
      - understanding its structure, strengths / weaknesses, and sensitivities
    - many projects have complex future decisions that affect the value today
      - how do these future decisions impact the expected value today?
    - how do we measure whether the project lives up to forecasts and insure than management maintains oversight on project?
      - need to monitor that value is really being created
  - to do this we will discuss
    - sensitivity analysis and simulation
    - decision trees

Dealing with Uncertainty

- Sensitivity analysis
  - the NPV of a project depends heavily on the assumptions made in generating the cash flow estimates
    - also to some degree on the estimate of cost of capital
  - consider Otto’s electric scooter project
    - cash flow forecasts in table
    - cost of capital = 10%
    - NPV = ¥3.43b
  - you want to delve into these forecasts and identify key variables behind NPV > 0

<table>
<thead>
<tr>
<th>all in ¥</th>
<th>year 0</th>
<th>year 1 -10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>-15</td>
<td></td>
</tr>
<tr>
<td>Sales</td>
<td>37.5</td>
<td></td>
</tr>
<tr>
<td>VariableCosts</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>FixedCosts</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Depreciation *</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Pretaxprofit</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Taxes@50%</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Profitafter tax</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>OperatingCashflow</td>
<td>3.0</td>
<td></td>
</tr>
<tr>
<td>NetCashFlow</td>
<td>-15</td>
<td>3</td>
</tr>
</tbody>
</table>

* 10 yr straight line depreciation
Some Important Relations

- Project features
  - unit sales = market share x size of market
    - forecast = 10% x 1million = 100,000 units
  - revenue = unit sales x price per unit
    - forecast = 100,000 x ¥375,000 = ¥37.5b
  - unit costs
    - production engineers estimate unit costs of ¥300,000
    - these costs are incurred only if scooters are produced
  - total costs = unit costs x unit sales
    - forecast = ¥300,000 x 100,000 = ¥30b
  - fixed costs = ¥3b
    - these are the costs that do not change as production changes
  - knowing these things we can perform some sensitivity analysis on the project

Sensitivity Analysis

- Simple approach
  - optimistic and pessimistic values for each variable
  - change each variable one at a time and look at the impact the change has on NPV

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pessimistic</th>
<th>Expected</th>
<th>Optimistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Size</td>
<td>.9 m</td>
<td>1m</td>
<td>1.1m</td>
</tr>
<tr>
<td>NPV</td>
<td>+¥1.1b</td>
<td>+¥3.5b</td>
<td>+¥5.7b</td>
</tr>
<tr>
<td>Market Share</td>
<td>.04</td>
<td>.1</td>
<td>.16</td>
</tr>
<tr>
<td>NPV</td>
<td>-¥10.4b</td>
<td>+¥3.5b</td>
<td>+¥17.3b</td>
</tr>
<tr>
<td>Unit price</td>
<td>350,000</td>
<td>375,000</td>
<td>380,000</td>
</tr>
<tr>
<td>NPV</td>
<td>-¥4.2b</td>
<td>+¥3.5b</td>
<td>+¥5.0b</td>
</tr>
<tr>
<td>Unit Variable Costs</td>
<td>360,000</td>
<td>300,000</td>
<td>275,000</td>
</tr>
<tr>
<td>NPV</td>
<td>-¥15.0b</td>
<td>+¥3.5b</td>
<td>+¥11.1b</td>
</tr>
<tr>
<td>Fixed Cost</td>
<td>4 bil</td>
<td>3 bil</td>
<td>2 bil</td>
</tr>
<tr>
<td>NPV</td>
<td>+¥0.4b</td>
<td>+¥3.5b</td>
<td>+¥6.5b</td>
</tr>
<tr>
<td>Cost of Capital</td>
<td>14%</td>
<td>10%</td>
<td>7%</td>
</tr>
<tr>
<td>NPV</td>
<td>+¥0.65b</td>
<td>+¥3.5b</td>
<td>+¥6.1b</td>
</tr>
</tbody>
</table>
Limits to Sensitivity Analysis

- Ultimately sensitivity analysis depends on private assessments
  - what does pessimistic or optimistic mean?
    - is it defined by the group with knowledge about the issue
      - market size - marketing group
      - unit costs - production group
  - uncertain variables are likely to be related
    - things don’t change one at a time
  - it’s not really possible to get pessimistic or optimistic values for total cash flows from sensitivity tables
    - to do this we must consider scenarios in which we are explicit about consistent relations between the important variables
    - this is called scenario analysis
    - consider potential value impact of exogenous events
      - example: impact of oil shock on scooter project

Simulation

- Simulation is a technique for considering all possible outcomes
  - in simulation you let the computer randomly draw possible outcomes for uncertain variables from pre-defined distributions
    - you must pre-define the distributions for uncertain variables
    - computer just plays the game lots of times to show you the possible outcomes of this uncertainty on value
  - steps
    - develop a careful model of the project with specified sources of uncertainty
    - specify nature of uncertainty in terms of statistical distribution
    - identify output whose variability you are interested in measuring
Simulating Otto’s Scooter Project

- Start with model
  - cash flow = (rev - cash costs) \( \times (1-tax) + \text{depr} \times \text{tax} \)
  - rev = market size \( \times \text{market share} \times \text{unit price} \)
  - cash costs = (mkt size \( \times \text{mkt share} \times \text{var unit cost} \) + fixed costs

- then specify uncertainty
  - example: mkt size, = \( E(\text{mkt size}) \times (1+ \text{mkt size forecast error}) \)
    - where forecast error is defined as a random variable with a mean of zero and a high and low of \( \pm 10\% \)
      - perhaps normally distributed or uniformly distributed

- be aware of potential linkages in uncertainty
  - links between demand and price
    - example:
      - unit price, = \( E(\text{unit price}) \times (1+ 0.3 \times \text{mkt size forecast error}) \)

- then run model through many iterations over uncertainty
  - look at the resulting distribution of NPV or annual cash flows

Monte Carlo Simulation

1,000 trials of simple model

distribution of NPV runs from around -6b to +12b yen
mean of distribution is ¥3.5b, but result is highly variable
**Decision Trees**

- Investments often have subsequent decisions that depend on the decisions made today
  - to deal with these situations we use a decision tree framework
    - decision tree is a way to map out possible outcomes allowing the decision maker to make optimal decision
  - example of Vegetron and the electric mop
    - new product, might work, might not work
    - should we invest in tests to see if it will sell
  - 1st stage decision: preliminary trials cost $125,000
    - assumed 50-50% chance of success
  - 2nd stage decision: build a full scale production plant
    - plant will cost $1000
    - if tests are successful, Vegetron earns a CF stream of $150 a year forever
    - if the tests are not successful, Vegetron earns a CF stream of $75 a year forever
    - opportunity cost of capital for project is 10%

**Using Decision Trees**

- Solve by working backwards and taking expected values
  - choose Invest if test is successful and Don't Invest if test is unsuccessful

**Decision Tree**

1. **Stage 1 decision**
   - Test -$125
   - Don't Test
   - Outcome
     - success (50%)
     - failure (50%)
   - Stage 1 NPV = 0

2. **Stage 2 decision**
   - Invest $1000 for full scale production
     - NPV = $1000 + 150 / 1 = +500
     - NPV = 0
   - Don't invest
     - NPV = $1000 + 75 / 1 = -250
     - NPV = 0

- Test -$125
  - success (50%)
    - $500
  - failure (50%)
    - $0
  - Don't Test
    - NPV = 0

- Stage 1 decision: NPV(Test) = $102.3, NPV (Don't Test) = 0
- Choose to Test the mop
More Complex Sequential Decisions

- Consider the case of Magna Charter airline deciding on turboprop or piston engine planes
  - cost of capital = 10%
  - cash flows and probabilities across states of the world

\[ \text{Turboprop} \]
\[ \text{NPV} = ? \]
\[ -550 \]

\[ \begin{align*}
\text{High Demand} & : +150(0.6) \\
\text{Low Demand} & : +30(0.4)
\end{align*} \]

\[ \text{Piston} \]
\[ \text{NPV} = ? \]
\[ -250 \]

\[ \begin{align*}
\text{High Demand} & : +100(0.6) \\
\text{Low Demand} & : +50(0.4)
\end{align*} \]

Collapse Outer Branches

- Collapse last set of branches using expected value

\[ E(CF) = CF_{HD} \times \text{Prob}(HD) + CF_{LD} \times \text{Prob}(LD) \]

\[ \text{Turboprop} \]
\[ \text{NPV} = ? \]
\[ -550 \]

\[ \begin{align*}
\text{High Demand} & : +150(0.6) \\
\text{Low Demand} & : +30(0.4)
\end{align*} \]

\[ \text{Piston} \]
\[ \text{NPV} = ? \]
\[ -250 \]

\[ \begin{align*}
\text{High Demand} & : +100(0.6) \\
\text{Low Demand} & : +50(0.4)
\end{align*} \]
**Consider Optional Decision**

- Firm has the option to add an additional piston plane for $150, if demand is strong
  - determine optimal decision
    - we would invest in plane as NPV is greater
    - this eliminates the 'do not invest' branch

\[
\text{NPV} = \frac{660 - 150}{1.10} = 450
\]

\[
\frac{364}{1.10} - 0 = 331
\]

\[\text{NPV} = 331 \]

\[\text{NPV} = ?
\]

**Collapse Outer Branches**

- Discount period 2 $E(CF)$s back to period 1

<table>
<thead>
<tr>
<th>Turboprop</th>
<th>High Demand</th>
<th>+150(.6)</th>
<th>(\frac{738}{1.1} = 812)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV= ?</td>
<td>Low Demand</td>
<td>+30(.4)</td>
<td>(\frac{415}{1.1} = 456)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Piston</th>
<th>High Demand</th>
<th>+100(.6)</th>
<th>(\frac{450}{1.1} = 660)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPV= ?</td>
<td>Low Demand</td>
<td>+50(.4)</td>
<td>(\frac{135}{1.1} = 148)</td>
</tr>
</tbody>
</table>

\[\text{NPV} = 148\]
Collapse Next Set of Branches

- Determine E(CF)s for period 1
  - use expectations across uncertainty at time 1

\[
\begin{align*}
\text{Turboprop} & \\
\text{NPV} & = -550 \\
\text{Prob} & = 0.6 \\
E(CF) & = 711 = 888 (0.6) + 445 (0.4) \\
\text{Prob} & = 0.4 \\
& + 738 = 888 \\
\text{Prob} & = 0.6 \\
& +150 + 738 = 888 \\
\text{Prob} & = 0.4 \\
& +30 + 415 = 445 \\
\text{Prob} & = 0.6 \\
& +100 + 450 = 550 \\
\text{Prob} & = 0.4 \\
& +50 + 135 = 185
\end{align*}
\]

Do Final NPV Calculations

- Now one is left with a simple NPV calculation
  - the piston plane with the option to expand is a more valuable investment than the turboprop
    - NPV of piston without expansion decision = 52
      - thus, value of option to expand is worth 65 (117 - 52)
      - this is an important part of the project's value
Summary

- **Capital budgeting**
  - 2 important components
    - cost of capital
      - estimate of opportunity cost of capital for specific assets being considered
      - estimating opportunity cost of capital for assets
        » purely a function of the business risk of the assets
    - estimating incremental expected cash flows
      - do NOT use accounting income, instead create free cash flow
      - adjust for non-cash expenses (i.e. depreciation)
      - think about actual timing of cash-in and cash-out
      - think carefully, take incremental cash flows and include opportunity costs of existing assets
  - don’t settle for one number, must look more deeply
    - do sensitivity analysis or simulation to determine degree of uncertainty