Chapter 7

In[1]:=
```
thinn = AbsoluteThickness[.5];
medum = AbsoluteThickness[1.];
thick = AbsoluteThickness[1.5];
black = GrayLevel[0];
BGray = GrayLevel[0.3];
WGray = GrayLevel[0.6];
LGray = GrayLevel[0.8];
SetOptions[Plot, PlotStyle → {{thinn, Black}, {thinn, Black}, {thinn, Black}},
  PlotPoints → 40, ImageSize → 360,
  FrameStyle -> medum, AxesStyle -> medum,
  BaseStyle -> {FontFamily -> "Helvetica", FontSlant → Plain, FontSize → 12}];
SetOptions[ListPlot, AxesStyle -> medum, PlotStyle → medum, ImageSize → 384,
  BaseStyle -> {FontFamily -> "Helvetica", FontSlant -> "Plain", FontSize → 12}];
SetOptions[ParametricPlot, PlotStyle →
   {{thinn, Black}, {thinn, Black}, {thinn, Black}}, PlotPoints → 40,
  FrameStyle -> medum, AxesStyle -> medum, PlotStyle → medum,
  BaseStyle -> {FontFamily -> "Helvetica", FontSlant -> "Plain", FontSize → 12}];
SetOptions[Graphics, BaseStyle ->
   {FontFamily -> "Helvetica", FontSlant -> "Plain", FontSize → 12}];
```

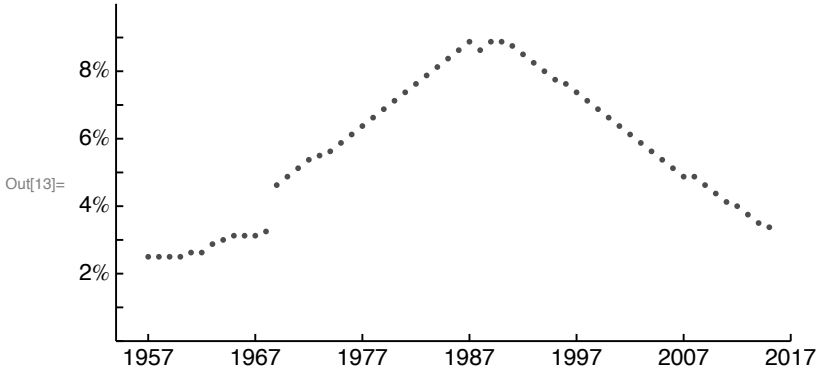
7.1; US federal water discounting

www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/econ/costs/?cid=nrcs143_009685

In[12]:=
```
rates = {{1957, 2.5}, {1958, 2.5}, {1959, 2.5}, {1960, 2.5},
   {1961, 2.625}, {1962, 2.625}, {1963, 2.875}, {1964, 3}, {1965, 3.125},
   {1966, 3.125}, {1967, 3.125}, {1968, 3.250}, {1969, 4.625}, {1970, 4.875},
   {1971, 5.125}, {1972, 5.375}, {1973, 5.5}, {1974, 5.625}, {1975, 5.875},
   {1976, 6.125}, {1977, 6.375}, {1978, 6.625}, {1979, 6.875}, {1980, 7.125},
   {1981, 7.375}, {1982, 7.625}, {1983, 7.875}, {1984, 8.125}, {1985, 8.375},
   {1986, 8.625}, {1987, 8.875}, {1988, 8.625}, {1989, 8.875}, {1990, 8.875},
   {1991, 8.75}, {1992, 8.5}, {1993, 8.25}, {1994, 8}, {1995, 7.75},
   {1996, 7.625}, {1997, 7.375}, {1998, 7.125}, {1999, 6.875}, {2000, 6.625},
   {2001, 6.375}, {2002, 6.125}, {2003, 5.875}, {2004, 5.625}, {2005, 5.375},
   {2006, 5.125}, {2007, 4.875}, {2008, 4.875}, {2009, 4.625}, {2010, 4.375},
   {2011, 4.125}, {2012, 4.000}, {2013, 3.750}, {2014, 3.500}, {2015, 3.375}};
```

In[13]:=
```
pl71 = ListPlot[rates,
  AxesOrigin → {1954, 0},
  PlotRange → {{1954, 2017}, {0, 10}},
  Ticks → {Range[1957, 2017, 10],
    {{0, "0%"}, {1, ""}, {2, "2%"}, {3, ""},
     {4, "4%"}, {5, ""}, {6, "6%"}, {7, ""}, {8, "8%"}, {9, ""}}},
  PlotStyle → {{BGray, medum}},
  AspectRatio → 0.5]
```

Out[13]=



7.2; p times q as a good approximation

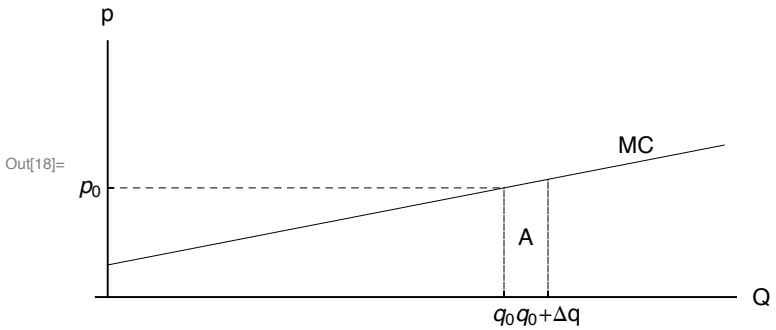
In[14]:=
```
MC = 1.5 + 0.08 * q;
MC /. q → 45.
MC /. q → 50.
```

Out[15]= 5.1

Out[16]= 5.5

In[17]:=
```
pl72i = Plot[{MC}, {q, 0, 70.},
    AxesLabel → {"Q", "p"},
    Ticks → {{{45, "q₀"}, {50, "q₀+Δq"}}, {{5.1, "p₀"}}},
    PlotRange → {0, 12}];
pl72 = Show[pl72i,
  Graphics[Text["A", {47.5, 2.8}]],
  Graphics[Text["MC", {60., 7.1}]],
  Graphics[{Dashing[{.01, .01}], thinn, Line[{{0, 5.1}, {45, 5.1}}]}],
  Graphics[{Dashing[{.01, .0}], thinn, Line[{{45, 0}, {45, 5.1}}],
    Line[{{50, 0}, {50, 5.5}}]}],
  AspectRatio → 0.4]
```

Out[18]=



7.3; Costs as area under MB

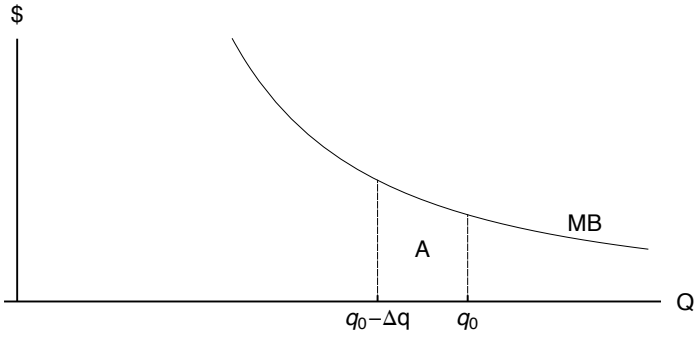
In[19]:=
```
MB = 700. / q^1.5;
MB /. q → 40.
MB /. q → 50.
```

Out[20]= 2.76699

Out[21]= 1.9799

In[22]:=
```
pl73i = Plot[{MB}, {q, 0, 70.},
    AxesLabel → {"Q", "$"},
    Ticks → {{{40, "q₀-Δq"}, {50, "q₀"}}, {}},
    PlotRange → {0, 6}];
pl73 = Show[pl73i,
  Graphics[Text["A", {45, 1.2}]],
  Graphics[Text["MB", {63., 1.8}]],
  Graphics[{Dashing[{.01, .0}], thinn, Line[{{40, 0}, {40, 2.767}}],
    Line[{{50, 0}, {50, 1.98}}]}],
  AspectRatio → 0.4]
```

Out[23]=



7.4; Shifting MB with Population Growth

In[24]:=
```
Solve[MB == price, q]
```

Solve::ifun : Inverse functions are being used by Solve, so
some solutions may not be found; use Reduce for complete solution information. >>

Out[24]= $\left\{\left\{q \to \frac{78.8374}{\text{price}^{0.6666666666666667}}\right\}\right\}$

In[25]:=
```
Q₀ = 78.8374 * p^(-2 / 3)
Qₜ = Q₀ * (1 + g)^tt
```

Out[25]= $\frac{78.8374}{p^{2/3}}$

Out[26]= $\frac{78.8374\ (1+g)^{tt}}{p^{2/3}}$

In[27]:=
```
g = .03;
tt = 16.;
```

In[29]:=
```
Solve[Qt == Q, p]
```

Out[29]=
$$\left\{\left\{p \to \frac{1422.96}{Q^{3/2}}\right\}\right\}$$

In[30]:=
```
MB2 = 1422.96 * q^(-1.5);
```

In[31]:=
```
pl74i = Plot[{MB, MB2}, {q, 0., 170.},
    AxesLabel → {"Q", "$"},
    Ticks → {{{70, "", {0.00625, 0.}, {black, medum}},
       {80, "", {0.00625, 0.}, {black, medum}}}, {}},
    PlotRange → {0, 6}];
pl74 = Show[pl74i,
  Graphics[Text["MB0", {20., 4.8}]],
  Graphics[Text["MBt", {54., 4.8}]],
  Graphics[{Arrowheads[0.03], Arrow[{{30., 4.8}, {42., 4.8}}]}],
  AspectRatio → 0.4]
```

Out[32]=