

A very minimal introduction to TikZ*

Jacques Crémer
Toulouse School of Economics
`jacques.cremer@tse-fr.eu`

March 11, 2011

Contents

1	Introduction	3
2	Setting up a picture	3
3	Drawing lines and curves	4
3.1	Simple straight lines	4
3.2	Scaling pictures	5
3.3	Arrows and the like	6
3.4	Changing the thickness of lines	7
3.5	Dashes and dots	8
3.6	Colors	8
3.7	Pictures in the middle of the text	8
3.8	Curves	8
3.9	Plotting functions	11
4	Filling up areas	12
4.1	Filling up simple areas	12
4.2	Filling up arbitrary areas	13
5	Putting labels in pictures	13
6	Integration with Beamer	16
7	Hints and tricks	17

*Thanks to Christophe Bontemps, Michel-Benoît Bouissou and Florian Schuett for comments which have improved this document.

8	Examples	17
8.1	Hotelling	17
8.1.1	The whole picture	17
8.1.2	Step by step	18
8.2	Vertical differentiation	18
8.2.1	The whole picture	18
8.2.2	Step by step	18
8.3	A curve	19
8.3.1	The whole picture	19
8.3.2	Step by step	20
8.4	Tangency	20
8.4.1	The whole picture	20
8.4.2	Step by step	21
8.5	Consumer surplus	22
8.5.1	The whole picture	22
8.5.2	Step by step	22
8.6	Plotting lots of curves	23
9	Conclusion	24

1 Introduction

The aim of this document is to provide the minimum useful introduction to the TikZ package (written by Till Tantau), which enables you to do nice figures in L^AT_EX. I hope it will encourage for further exploration, but I also believe that at least 70% of the figures found in the economic literature can be drawn with the commands I present here.¹

There are certainly mistakes left in this document. Be careful and if you find a mistake, drop me an e-mail!

The latest version of this document can be found at <http://bit.ly/gNfVn9>.

2 Setting up a picture

Just write² `\usepackage{tikz}` in the preamble of your document. Modern T_EX engines³ such as MikTeX will automatically install the package. Then when you want to do a picture just write

```
\begin{tikzpicture}
code
\end{tikzpicture}
```

If you want to do a figure (you know the kind of thing that “floats” to the top of the page) you need to set it up as

```
\begin{figure}
\begin{tikzpicture}
code
\end{tikzpicture}
\caption{Do not forget!
  Make it explicit enough that readers
  can figure out what you are doing.}
\end{figure}
```

You then compile your document using PDF_TE_X or Xe_TE_X.

¹There is another popular package for doing figures in L^AT_EX, PSTricks, whose original version is due to the economist Tim van Zandt. The two packages are pretty much equivalent in terms of ease of use and features. TikZ has the advantage of better compatibility with PDF_TE_X; PSTricks has the advantage of some nice commands for drawing curves. You can find an introduction to PSTricks in the book “The L^AT_EX Graphics Companion”.

²This assumes that you are using L^AT_EX. TikZ can also be used in raw T_EX, but if you are hardcore enough to do that, you probably are better off going straight to the manual.

³I do not know how to set up TikZ for use with Scientific Word (which you should not be using in any case). If you know how to do it, please tell me so that I can put the instructions in the next version of this document. (I assume that if you can do it is still pretty uncomfortable, as the code for the pictures will be in the infamous gray boxes.)

There is a very extensive (over 700 pages!) manual. You can find it at <http://bit.ly/e3eQQd>.^{4,5,6}

3 Drawing lines and curves

3.1 Simple straight lines

To draw a line you do something like

```
\begin{tikzpicture}  
\draw (0,0) --(1,2);  
\end{tikzpicture}
```

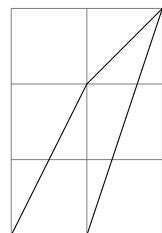
and you get



TikZ automatically draws a line between the points (0,0) and (1,2) and sets up the right space for the figure (by default, coordinates are in centimeters). You can do a sequence of segments which goes from point to point:

```
\begin{tikzpicture}  
\draw (0,0) --(1,2) -- (2,3) -- (1,0);  
\end{tikzpicture}
```

to get



(I have added the grid lines on the graphic to make it clearer. This is done through the command `\draw[help lines] (0,0) grid (2,3);`, which draws a grid from (0,0) to (2,3). The “help lines” option makes the presentation neater

⁴You can also find it on your computer once TikZ is installed. Go to the command line window and type `texdoc pgf` and choose `pgfmanual.pdf` in the list which is offered. Or, if you are using the WinEdt editor, you can go to L^AT_EX help and ask it for the help of the `pgf` package. (See the manual about the reasons for the two names TikZ and `pgf`.)

⁵In French, there also exists an introduction to TikZ which is shorter (but still 189 pages long) and may be more accessible than the manual. It is called “TikZ pour l’impatient”, was written by Gérard Tisseau and Jacques Duma, and can be found at <http://math.et.info.free.fr/TikZ/bdd/TikZ-Impatient.pdf>.

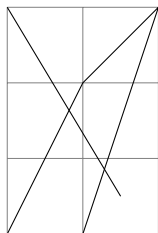
⁶There are a number of WYSIWYG or semi-WYSIWYG tools which can help you do graphics. For instance, while still in beta state TikZEdt seems useful (<http://code.google.com/p/tikzedt/>).

— I discuss this below. I will add grid lines as useful in what follows without putting the corresponding line in the code.)

Of course, you can put several lines on the same graph:

```
\begin{tikzpicture}
\draw (0,0) --(1,2) -- (2,3) -- (1,0);
\draw (3,0) -- (1.5,0.5);
\end{tikzpicture}
```

yields



Notice the semi-colons “;” at the end of lines — it is these semi-colons which mark the end of instructions. You will see below examples where one instruction is spread over several lines. We could also put several instructions on one line: in the last picture I could have written

```
\draw (0,0) --(1,2) -- (2,3) -- (1,0); \draw (3,0) -- (1.5,0.5);
```

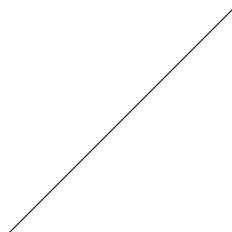
without changing the output. You can also add and suppress spaces, for instance in order to make the code easier to read, without changing anything in the output.

3.2 Scaling pictures

One very useful feature of TikZ is that you can blow up the picture, by adding an option “scale” to the environment.

```
\begin{tikzpicture}[scale=3]
\draw (0,0) -- (1,1);
\end{tikzpicture}
```

to get



which you can compare to the following:

```
\begin{tikzpicture}
\draw (0,0) -- (1,1);
\end{tikzpicture}
```

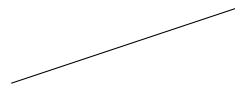
which yields



You can scale only one dimension:

```
\begin{tikzpicture}[xscale=3]
\draw (0,0) -- (1,1);
\end{tikzpicture}
```

to get



or both dimensions in different proportions:

```
\begin{tikzpicture}[xscale=2.5,yscale=0.5]
\draw (0,0) -- (1,1);
\end{tikzpicture}
```

to get

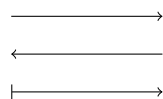


3.3 Arrows and the like

You can “decorate” the lines. For instance we can put arrows or bars on one of both extremities:

```
\begin{tikzpicture}
\draw [->] (0,0) -- (2,0);
\draw [<-] (0, -0.5) -- (2,-0.5);
\draw [|->] (0,-1) -- (2,-1);
\end{tikzpicture}
```

which yields



When you draw several segments, the arrows are placed at the extremities of the first and the last segments. This is convenient, among other things to draw axes (we will see later how to label them):

```
\begin{tikzpicture}
\draw [<->] (0,2) -- (0,0) -- (3,0);
\end{tikzpicture}
```

which gives you

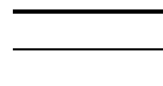









3.4 Changing the thickness of lines

Other decorations include changing the thickness:

```
\begin{tikzpicture}
\draw [ultra thick] (0,1) -- (2,1);
\draw [thick] (0,0.5) -- (2,0.5);
\draw [thin] (0,0) -- (2,0);
\end{tikzpicture}
```

to obtain

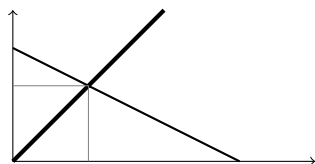


You can use: ultra thin , very thin , thin , semithick , thick , very thick  and ultra thick .

There is also the “help lines” option, discussed above, which is made specially to be fine gray lines for showing special points:

```
\begin{tikzpicture}
\draw [lt] (0,2) -- (0,0) -- (4,0);
\draw [thick] (0,1.5) -- (3,0);
\draw [ultra thick] (0,0) -- (2,2);
\draw [help lines] (1,0) -- (1,1) -- (0,1);
\end{tikzpicture}
```

which yields



You can also use custom widths:

```
\begin{tikzpicture}
\draw [line width=12] (0,0) -- (2,0);
\draw [line width=0.2cm] (4,.75) -- (5,.25);
\end{tikzpicture}
```

which gives a line 12pt wide (the default dimension for width is point) and another one .2cm wide:



3.5 Dashes and dots

You can also make dotted and dashed lines

```
\begin{tikzpicture}
\draw [dashed, ultra thick] (0,1) -- (2,1);
\draw [dashed] (0, 0.5) -- (2,0.5);
\draw [dotted] (0,0) -- (2,0);
\end{tikzpicture}
```

This gives:

.....

.....




















The top line shows you that you can mix types of decorations. You have lots of control over the style of your dotted and dashed lines (see the manual).

3.6 Colors


And finally, you can color your lines.

```
\begin{tikzpicture}
\draw [gray] (0,1) -- (2,1);
\draw [red] (0, 0.5) -- (2,0.5);
\draw [blue] (0,0) -- (2,0);
\end{tikzpicture}
```

This gives

You have direct access to the following colors: red , green , blue , cyan , magenta , yellow , black , gray , darkgray , lightgray , brown , lime , olive , orange , pink , purple , teal , violet , and white . And you can define all the colors you might want — see the manual.

3.7 Pictures in the middle of the text

By the way, you may wonder how I included these rectangles in the text. TikZ makes a picture wherever  you want; I just typed

```
wherever \begin{tikzpicture} \draw [yellow, line width=6]
(0,0) -- (.5,0); \end{tikzpicture} you want
```

(To make these constructions easier to type you can use the command `\tikz` — see the manual.)

3.8 Curves

You are not limited to straight lines:


```

\begin{tikzpicture}
\draw [blue] (0,0) rectangle (1.5,1);
\draw [red, ultra thick] (3,0.5) circle [radius=0.5];;
\draw [gray] (6,0) arc [radius=1, start angle=45, end angle= 120];
\end{tikzpicture}

```

This gives:



(The arc is of radius 1, starts at the point (6,0) leaving it at an angle of 45 degrees and stops when its slope is 120 degrees — this is not the most convenient notation!)

You can make paths take smoother turns:

```

\begin{tikzpicture}
\draw [<->, rounded corners, thick, purple] (0,2) -- (0,0) -- (3,0);
\end{tikzpicture}

```

which gives you



If you want a precise curve you can do it by computing lots of points in a program such as Mathematica[©] and then putting them into TikZ:

```

\begin{tikzpicture}[xscale=25,yscale=5]
\draw [<->, help lines] (0.6,1.34) -- (0.6,1) -- (1.05,1);
\draw[orange] (0.6, 1.0385) --
(0.61, 1.06372) -- (0.62, 1.08756) -- (0.63, 1.11012) -- (0.64,
1.13147) -- (0.65, 1.15166) -- (0.66, 1.17074) -- (0.67, 1.18874) -- (0.68,
1.20568) -- (0.69, 1.22157) -- (0.7, 1.23643) -- (0.71, 1.25026) -- (0.72,
1.26307) -- (0.73, 1.27486) -- (0.74, 1.28561) -- (0.75, 1.29534) -- (0.76,
1.30402) -- (0.77, 1.31165) -- (0.78, 1.31821) -- (0.79, 1.32369) -- (0.8,
1.32806) -- (0.81, 1.33131) -- (0.82, 1.3334) -- (0.83, 1.33431) -- (0.84,
1.334) -- (0.85, 1.33244) -- (0.86, 1.32956) -- (0.87, 1.32533) -- (0.88,
1.31966) -- (0.89, 1.3125) -- (0.9, 1.30373) -- (0.91, 1.29325) -- (0.92,
1.2809) -- (0.93, 1.26649) -- (0.94, 1.24976) -- (0.95, 1.23032) -- (0.96,
1.2076) -- (0.97, 1.18065) -- (0.98, 1.14763) -- (0.99, 1.1038) -- (0.991,
1.09836) -- (0.992, 1.09261) -- (0.993, 1.0865) -- (0.994, 1.07994) -- (0.995,
1.07282) -- (0.996, 1.06497) -- (0.997, 1.0561) -- (0.998, 1.04563) -- (0.999,
1.03209) -- (0.9991, 1.03042) -- (0.9992, 1.02866) -- (0.9993,
1.02679) -- (0.9994, 1.02478) -- (0.9995, 1.0226) -- (0.9996, 1.02019) -- (0.9997,
1.01747) -- (0.9998, 1.01424) -- (0.9999, 1.01005) -- (0.9999,
1.01005) -- (0.99991, 1.00953) -- (0.99992, 1.00898) -- (0.99993,
1.0084) -- (0.99994, 1.00778) -- (0.99995, 1.0071) -- (0.99996,
1.00634) -- (0.99997, 1.00549) -- (0.99998, 1.00448) -- (0.99999, 1.00317) -- (1,
1) ;
\end{tikzpicture}

```

which gives you



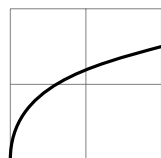
Two remarks:

- This was overkill: I do not need so many points;
- This can also serve as a reminder that one TikZ instruction can be spread over several lines and cut arbitrarily over several lines. The marker is the semi-colon, not the end of line!

There are a number of ways by which you can do curves without plotting all the points. Here is an easy one:

```
\begin{tikzpicture}
\draw[very thick] (0,0) to [out=90,in=195] (2,1.5);
\end{tikzpicture}
```

This gives us a curve from (0,0) to (2,1.5) which leaves at an angle of 90° and arrive at an angle of 195° :



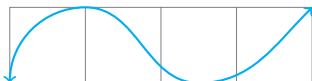
Note that I had to replace the – by “to”. Notice how the angles work:

- When the curves goes “out” of (0,0), you put a needle with one extremity on the starting point and the other one facing right and you turn it counterclockwise until it is tangent to the curve. The angle by which you have to turn the needle gives you the “out” angle.
- When the curves goes “in” at (2,1.5), you put a needle with one extremity on the arrival point and the other one facing right and you turn it counterclockwise until it is tangent to the curve. The angle by which you have to turn the needle gives you the “in” angle.

As with straight lines you can put several to instructions in the same TikZ instruction:

```
\begin{tikzpicture}
\draw [<->,thick, cyan] (0,0) to [out=90,in=180] (1,1)
to [out=0,in=180] (2.5,0) to [out=0,in=-135] (4,1) ;
\end{tikzpicture}
```

which gives you



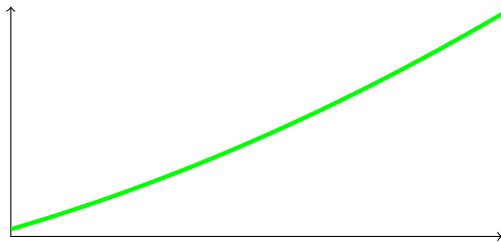
Note that we can put arrows on curves also. They are put at the extremities of the first and last segments. If you want an arrow on each segment, you have to build the curve from individual components.

3.9 Plotting functions

TikZ also has a math engine which enables you to plot functions:

```
\begin{tikzpicture}[xscale=13,yscale=3.8]
\draw [<->] (0,0.8) -- (0,0) -- (0.5,0);
\draw[green, ultra thick, domain=0:0.5] plot (\x, {0.025+\x+\x*\x});
\end{tikzpicture}
```

gives you



The domain instruction shows the range of x which is plotted. In this case we are plotting the function $0.025 + x + x^2$. Note the braces around the function that we plot in `plot (\x, {function})`.

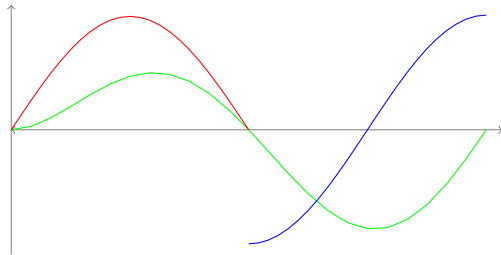
Many mathematical functions are possible; you will probably have enough with `factorial(\x)`, `sqrt(\x)`, `pow(\x,y)` (which gives x^y), `exp(\x)`, `ln(\x)`, `log10(\x)`, `log2(\x)`, `abs(\x)` (the absolute value of x), `mod(\x,y)` (x modulo y), `round(\x)` (rounds x to the nearest integer), `floor(\x)` (the largest integer smaller than x), `ceil(\x)` (the smallest integer larger than x), `sin(\x)` ($\sin(x)$, it assumes that x is in degrees; if x is expressed in radians use `sin(\x r)`), `cos(\x)` ($\cos(x)$, it assumes that x is in degrees; if x is expressed in radians use `cos(\x r)`), `tan(\x)` ($\tan(x)$, it assumes that x is in degrees; if x is expressed in radians use `tan(\x r)`), `min(\x,y)`, `max(\x,y)`. You can even use `rnd` (without argument) which yields a random number between 0 and 1.

In mathematical expressions the two following variables can be useful: `e`, which is equal to 2.718281828, and `pi`, which is equal to 3.141592654.

You can mix functions to compute more complicated expressions (see above for the reason for the `r` parameter in the argument of `sin` and `cos` and note the use of `pi` to define the domains):

```
\begin{tikzpicture}[yscale=1.5]
\draw [help lines, <->] (0,0) -- (6.5,0);
\draw [help lines, ->] (0,-1.1) -- (0,1.1);
\draw [green,domain=0:2*pi] plot (\x, {(sin(\x r)* ln(\x+1))/2});
\draw [red,domain=0:pi] plot (\x, {sin(\x r)});
\draw [blue, domain=pi:2*pi] plot (\x, {cos(\x r)*exp(\x/exp(2*pi))});
\end{tikzpicture}
```

which gives you



4 Filling up areas

4.1 Filling up simple areas

You can also fill paths when they are closed:

```
\begin{tikzpicture}
\draw [fill=red,ultra thick] (0,0) rectangle (1,1);
\draw [fill=red,ultra thick,red] (2,0) rectangle (3,1);
\draw [blue, fill=blue] (4,0) -- (5,1) -- (4.75,0.15) -- (4,0);
\draw [fill] (7,0.5) circle [radius=0.1];
\draw [fill=orange] (9,0) rectangle (11,1);
\draw [fill=white] (9.25,0.25) rectangle (10,1.5);
\end{tikzpicture}
```

to get



Notice the difference between the first two squares. The second `red` in `[fill=red,ultra thick,red]` tells TikZ to draw the line around the shape in red. We have indicated no color in the first, so the line is black.

If you do not want to see the outline at all, replace the `\draw` command by `\path`:

```
\begin{tikzpicture}
\path [fill=gray] (0,0) rectangle (1.5,1);
\draw [fill=yellow] (2,0) rectangle (3.5,1);
\end{tikzpicture}
```

gives you



Of course, we could have replaced the first line by `\draw [fill=yellow,yellow] (0,0) rectangle (1.5,1);`; we would have obtained a square like the second one, except for the fact that it is surrounded by a yellow line.

4.2 Filling up arbitrary areas

The content in this subsection are not necessary to understand the rest of the document. You can skip it at first reading. (But example 8.5 uses these techniques.)

You can draw paths which mix the `--` and the `to` constructions above. This is useful for filling up strange looking areas.

```
\begin{tikzpicture}
\draw [ultra thick] (0,0) to [out=87,in=150] (1,1) -- (.85,.15) -- (0,0);
\draw [ultra thick, fill=purple] (2,0) to [out=87,in=150] (3,1) -- (2.85,.15) -- (2,0);
\path [fill=purple] (4,0) to [out=87,in=150] (5,1) -- (4.85,.15) -- (4,0);
\end{tikzpicture}
```

to get



Actually if you put the `to` constructions without any “options” you get a straight line:

```
\begin{tikzpicture}
\draw [ultra thick] (0,0) to (1,1) to (.85,.15) to (0,0);
\end{tikzpicture}
```

gives you

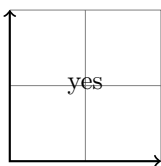


5 Putting labels in pictures

When you do a picture, in 99% of cases you also need to put labels. This is easy. Let us start by seeing how we would place some text in a picture.

```
\begin{tikzpicture}
\draw [thick, <->] (0,2) -- (0,0) -- (2,0);
\node at (1,1) {yes};
\end{tikzpicture}
```

yields



Notice how the “yes” is positioned: the center of its “baseline” is at (1,1).

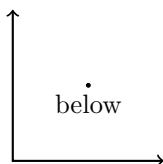
Sometimes you want a label to be situated relative to a point. *TikZ* has neat commands for this. For instance you can write

```

\begin{tikzpicture}
\draw [thick, <->] (0,2) -- (0,0) -- (2,0);
\draw[fill] (1,1) circle [radius=0.025];
\node [below] at (1,1) {below};
\end{tikzpicture}

```

to get



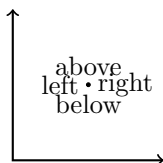
You are not limited to put things below a point:

```

\begin{tikzpicture}
\draw [thick, <->] (0,2) -- (0,0) -- (2,0);
\draw[fill] (1,1) circle [radius=0.025];
\node [below] at (1,1) {below};
\node [above] at (1,1) {above};
\node [left] at (1,1) {left};
\node [right] at (1,1) {right};
\end{tikzpicture}

```

yields



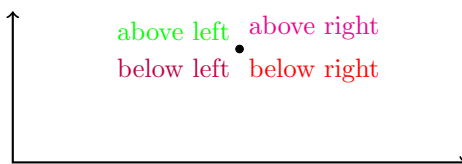
And, you can also mix and match

```

\begin{tikzpicture}[scale=2]
\draw [thick, <->] (0,1) -- (0,0) -- (1,0);
\draw[fill] (1,1) circle [radius=0.025];
\node [below right, red] at (.5,.75) {below right};
\node [above left, green] at (.5,.75) {above left};
\node [below left, purple] at (.5,.75) {below left};
\node [above right, magenta] at (.5,.75) {above right};
\end{tikzpicture}

```

yields



This makes it possible to label axes and points:

```

\begin{tikzpicture}[xscale=3, yscale=1.5]
\draw [thick, <->] (0,1) -- (0,0) -- (1,0);
\node [below right] at (1,0) {$x$};

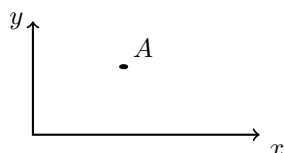
```

```

\node [left] at (0,1) {$y$};
\draw[fill] (.4,.6) circle [radius=.5pt];
\node[above right] (.4,.6) {$A$};
\end{tikzpicture}

```

gives you



You can avoid some typing by mixing nodes in the middle of paths. For instance the last figure could have been written as follows:

```

\begin{tikzpicture}[xscale=3, yscale]
\draw [thick, <->] (0,1) node [left] {$y$}
-- (0,0) -- (1,0) node [below right] {$x$};
\draw[fill] (.4,.6) circle [radius=.5pt]
node[above right] (.4,.6) {$A$};
\end{tikzpicture}

```

which would have given exactly the same result. Note that the node is put after the point to which it is attached and that we suppress the `\` in `\node`.

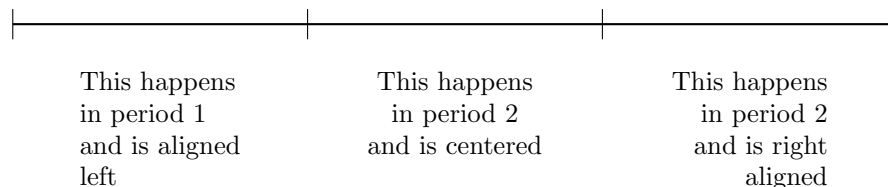
Sometimes, you may want to put several lines in your “node” (this is convenient when drawing time lines for instance). This can be done by using the standard L^AT_EX `\\` for indicating a new line but *you must* tell TikZ how to align things. Type

```

\begin{tikzpicture}[xscale=1.3]
\draw [thick] (0,0) -- (9,0);
\draw (0,-.2) -- (0, .2);
\draw (3,-.2) -- (3, .2);
\draw (6,-.2) -- (6, .2);
\draw (9,-.2) -- (9, .2);
\node[align=left, below] at (1.5,-.5)%
{This happens\\in period 1\\and is aligned\\ left};
\node[align=center, below] at (4.5,-.5)%
{This happens\\in period 2\\and is centered};
\node[align=right, below] at (7.5,-.5)%
{This happens\\in period 2\\and is right\\aligned};
\end{tikzpicture}

```

to obtain



Without the option `align=` TikZ will make one big line. If I made the mistake to write


```

\begin{tikzpicture}
\draw [->] (0,0) -- (2,0);
\node [right] at (2,0) {above\\below};
\end{tikzpicture}

```

I would have obtained

—————→ abovebelow

The TikZ manual will give you information about the way in which you can control more precisely the position and shapes of the labels, and also on the way in which you can put labels on lines and curves as in .

6 Integration with Beamer

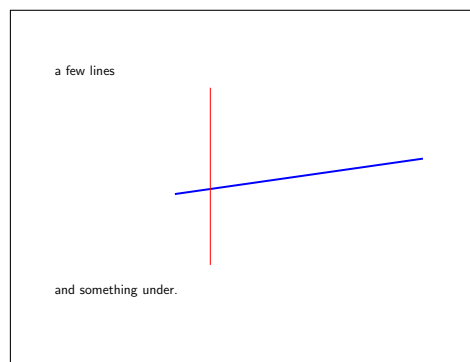
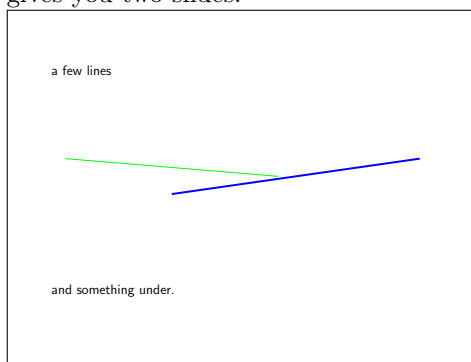
TikZ works very well with Beamer (they were written by the same person!). In particular it is very easy to uncover figures progressively. For instance

```

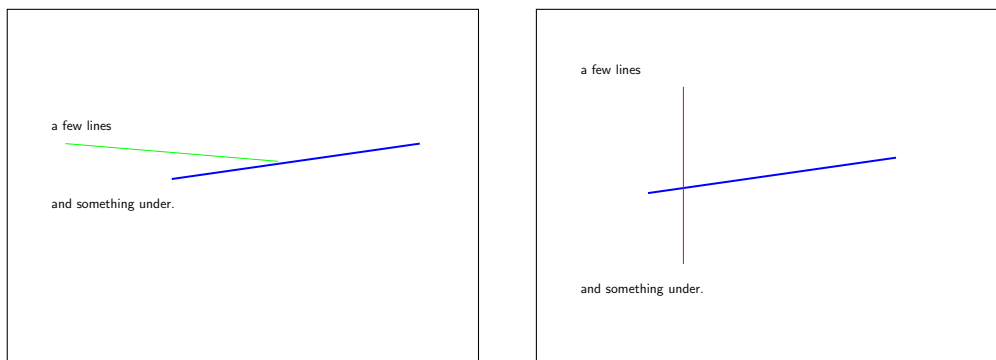
\begin{frame}
a few lines
\begin{center}
\begin{tikzpicture}
\draw [blue, ultra thick] (-1,2) -- (6,3);
\uncover<1>{\draw [green,thick] (-4,3) -- (2,2.5);}
\uncover<2>{\draw [red,thick] (0,0) -- (0,5);}
\end{tikzpicture}
\end{center}
and something under.
\end{frame}

```

gives you two slides:



It is important to use `\uncover` and `\cover` (or, nearly equivalently, `\visible` and `\invisible`) rather than `\only`. If I replace `\uncover` by `\only` in the code above I get



Notice how the text changes position. With `\uncover` the lines are “drawn” on all the slides but made invisible when not called for. With `\only` the lines are only drawn when called for.

7 Hints and tricks

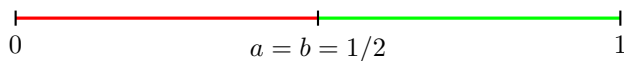
- It takes some time to draw figures. And it is normal to make mistakes. Proceed by trial and error, compiling your code often.
- If you have problems placing things, it is useful to draw a grid; you can comment it out when compiling the final version. Put the grid as the first instruction in the picture, so that it does not overwrite the interesting part! (There are lots of possible options for the grid: see the manual.)

8 Examples

A few examples.

8.1 Hotelling

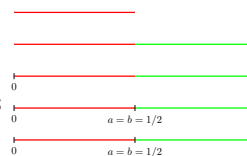
8.1.1 The whole picture



```
\begin{tikzpicture}[xscale=8]
\draw[-][draw=red, very thick] (0,0) -- (.5,0);
\draw[-][draw=green, very thick] (.5,0) -- (1,0);
\draw [thick] (0,-.1) node[below]{0} -- (0,0.1);
\draw [thick] (0.5,-.1) node[below]{$a=b=1/2$} -- (0.5,0.1);
\draw [thick] (1,-.1) node[below]{1} -- (1,0.1);
\end{tikzpicture}
```

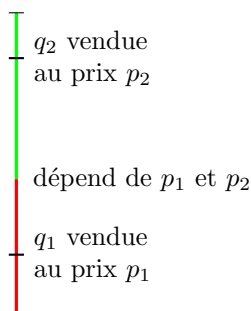
8.1.2 Step by step

```
\draw[-][draw=red, very thick] (0,0) -- (.5,0);
\draw[-][draw=green, very thick] (.5,0) -- (1,0);
\draw [thick] (0,-.1) node[below]{0} -- (0,0.1);
\draw [thick] (0.5,-.1) node[below]{ $a=b=1/2$ } -- (0.5,0.1);
\draw [thick] (1,-.1) node[below]{1} -- (1,0.1);
```



8.2 Vertical differentiation

8.2.1 The whole picture



```
\begin{tikzpicture}[yscale=4]
\draw[-][draw=red, very thick] (0,0) -- (0,.45);
\draw[-][draw=green, very thick] (0,.45) -- (0,1);
\draw [thick] (-0.1,0.2) -- (0.1,.2) node[align=left, right]
    { $q_1$  vendue\ au prix  $p_1$ };
\node[right] at (0.1,.45) {d'epend de  $p_1$  et  $p_2$ };
\draw [thick] ((-0.1,0.85) -- (0.1,.85) node[align=left, right]
    { $q_2$  vendue\ au prix  $p_2$ };
\draw (-0.1,0) -- (0.1,0);
\draw (-0.1,1) -- (0.1,1);
\end{tikzpicture}
```

The figure looks better with the labels “ q_i vendue au prix p_i ” on one line, but I wanted to remind you of the possibility of writing the text in a node over several lines! Note that in `[align=left, right]` the `align=left` tells TikZ to align the text to the left whereas the `right` option tells it to put the node to the right of the coordinate.

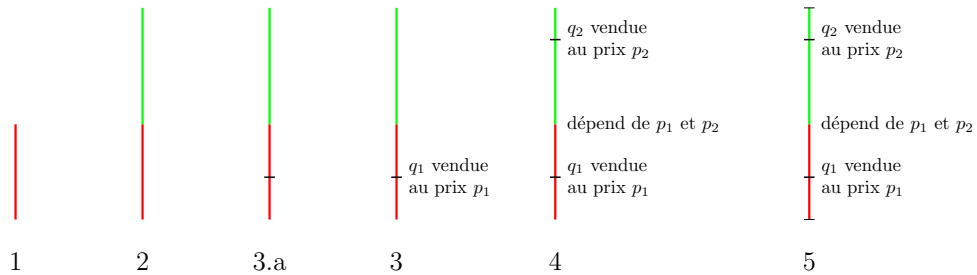
8.2.2 Step by step

```
\begin{tikzpicture}[yscale=4]
1. \draw[-][draw=red, very thick] (0,0) -- (0,.45);
2. \draw[-][draw=green, very thick] (0,.45) -- (0,1);
3.a. \draw [thick] (-0.1,0.2) -- (0.1,.2);
```

```

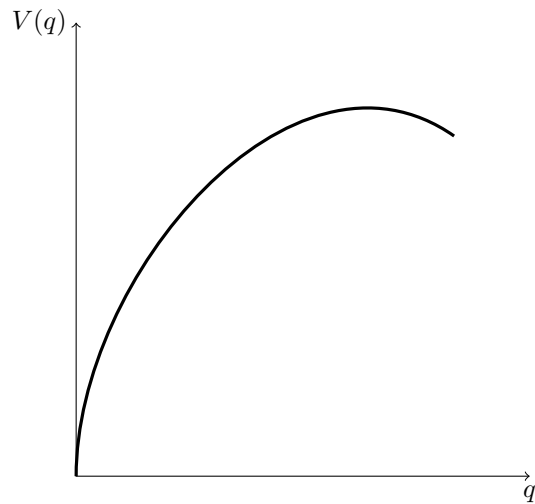
3. \draw [thick] (-0.1,0.2) -- (0.1,.2) node[align=left, right]
    {$q_1$ vendue\ au prix $p_1$};
4. \node[right] at (0.1,.45) {d\'epend de $p_1$ et $p_2$};
4. \draw [thick] ((-0.1,0.85) -- (0.1,.85) node[align=left, right]
    {$q_2$ vendue\ au prix $p_2$};
5. \draw (-0.1,0) -- (0.1,0);
5. \draw (-0.1,1) -- (0.1,1);
\end{tikzpicture}

```



8.3 A curve

8.3.1 The whole picture



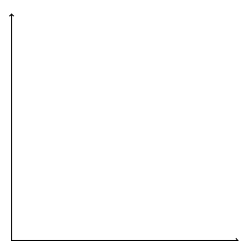
```

\begin{center}
\begin{tikzpicture}
\draw[<->] (6,0) node[below]{$q$} -- (0,0) --
    (0,6) node[left]{$V(q)$};
\draw[very thick] (0,0) to [out=90,in=145] (5,4.5);
\end{tikzpicture}
\end{center}

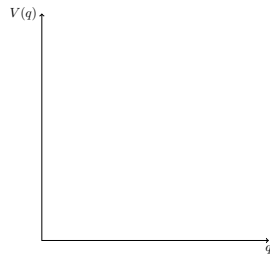
```

8.3.2 Step by step

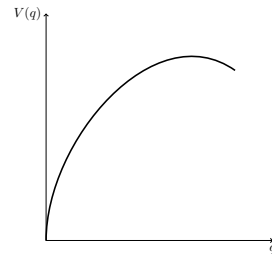
```
\begin{tikzpicture}
1.a. \draw[<->] (6,0) -- (0,0) --
      (0,6);
1. \draw[<->] (6,0) node[below]{$q$} -- (0,0) --
      (0,6) node[left]{$V(q)$};
2. \draw[very thick] (0,0) to [out=90,in=145] (5,4.5);
\end{tikzpicture}
```



1.a



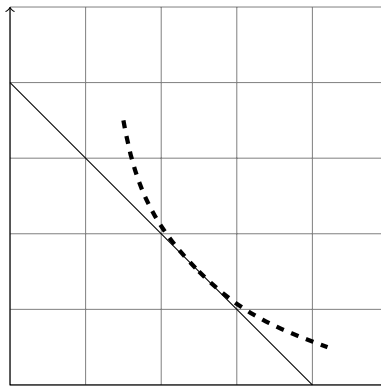
1



3

8.4 Tangency

8.4.1 The whole picture



```
\begin{tikzpicture}
\draw [help lines] (0,0) grid (5,5);
\draw [<->] (5,0) -- (0,0) -- (0,5);
\draw (4,0) -- (0,4);
\draw[dashed,ultra thick]
  (1.5,3.5) to [out=-80,in=135] (2.5,1.5);
\draw [dashed,ultra thick]
  (2.5,1.5) to [out=-45,in=160] (4.2,0.5);
\end{tikzpicture}
```

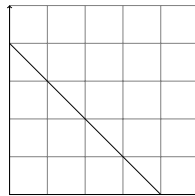
You have recognized a consumer! Note the use of “in” and “to” to get the tangents. We could have made this a bit more compact by writing the dashed line in one instruction:

```
\draw[dashed,ultra thick]
  (1.5,3.5) to[out=-80,in=135] (2.5,1.5)
  to [out=-45,in=160] (4.2,0.5);
```

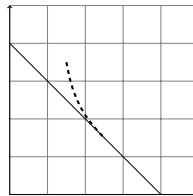
Notice also that the curves goes “in” (2.5,1.5) at an angle of 135° and goes “out” at an angle of 45° . This is consistent with the behavior explained on page 10.

8.4.2 Step by step

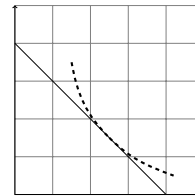
```
\begin{tikzpicture}
1. \draw [help lines] (0,0) grid (5,5);
1. \draw [<->] (5,0) -- (0,0) -- (0,5);
1. \draw (4,0) -- (0,4);
2. \draw[dashed,ultra thick]
  (1.5,3.5) to [out=-80,in=135] (2.5,1.5);
3. \draw [dashed,ultra thick]
  (2.5,1.5) to [out=-45,in=160] (4.2,0.5);
\end{tikzpicture}
```



1



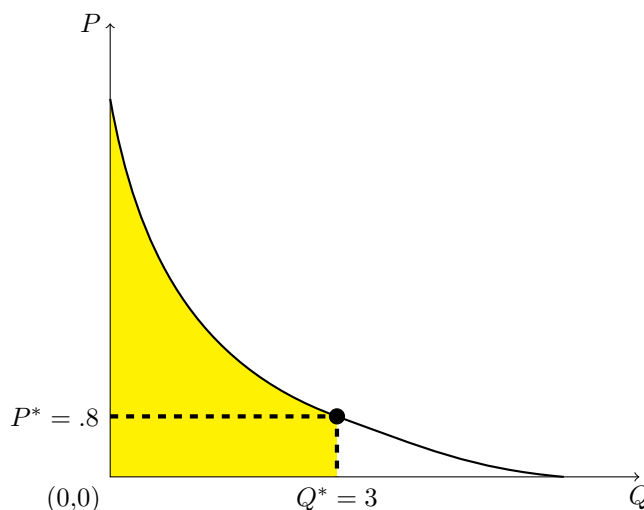
2



3

8.5 Consumer surplus

8.5.1 The whole picture



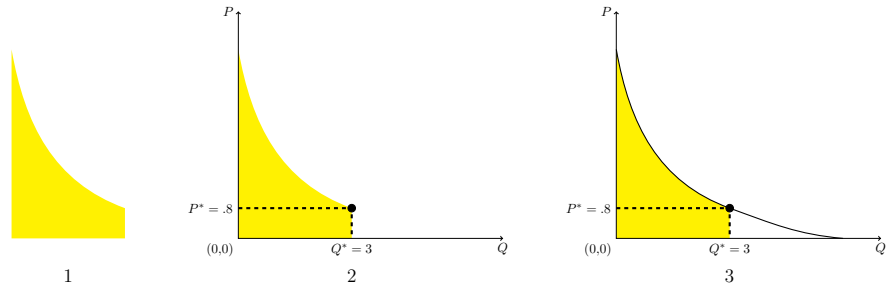
```
\begin{tikzpicture}
\path [fill=yellow] (0,0) -- (0,5) to [out=-80, in=160]
    (3,.8) -- (3,0) -- (0,0);
\draw [<->] (0,6) node [left] {$P$} -- (0,0)
    node [below left] {(0,0)} -- (7,0) node [below] {$Q$};
\draw [ultra thick, dashed] (0,.8) node [left] {$P^*=.8$} -- (3,.8)
    -- (3,0) node [below] {$Q^*=3$};
\draw [fill] (3,.8) circle [radius=.1];
\draw [thick] (0,5) to [out=-80, in=160] (3,.8) to
    [out=-20, in=175] (6,0);
\end{tikzpicture}
```

Note that I color the filled area before drawing the lines, to make sure that those come on top and are visible. (There is, of course, no serious reason for the P^* and the Q^* to be equal to the “real” coordinates of the circled point in the picture, except to help you understand what is happening.)

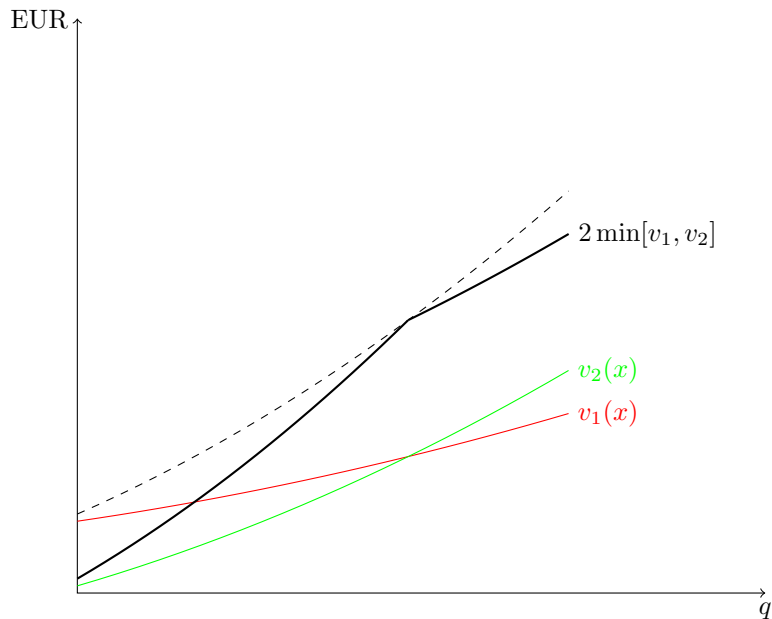
8.5.2 Step by step

```
\begin{tikzpicture}
1. \path [fill=yellow] (0,0) -- (0,5) to [out=-80, in=160]
    (3,.8) -- (3,0) -- (0,0);
2. \draw [<->] (0,6) node [left] {$P$} -- (0,0)
    node [below left] {(0,0)} -- (7,0) node [below] {$Q$};
2. \draw [ultra thick, dashed] (0,.8) node [left] {$P^*=.8$} -- (3,.8)
    -- (3,0) node [below] {$Q^*=3$};
2. \draw [fill] (3,.8) circle [radius=.1];
3. \draw [thick] (0,5) to [out=-80, in=160] (3,.8) to
```

```
[out=-20, in=175] (6,0);
\end{tikzpicture}
```



8.6 Plotting lots of curves



```
\begin{center}
\begin{tikzpicture}[domain=0:0.5,xscale=13,yscale=3.8]
\draw[<->] (0,2) node[left]{EUR}-- (0,0) -- (.7,0) node[below] {$q$};
\draw[red] plot (\x, {0.25+\x/2+\x*\x/2}) node[right] {$v_1(x)$};
\draw[green] plot (\x, {0.025+\x+\x*\x}) node[right] {$v_2(x)$};
\draw[thin, dashed] plot (\x, {0.275+1.5*\x+1.5*\x*\x}) ;
\draw[thick,domain=0:0.33666] plot (\x, {0.05+2*\x+2*\x*\x}) ;
\draw[thick,domain=0.33666:0.5]
  plot (\x, {0.5+\x+\x*\x}) node[right] {$2\min[v_1,v_2]$};
\end{tikzpicture}
\end{center}
```

You should be able to figure it out. Note that I can also attach nodes to the plots of mathematical functions.

9 Conclusion

TikZ is a very large program which can do lots of things. You will find commands to draw hierarchial trees, to draw lots of different types of shapes, to do some elementary programming, to align elements of a picture in a matrix frame, to decorate nodes, to compute the intersections of paths, etc. The main message is “if it is not in these notes, it is most probably somewhere in the manual”.