

# HOW TO MAKE A FORMATTED CDF DEMONSTRATION

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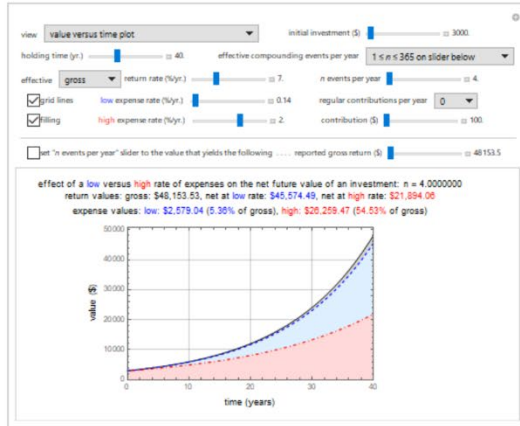
Effect of High Expense Charges on an Investment's Net Return - Wolfram Mathematica 11.3

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Wolfram Demonstrations Project

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## Effect of High Expense Charges on an Investment's Net Return



The net yield of a long-term investment primarily depends on an effective interest return rate and the way in which it is compounded. However, the actual yield also heavily depends on the total expense rate charged to maintain the account, which typically ranges from a fraction of a percent to a few percent. The expense rate can have a huge accumulated effect as time goes on. This Demonstration generates and plots investment value versus time curves at various effective return rates. Both the low and high expense rates, with various effective compounding frequencies, are shown in scenarios where regular fixed contributions may be added periodically to the original investment amount. The difference between the gross and net yields at both low and high expense rates is calculated and tables are generated that show the yield after different combinations of holding times, return rates and expense rates.

### THINGS TO TRY

Resize Images · Slider Zoom · Gamepad Controls · Automatic Animation

### DETAILS

#### Snapshots

Snapshot 1: Growth curve (plotted as a solid black line) of a \$10,000 investment over a holding time of 40 years with no added contributions at a 7% effective gross return rate compounded continuously. It also shows growth curves at two expense rates, low (0.04%, dashed line plotted in blue) and high (2%, dash-dot line plotted in red).

Snapshot 2: Table showing the conditions from Snapshot 1 (continuous compounding at a 7% effective gross return rate with no added contributions) that contains 18 different expense rate percentage rows ranging from 0.05% to 2.5% and 14 different holding time columns ranging from 10 to 75 years in 5-year increments. Note that when the number of regular contributions per year is set to 0 and continuous compounding is chosen, a change to either the initial amount or effective gross return rate slider does not affect any of the compounding table's percentage entries. Snapshots 1 and 2 represent theoretical maximum compounding scenarios that are unlikely to be encountered in reality.

Snapshot 3: Growth curve (plotted as a solid black line) of a \$10,000 investment over a holding time of 40 years with no added contributions at a 7% effective gross return rate compounded annually (1 time/year). It also shows growth curves at two expense rates, low (0.04%, dashed line plotted in blue) and high (2%, dash-dot line plotted in red).

Snapshot 4: Growth curve (plotted as a solid black line) of a \$10,000 investment over a holding time of 40 years with no added contributions at a 8.96% effective gross return rate compounded annually. It also shows growth curves at two expense rates, low (0.04%, dashed line plotted in blue) and high (2%, dash-dot line plotted in red). Note that the net yield returned to the investor at a high 2% expense rate (\$158,007.36 shown in red on line 2 above the plot) in Snapshot 4 is exactly the same as the low expense rate net yield amount (shown in blue on line 2 above the plot) from Snapshot 3. This shows that a fund charging a 2% expense rate needs to produce an effective gross return rate of 8.96% for 40 years to yield the same net amount to the investor as did a fund that had a 7% gross return rate but charged only a 0.04% expense rate over those 40 years.

Snapshot 5: Growth curve (plotted as a solid black line) of a \$10,000 investment over a holding time of 40 years with no added contributions at a 7% effective gross return rate. It also shows growth curves at two expense rates, low (0.04%, dashed line plotted in blue) and high (2%, dash-dot line plotted in red). Specification of the investment's total return after the low expense rate has been subtracted is selected by the popup menu option "net (-lo)". As shown, you can use the slider "reported net (-lo) return (\$)" to enter a known reported net value of the investment after expenses at the low rate have been subtracted. Once the checkbox "set 'n' events per year" slider to the value that yields the following" is checked,  $n$ , the number of effective compounding events per year is computed, and its new value appears on the "n events per year" slider as well as on the first line of text above the plot.

#### Explanation of Terms

The actual (net) yield to the investor of a long-term investment, with or without periodic additional deposits, can be dramatically influenced by the expense rate charged to maintain the account. This Demonstration calculates an investment's growth under various hypothetical conditions and highlights the difference between the gross yield without expenses and the actual yield after their subtraction. It should be noted that the total expense rate must include all expenses and fees that are charged for maintenance of the account, since all such charges cause a reduction in the net yield of the account to the investor. The effective return rate and the expense rate (also called "expense ratio") are typically reported as percentages in a fund's quarterly investment report of past performance and in the fund's prospectus of future performance. The return rate reported may be the gross return rate (the rate before the expense rate has been subtracted) or the net return rate (the rate after either the low or the high expense rate has been subtracted). If those percentages are not readily available, it is reasonable to assume the fund managers are attempting to conceal a high expense rate.

It must be emphasized that a fund's expense percentage rate is not the percentage of the total gross return of that fund at the end of its holding time (e.g., a reported 2% expense rate does not mean that 2% out of the 100% of a fund's gross return at the end of a typical 40-year holding time is the percentage lost to expenses). A reported 2% expense rate also does not represent a linear fraction of the effective gross return rate percentage of the fund (e.g., for a fund whose gross return rate is 7% but which charges a 2% expense rate, 2/7% is  $\approx 28.57\%$ , which is still much less than the actual percentage taken by expenses after 40 years). In fact, the reported expense percentage is a percentage rate that should be subtracted from the effective gross return rate percentage and the difference then used to compute the actual net yield of the fund to the investor at that lower rate. For example, a fund that has an effective gross return rate of 9% but charges a 2% expense rate is actually only returning a net yield rate of 7% to the investor, which after a holding time equal to a typical working lifetime of 40 years can easily represent more than 50% of the total gross return value of the fund, as shown in the Thumbnail image and also as illustrated in Snapshots 3 and 4.

Because all money earned by a typical investment fund is automatically reinvested in the fund, the value of the fund increases over time by the same process as the accumulation of compound interest in a bank savings account. The upper limit of that process is described by the equation  $\lim_{n \rightarrow \infty} (1 + 1/n)^n = e$  where  $n$  is the number of compounding events per year and  $e$  is Euler's constant, the base of the natural logarithm ( $\approx 2.718281828459 \dots$ ). The future value  $f$  of an amount  $a$  invested in an account that compounds continuously at an annual interest rate  $r$  over  $t$  years is  $f = ae^{rt}$ .

#### Use of Manipulate Control Items

Use the "View" popup menu to choose the plot or table display mode. Use the "initial investment (\$)" slider to set the investment's initial deposit amount (in US dollars). Enter the investment's holding time (in years) using its slider. The investment's reported effective return rate (either gross, net after subtraction of the entered low expense rate or net after subtraction of the entered high expense rate) is chosen from a popup menu and the effective return rate value (in %/yr.) is entered with a slider. Two total expense rates, one specifying a low rate (in blue) and another a high rate (in red) and both in units of %/yr., are entered with sliders.

The estimated effective compounding frequency is entered by first choosing from the "effective compounding events per year" popup menu "n" on slider below" to enter a real number  $n$  of compounding events per year from 0.00001 to 1, inclusive, or "1 <= n <= 365 on slider" to enter a real number  $n$  from 1 to 365, inclusive, or "n = continuous" to select continuous compounding. If either of the first two options is chosen, a real number is entered using the "n events per year" slider directly below the popup menu. The new number can be typed directly over the slider's displayed numeric value to enter a number not easily specified with the slider. In that case the popup menu will automatically switch if necessary to the appropriate setting. Unlike a regular bank savings account where  $n$  is fixed,  $n$  in an investment account varies as the share price changes. The changing value of  $n$  reflects the choice that the same profits be reinvested in the same account.

From the "regular contributions per year" popup menu, the number of regular periodic contributions per year may be selected from the following choices: 0, 1, 2, 3, 4, 6, 12, 26, 52, and the chosen amount to be regularly contributed is specified by the "contribution (\$)" slider.

Whether or not the region below the red or blue curve is filled in with the corresponding color and whether or not a grid of lines is drawn on the plot are controlled by the "filling" and "grid lines" checkboxes, respectively.

The solid black growth curve in the "value versus time plot" is that of the investment's gross return, and the dashed blue curve is that of the investment's growth after low total expenses have been subtracted. The dashed red curve is that of the investment's growth after high total expenses have been subtracted. The distance between each dashed curve and the solid black curve represents the investor's loss in expenses to each fund's management, both of which can increase exponentially with time.

Once all other controls have been set to values chosen to match a particular investment, other choices of the "n events per year" slider can be tried, attempting to match the calculated net return, in red or blue, to that reported for the particular investment. The program can also compute the exact value of  $n$  using the reported total value of the account, entered with the slider "reported net (-lo) return (\$)". The chosen  $n$  can be either "gross", "net (-lo)" or "net (-hi)", depending on the setting of the "effective return rate" popup menu. To calculate  $n$  for a reported return type  $x$ , check the box "set 'n' events per year" slider to the value that yields the following". The number to the right of the "n events per year" slider is the new value of  $n$  and is also shown on the first line of text above the plot with increased precision. Notice that the same entered return value also appears on the second line of text above the plot.

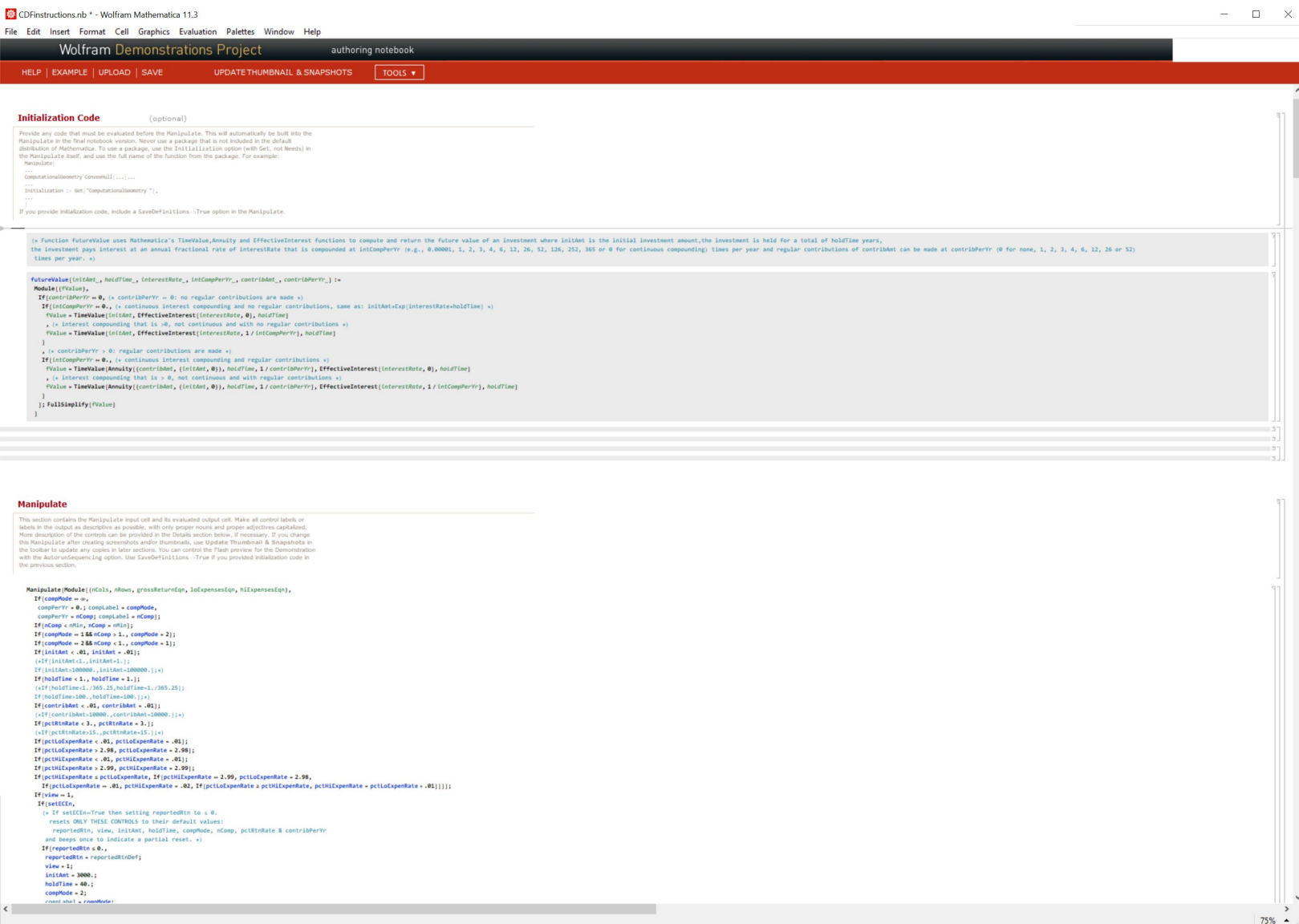
Note that the number that appears to the right of all sliders is rounded to six digits even if more digits were entered. However, the actual value entered is preserved in the program.

If the checkbox "set 'n' events per year" slider to the value that yields the following" is unchecked and a reported return value  $< 0$  is entered, the default settings of all controls (as show in the Thumbnail image) are restored accompanied by two beeps. If the above box is checked and a value  $< 0$  is entered, some but not necessarily all controls are returned to their default settings accompanied by one beep.

#### Typical Examples

To include a typical example of a fund with a low expense rate, the default Thumbnail image setting of 3000, for the "initial amount (\$)" slider shows the minimum investment amount in a stock index fund that tracks the S&P 500 stock market index. The default value of 7% for the "effective gross return rate (%/yr.)" slider is the approximate return rate of such a fund over the past 10 years, and the "low expense rate (%/yr.)" value of 0.14% is that of a fund for an investment of less than \$10,000. Some such funds automatically reduce the expense rate to 0.04% when more than \$10,000 has been accumulated in the fund. A "high expense rate (%/yr.)" control value of 2% is typical of that found in many funds offered as 401(k) or 402(b) retirement accounts. Notice that an expense rate of 2% is 50 times higher than a rate of 0.04% and that for an investment held for a long time, even a much smaller difference in the expense rates results in a very large difference in the net return to the investor.

But you only have a demonstration that looks like this, and you don't want to publish it publicly:



You might notice that if you save this as a .CDF file, it doesn't automatically format this .nb file to look like the first picture ... Well there is a quick solution! Just follow these instructions.

1. When you have finished making your demonstration and want to turn it into a formatted .CDF, first save the completed notebook as you normally would with any regular demonstration:

The screenshot shows the Wolfram Mathematica 11.3 interface. The 'File' menu is open, displaying options such as 'New', 'Open...', 'Open from Wolfram Cloud...', 'Close', 'Save...', 'Save As...', 'Save to Wolfram Cloud...', 'Publish to Cloud...', 'Save Selection As...', 'Revert...', 'CDF Preview', 'Install...', 'Send To...', 'Printing Settings', 'Print...', 'Print Preview...', and a list of recent notebooks. The 'Save As...' option is highlighted, showing the keyboard shortcut 'Shift+Ctrl+S'.

The background displays a CDF demonstration titled 'Project' with the subtitle 'authoring notebook'. The demonstration includes a series of sliders and checkboxes for controlling various parameters:

- initial investment (\$): 3000.
- holding time (yr.): 40.
- effective compounding events per year: 1 ≤ n ≤ 365 on slider below
- effective gross return rate (%/yr.): 7.
- n events per year: 4.
- low expense rate (%/yr.): 0.14
- regular contributions per year: 0
- high expense rate (%/yr.): 2.
- contribution (\$): 100.
- checkboxes for 'grid lines' and 'filling' are checked.
- checkbox for 'set "n events per year" slider to the value that yields the following ... reported gross return (\$)' is unchecked.

The demonstration also shows a plot of 'value (\$)' versus time, with a legend indicating 'effect of a low versus high rate of expenses on the net future value of an investment: n = 4.0000000'. The plot shows two curves: a solid blue line for the low expense rate and a dashed red line for the high expense rate. The area between the curves is shaded in light blue and light red.

Below the plot, the following text is displayed:

return values: gross: \$48,153.33, net at low rate: \$45,574.49, net at high rate: \$21,894.06  
 expense values: low: \$2,579.04 (5.36% of gross), high: \$26,259.47 (54.53% of gross)

2. Next, go to the Wolfram Demonstrations website, find the authoring area and sign in:

The screenshot shows a web browser window with the address bar displaying "demonstrations.wolfram.com/participate/authoringarea.jsp". The page header features the Wolfram logo and the text "WOLFRAM Demonstrations Project" on the left, and "12,000+ Interactive Demonstrations" and "Powered by Notebook Technology »" on the right. Below the header is a navigation bar with links: SEARCH, EXPLORE, LATEST, ABOUT, PARTICIPATE, and AUTHORIZING AREA. The main content area is titled "Authoring Area Sign In" in red. It contains a sign-in form with fields for "Email address" (containing "nehe8116@colorado.edu") and "Password" (masked with dots). There is a "Forgot your password?" link and a "Sign In" button. Below the form is a link for "Don't have an account?" with a "Sign Up »" button. To the right of the form, a box titled "As a member of our global community, you can:" lists three bullet points: "Publish your ideas with groundbreaking interactive technology", "Upload and share your Demonstrations with the world", and "Track the status of your submitted Demonstrations". A "Learn more »" link is at the bottom of this box.

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3. Once you have signed in, upload your demonstration the same way you would if you were going to submit it for publication on the website (don't worry, we won't be submitting it to Wolfram to publish):

WOLFRAM Demonstrations Project

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## Effect of High Expense Charges on an Investment's Net Return

view: as compounding events per year-table

initial investment (\$): 10,000

holding time (yr.): 40

effective compounding events per year:  $n = \infty$  (continuous)

effective gross return rate:  $r = 0.05$

☒ grid lines ☒ low expense rate

☒ filling ☒ high expense rate (%/yr.): 2

contribution (\$): 0

contribution (\$): 100

☐ set "n events per year" slider to the value that yields the following ... reported gross return (\$): 48153.5

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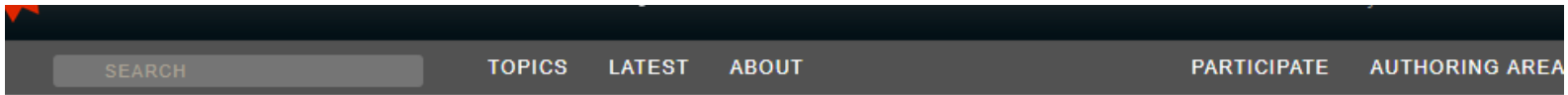
at current settings, percentage of gross return value obtained by expenses after a holding time of																			
% expenses	10 yrs.	15 yrs.	20 yrs.	25 yrs.	30 yrs.	35 yrs.	40 yrs.	45 yrs.	50 yrs.	55 yrs.	60 yrs.	65 yrs.	70 yrs.	75 yrs.	80 yrs.	85 yrs.	90 yrs.	95 yrs.	100 yrs.
2.50	22.12	31.27	38.35	46.47	52.76	58.31	63.21	67.53	71.35	74.72	77.68	80.31	82.82	84.66					
2.25	20.15	28.64	36.24	43.02	49.08	54.50	59.24	63.30	66.90	70.09	72.93	75.53	77.90	79.50					
2.00	18.15	25.92	32.87	39.35	45.12	50.34	55.00	59.14	62.81	66.04	68.88	71.45	73.79	75.34					
1.75	16.08	23.09	29.53	35.44	40.84	45.90	50.54	54.73	58.51	61.84	64.76	67.32	69.59	71.50					
1.50	13.93	20.15	25.92	31.27	36.24	40.84	45.12	49.08	52.76	56.18	59.34	62.28	65.01	67.53					
1.25	11.78	17.10	22.12	26.84	31.27	35.44	39.35	43.02	46.47	49.72	52.76	55.60	58.31	60.84					
1.00	9.52	13.93	18.15	22.12	25.92	29.53	32.87	36.24	39.35	42.31	45.12	47.80	50.34	52.76					
0.75	7.23	10.64	13.93	17.10	20.15	23.09	25.92	28.64	31.27	33.80	36.24	38.58	40.84	43.02					
0.50	4.88	7.23	9.52	11.78	13.93	16.08	18.15	20.15	22.12	24.04	25.92	27.76	29.53	31.27					
0.40	4.40	6.53	8.41	10.04	11.69	13.27	14.87	16.33	17.75	19.13	20.46	21.75	23.00	24.24					
0.40	3.92	5.82	7.69	9.52	11.31	13.06	14.76	16.41	18.03	19.61	21.14	22.62	24.05	25.42					
0.35	3.44	5.11	6.76	8.38	9.97	11.53	13.06	14.57	16.05	17.51	18.94	20.35	21.73	23.09					
0.30	2.96	4.40	5.82	7.23	8.61	9.97	11.31	12.63	13.93	15.21	16.47	17.72	18.94	20.15					
0.25	2.47	3.68	4.88	6.06	7.23	8.38	9.52	10.64	11.75	12.82	13.89	14.90	15.88	16.83					
0.20	1.93	2.96	3.92	4.88	5.82	6.76	7.69	8.61	9.52	10.42	11.31	12.19	13.06	13.93					
0.15	1.49	2.32	3.08	3.80	4.40	5.11	5.82	6.53	7.23	7.92	8.61	9.29	9.97	10.64					
0.10	0.99	1.49	1.98	2.47	2.96	3.44	3.92	4.40	4.88	5.35	5.82	6.29	6.76	7.23					
0.05	0.50	0.75	0.99	1.24	1.49	1.73	1.98	2.23	2.47	2.71	2.96	3.20	3.44	3.68					

Wolfram Demonstrations Project

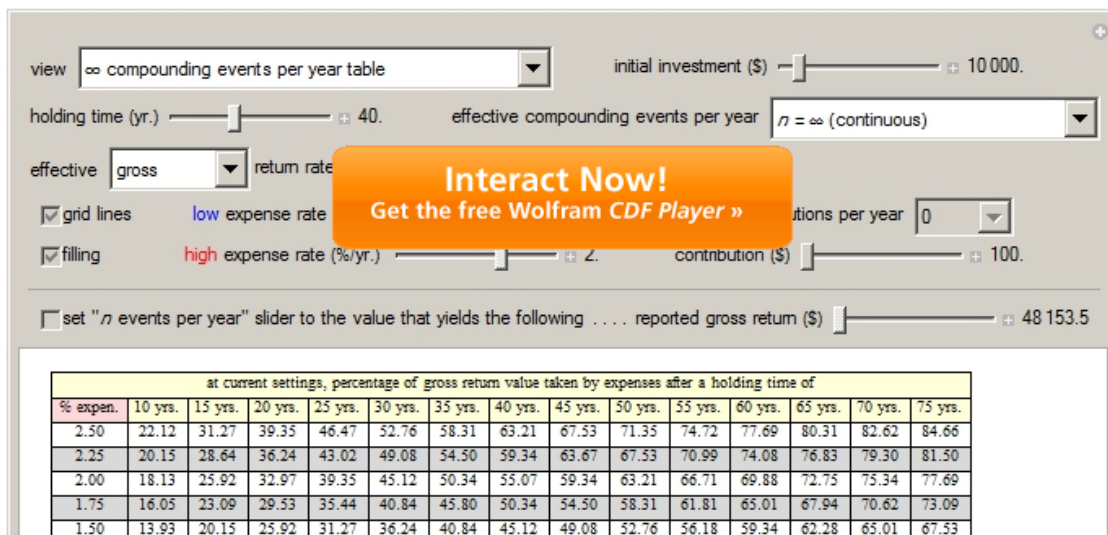
The net yield of a long-term investment primarily depends on an effective interest return rate and the way in which it is compounded. However, the actual yield also heavily depends on the total expense rate charged to maintain the account, which typically ranges from a fraction of a percent to a few percent. The expense rate can have a huge



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