Manual for the VCC Program

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1 Purpose

The VCC program estimates the time-varying coefficients $a_t' = (a_{1,t}, a_{2,t}, \ldots, a_{n,t})$ of the linear regression

$$y_t = a_t' x_t + u_t$$

with $x_t' = (x_{1,t}, x_{2,t}, \ldots, x_{n,t})$ and y_t denoting the observations at time $t = 1, 2, \ldots, T$. The disturbance u_t is a random variable with mean zero and variance σ^2. The coefficients $a_{i,t}$ are assumed to be generated by a random walk

$$a_{i,t+1} = a_{i,t} + v_{i,t},\ \ t = 1, 2, \ldots, T;\ \ i = 1, 2, \ldots, n$$

with disturbances $v_{i,t}$ with mean zero and variances σ_i^2. The program estimates the conditional expected values of the coefficients $a_{1,t}, a_{2,t}, \ldots, a_{n,t}$ and the variances $\sigma^2, \sigma_1^2, \sigma_2^2, \ldots, \sigma_n^2$, given the observations $x_{i,t}$ and y_t for $t = 1, 2, \ldots, T$ and $i = 1, 2, \ldots, n$. The standard deviations and confidence bands are given and the covariance matrix of the coefficients can be computed. The statistical background for these calculations is provided in Schlicht (2021a).

The estimators for the variances are moments estimators. With given variances, the time-paths of the coefficients are determined by minimizing the weighted sum of squares

$$Q = \sum_{t=1}^{T} u_t^2 + \sum_{t=2}^{T} \sum_{i=1}^{n} \gamma_i \left(a_{i,t} - a_{i,t-1}\right)^2 \tag{1}$$

with smoothing weights given by the inverse variance ratios

$$\gamma_i = \frac{\sigma^2}{\sigma_i^2}\ ,\ \ i = 1, 2, \ldots n.$$

The matrix of coefficients

$$\begin{pmatrix} a_{1,1} & a_{2,1} & .. & a_{n,1} \\ a_{1,2} & a_{2,2} & .. & a_{n,2} \\ . & . & & \\ & & & \\ a_{1,T} & a_{2,T} & .. & a_{n,T} \end{pmatrix}$$

This updates the VCC manual of Schlicht (2003) for version 6 of the VCC program (Schlicht 2021c). The author is professor emeritus of economics, Ludwig-Maximilians-Universität München, Germany. Address: Hurtenstr. 13, 82346 Andechs, Germany, schlicht@lmu.de.

that minimizes the sum of squares Q gives the expectation of the coefficients $a_{i,t}$ for given variance ratios.

2 Usage

The program is called from a command window. Standard usage for Windows is

$$\texttt{vcc.exe} < \texttt{inputfile} >$$

and for Linux

$$./\texttt{vcc} < \texttt{inputfile} >.$$

Further, several switches can be added. The available switches are displayed if you type `vcc` or `vcc --h` or `vcc -help`. These switches will be explained in Section 4 below.

The program requires input data in the .CSV format (comma separated values).[1] The first row of the input file is reserved for data description - one label for each cell. No cell should be left empty. The number of cells in the first row tells the program how many cells to expect in the subsequent rows. The gives, starting with cell 3, the starting values for the variance ratios (the inverse smoothing weights). The first two cells are arbitrary. The first cell should not be kept blank.

Each of the subsequent rows gives the observations for successive points in time. Cell 1 gives the time index t, such a year or month, ignored by the program, but must be non-empty and can't contain a comma. Cell 2 gives the dependent variable (y_t in the above notation). Cell 3 gives the first independent variable ($x_{1,t}$), cell 4 second independent variable ($x_{2,t}$), cell 5 third independent variable ($x_{3,t}$), and so forth.

The example file $\texttt{OkunGER} - \texttt{adv.csv}$ illustrates this. It refers to Okun's Law in Germany. Okun's law describes the relationship between the change in production (`gGDP`) and the change in unemployment (`dU`). The data are taken from the study by João Jalles (2018) that covers many countries, Germany among them. The data file can be opened with spreadsheet programs like LibreOffice Calc, or Microsoft Excel. Its first rows are given in Figure 1. The

year	dU	gGDP	intercept
vr		1	1
1978	-0.471552	0.041377	1
1979	0.091001	0.012636	1
1980	1.47257	0.001102	1
1981	1.90275	-0.007913	1

Fig. 1: Beginning of the input file

first row gives the labels of the data, in its second row the variance ratios where iteration starts, and in the subsequent rows the observations for years 1978 to 2013.

Running the program on the example file returns the output depicted in Figure 2:

[1] Note that the English number format is presupposed, with a decimal dot denoting decimals, and a comma separating values. Other formats (the German one, for instance) use other conventions and need to be transformed accordingly.

year	dU	gGDP	intercept	a_gGDP	stderr_gGDP	lb_gGDP	ub_gGDP	a_intercept	stderr_intercept	lb_intercept	ub_intercept
1978	-0.4716	0.041377	1	-31.5921	9.03518	-49.6624	-13.5217	0.814483	0.391224	0.0320344	1.59693
1979	0.091	0.012636	1	-31.6695	8.88386	-49.4372	-13.9017	0.765901	0.263373	0.239155	1.29265
1980	1.47257	0.001102	1	-31.4399	8.68372	-48.8073	-14.0724	1.34837	0.226049	0.89627	1.80046
1981	1.90275	-0.007913	1	-31.2257	8.4609	-48.1475	-14.3039	1.56595	0.223288	1.11938	2.01253
1982	1.36502	0.015427	1	-30.9488	8.26089	-47.4706	-14.427	1.57748	0.248478	1.08052	2.07443

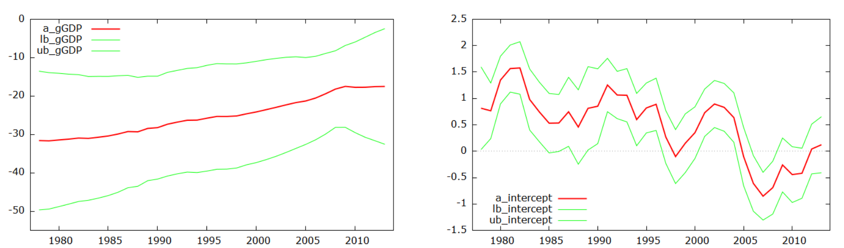
Fig. 2: Output File

The first four columns give the input data. Four further columns are added for each coefficient: the time series of its expectation, labeled `a_<label of coefficient>`, its standard error `(stderr_<label>)`, its lower bound `(lb_<label>` which is the estimated coefficient minus two standard errors), and its upper bound `(ub_<label>` which is the estimated coefficient plus two standard errors). At the bottom of the output, further information is provided: The estimated variance ratios used for filtering, the estimated variances of the disturbances in the equation σ^2 and the estimated variances of the disturbances in the coefficients σ_i^2. Further, the initial variances supplied by the input file are given along with the number of iterations and the relative error (which is the maximum of the percentage differences between the estimated weights in the last two iterations). If iterations did not converge, a warning is added.

	equation	gGDP	intercept
Filtered with variance ratios		88.4369	2.29702
Implied variances	0.0823336	7.28133	0.189122
Initial variance ratios		1	1
112 iterations			
Relative error 0.00089 per cent.			

Fig. 3: Output information

The output file can be opened with an appropriate statistical programs such as Gretl (2021) for further analysis and easy visualization of the results.. The estimated time series are depicted in Figure 4.



(a) slope (b) intercept

Fig. 4: Estimated time varying coefficients.

It can be seen that the Okun slope is negative and decreases in absolute value over time while the intercept (the constant term of the Okun relationship at a given point in time) follows the business cycle with a downward trend.

3 The Meaning of Non-Positive Initial Variance Ratios

Variances and variance ratios are positive. Entering non-positive initial variance ratios for some coefficients instructs the program to handle estimation of these coefficients differently:

– An initial variance ratio of zero tells the program to treat the respective coefficient as constant over time.[2]
– A negative initial variance ratio tells the program to take its absolute value as the variance ratio and not to change it throughout the iterations; the variance ratio is taken as constant.

The output obtained, for example, by using the initial variance ratio of zero for the intercept, gives the output

year	dU	gGDP	intercept	a_gGDP	stderr_gGDP	lb_gGDP	ub_gGDP	a_intercept	stderr_intercept	lb_intercept	ub_intercept
1978	-0.471552	0.041377	1	-23.8445	6.07977	-36.0041	-11.685	0.455199	0.158035	0.139129	0.771269
1979	0.091001	0.012636	1	-23.8446	6.0796	-36.0038	-11.6854	0.455199	0.158035	0.139129	0.771269
1980	1.47257	0.001102	1	-23.8446	6.07943	-36.0034	-11.6857	0.455199	0.158035	0.139129	0.771269
1981	1.90275	-0.007913	1	-23.8446	6.07926	-36.0031	-11.6861	0.455199	0.158035	0.139129	0.771269
1982	1.36502	0.015427	1	-23.8445	6.07909	-36.0027	-11.6864	0.455199	0.158035	0.139129	0.771269
1983	-0.041364	0.027869	1	-23.8446	6.07893	-36.0025	-11.6868	0.455199	0.158035	0.139129	0.771269

Fig. 5: Output for zero initial variance ratio for intercept.

and the additional information

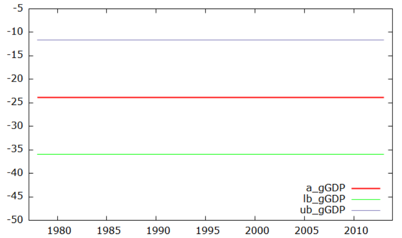
	equation	gGDP	intercept
Filtered with variance ratios		0.00486019	1.00002E-10
Implied variances	0.496621	0.00241367	4.9663E-11
Initial variance ratios		1	0
Coefficient of "intercept" constant.			
4976 iterations			
Relative error 0.001 per cent.			

Fig. 6: Output information for the case of an initial variance ratio of zero.

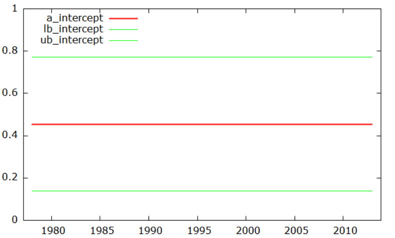
The results are plotted in Figure 7 It can be seen that holding the intercept constant (which was originally estimated as trended) nearly eliminates the trend in the slope coefficient. The variance and the variance ratio of the other coefficient are decreased (which implies an increase in its smoothing weight γ_i). The overall variance is shifted to the variance in the equation σ^2.

If the initial variance ratios of all coefficients are zero, all coefficients will be taken as time-invariant and coincide with the OLS estimates.

[2] Technically this is done by taking the respective variance ratio as $10^{-10}$and keep it constant throughout the calculations.



(a) slope



(b) intercept

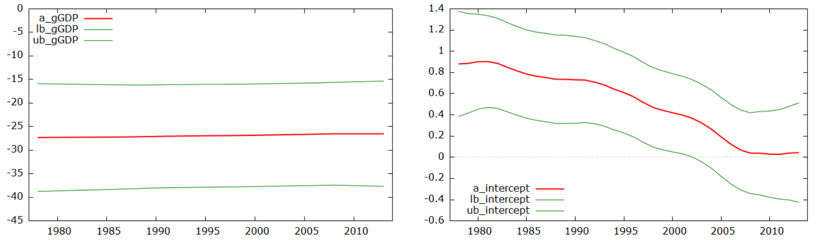
Fig. 7: Estimated time varying coefficients with intercept forced to be constant.

4 Switches

If the program is called without arguments, it gives instructions on usage and lists the available switches. These are:

```
Switches          Function
--h or --help     Show this help screen.
--f or --filter   Don't estimate variances, just filter.
--smooth n        Decrease the estimated variance ratios by a factor of 10^n.
                  Default is n=0 (no smoothing).
--p n             Set precision 10^-n.
                  Default is 5 which means 10^-5.
--it n            Set maximum number of iterations to 10^n.
                  Default is 10^5.
--cov             Calculate the complete covariance matrix.
--s or --slow     Slow down adjustment speed to improve numerical stability.
```

– The option "`--f`" or "`--filter`" calculates the time paths of the coefficients for the variance ratios given in the input file that minimize the weighted sum of squares Q, see equation (1).
– The option "`--smooth n`" decreases all estimated variance ratios by a factor of 10^n. This implies that the smoothing weights are increased accordingly. The outcome is depicted in Figure (8). A high smoothing value (8, for example) generates time-invariant coefficients that coincide with the corresponding OLS estimates.



(a) slope (b) intercept

Fig. 8: Estimated time varying coefficients smoothed with factor 2. To see the effect of smoothing, compare this with Figure 4.

The output information given for this case is depicted in Figure (8).

	equation	gGDP	intercept
Filtered with variance ratios		0.884369	0.0229702
Implied variances	0.355087	0.314028	0.00815641
Estimated variance ratios		88.4369	2.29702
Implied variances	0.0823409	7.28197	0.189139
Initial variance ratios		1	1

Fig. 9: Output information for time-varying coefficients smoothed with factor 2

– The option "`--cov`" tells the program to print the entire covariance matrix of the $T \times n$ vector

$$(a_{1,1}, a_{2,1}, \ldots, a_{n,1}, a_{1,2}, a_{2,2}, \ldots, a_{n,2}, \ldots \quad, a_{1,T}, a_{2,T}, \ldots, a_{n,T})$$

in a CSV file which is named like the input file with the added indicators `-VCC-covariances`.

The other options are self-explanatory.

5 The HP-Filter

As a matter of completeness let me mention that the Hodrick-Prescott filter (or Leser filter) is covered by the VCC program as special case, namely if the only explanatory variable is the intercept. To illustrate, delete the third column of the example file (the column labeled "gGDP") and enter -0.01 as the initial variance ratio in the second row. If the VCC program is run on this file, the series for "dU" will be HP-filtered with a smoothing constant of 100 (the inverse variance ratio). Figure 10 depicts the result. Practically the same result is obtained by running this file with an arbitrary positive variance ratio and the switch "`--smooth 6.4`". The unsmoothed case corresponds to the case where the HP smoothing constant is determined by the moments estimator described in Schlicht (2005), while the VCC results obtained with the smoothing constant of 100 or the smoothing switch of 6.4 are arbitrary.

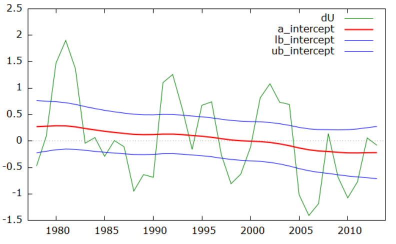


Fig. 10: Intercept filtered with variance ratio 0.01 which corresponds to a smoothing weight of 100. Practically the same result is obtained by using the switch "`--smooth 6.4`".

6 Implementations of the VC Method

There are several programs available that implement theVC method.

- The VCC program discussed here (Schlicht 2021c) is released as open source. Because the binaries are executable, the program can be called directly or from other programs via a shell command. The source code has been commented extensively to permit easy modification.
- The VC program is easier to use (Schlicht 2021b). It offers a graphical interface and uses the same VCC algorithms, but its possibilities are somewhat restricted. In particular, straightforward filtering is not possible because the program uses a simpler input format.
- Johannes Ludsteck's VC packages offer open source implementations of the VC method in the Wolfram Mathematica language (Ludsteck 2004; Ludsteck 2018). Because of the transparency of the code and the many advanced features offered by Mathematica, this can be easily adapted to all conceivable uses. The simulations reported in Schlicht (2021a) mad use of these packages.

7 License

The program is released under the GNU General Public License version 3 available at https://www.gnu.org/licenses/gpl-3.0.txt.

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References

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