

A Markov-switching Model of Emerging Economies Exchange rate Volatility

Nico Katzke^a, Robert Grant^{a,b}

^a*Prescient Securities, Cape Town, South Africa*

^b*Stellenbosch University, Stellenbosch, South Africa*

Abstract

This paper employs a Markov-switching GARCH model to identify differing regimes under which emerging market currency evolves. Then, this paper analyses how the correlation between currency volatility changes in these differing regimes.

Keywords: Multivariate GARCH, Kalman Filter, Copula

JEL classification L250, L100

1. Introduction

The comovement of financial variables between countries is a well researched topic. Particularly, the advent of the Global Financial Crisis (GFC) challenged what we know about the dynamics between international variables, with many established correlations breaking down after the GFC. Similarly, exchange rate comovements between emerging markets change during periods of economic uncertainty, such as oil price shocks, economic crashes, bank and currency crises and even across general business cycle up- and downswings.

This paper employs a Markov-switching GARCH (MS-GARCH) model on emerging market (EM) exchange rates in order to analyse the correlation between these currencies during periods (regimes) of high and low volatility. MS-GARCH models, since @Hamilton(1990) introduced the concept, have become a popular method for analysing the dynamics of financial variables through time.

I suggest renaming the top line after @article, as done in the template ref.bib file, to something more intuitive for you to remember. Do not change the rest of the code. Also, be mindful of the fact that bib references from google scholar may at times be incorrect. Reference Latex forums for correct bibtex notation.

*Corresponding author: Nico Katzke

Email addresses: `nfkatzke@gmail.com` (Nico Katzke), `robbiegrant1995@gmail.com` (Robert Grant)

To reference a section, you have to set a label using “\label” in R, and then reference it in-text as e.g.: section 2.

Writing in Rmarkdown is surprizingly easy - see [this website](#) cheatsheet for a summary on writing Rmd writing tips.

2. Data

Exchange rate series for 41 different countries are used.¹ The exchange rate are analysed at a weekly frequencty, as daily closing exchange rates create difficult analysis due to differing time zones. All exchange rates are shown relative to the US dollar. the period under analysis covers 1990-2019.

```
##
##
##      Mean    Volatiliy
## -----
## 0.0787894  0.0113821

## Specification type: Markov-switching
## Specification name: gjrGARCH_std gjrGARCH_std
## Number of parameters in each variance model: 4 4
## Number of parameters in each distribution: 1 1
## -----
## Fixed parameters:
## None
## -----
## Across regime constrained parameters:
## nu
## -----
## Fitted parameters:
##      Estimate Std. Error  t value  Pr(>|t|)
## alpha0_1    0.0000     0.0000   2.9465 1.607e-03
## alpha1_1    0.0219     0.0140   1.5693 5.829e-02
## alpha2_1    0.0001     0.0002   0.4332 3.324e-01
## beta_1      0.9678     0.0138  70.2472 <1e-16
```

¹See appendix for full list of exchange rates

```
## nu_1      5.8068      0.4507  12.8848    <1e-16
## alpha0_2   0.0000      0.0000   3.5632  1.832e-04
## alpha1_2   0.2039      0.0402   5.0679  2.011e-07
## alpha2_2   0.0002      0.0007   0.2304  4.089e-01
## beta_2     0.7314      0.0461  15.8813    <1e-16
## P_1_1      0.9881      0.0050  197.4845    <1e-16
## P_2_1      0.0109      0.0063   1.7325  4.159e-02
## -----
## Transition matrix:
##      t+1|k=1 t+1|k=2
## t|k=1  0.9881  0.0119
## t|k=2  0.0109  0.9891
## -----
## Stable probabilities:
## State 1 State 2
##  0.4783  0.5217
## -----
## LL: 17939.5478
## AIC: -35857.0955
## BIC: -35784.9877
## -----
```

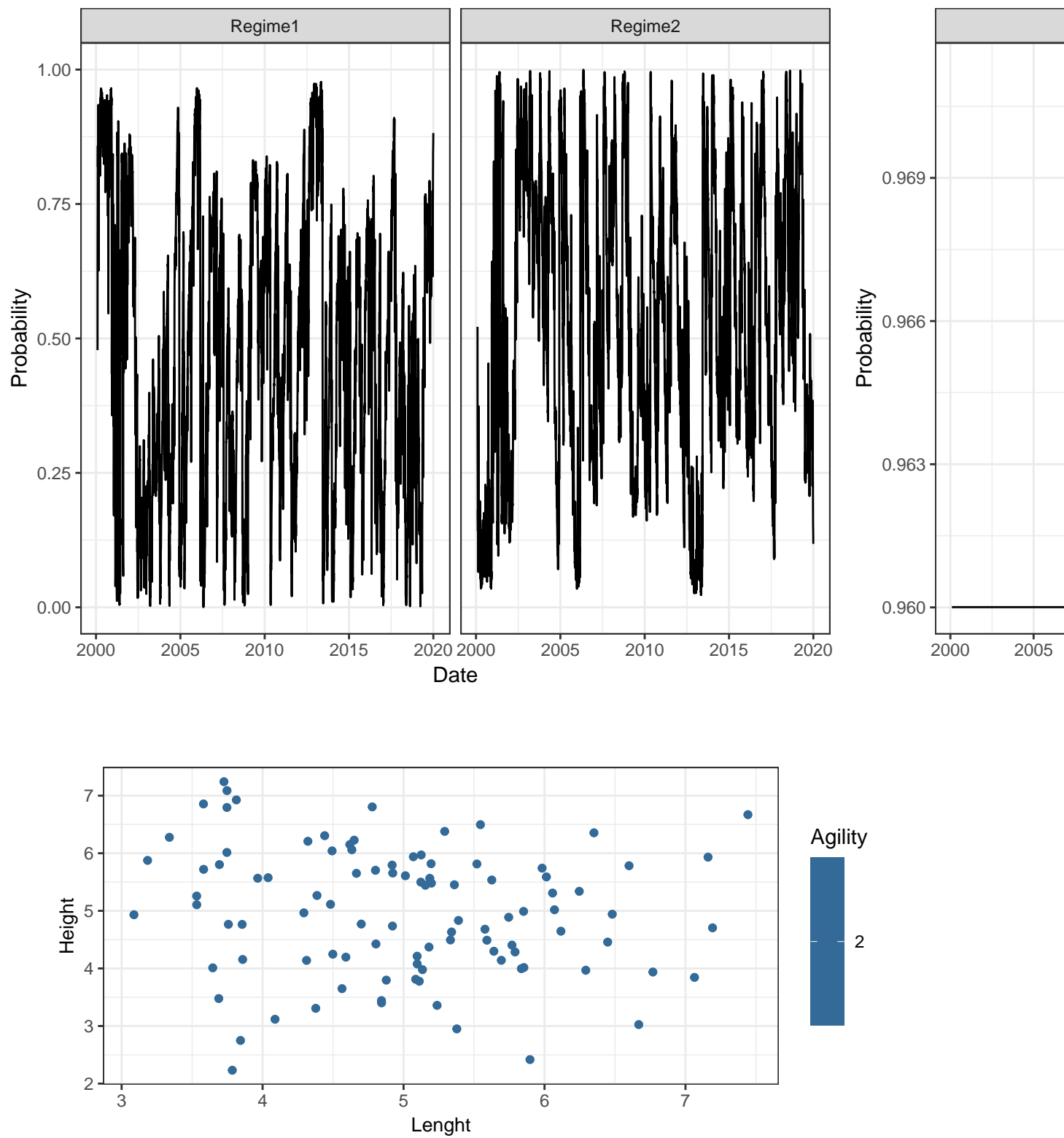


Figure 2.1: Caption Here

To reference the plot above, add a “\label” after the caption in the chunk heading, as done above. Then reference the plot as such: As can be seen, figure 2.1 is excellent. The nice thing now is that it correctly numbers all your figures (and sections or tables) and will update if it moves. The links are also dynamic.

I very strongly suggest using ggplot2 (ideally in combination with dplyr) using the ggtheme package to change the themes of your figures.

Also note the information that I have placed above the chunks in the code chunks for the figures. You can edit any of these easily - visit the Rmarkdown webpage for more information.

Here follows another figure from built-in ggplot2 data:

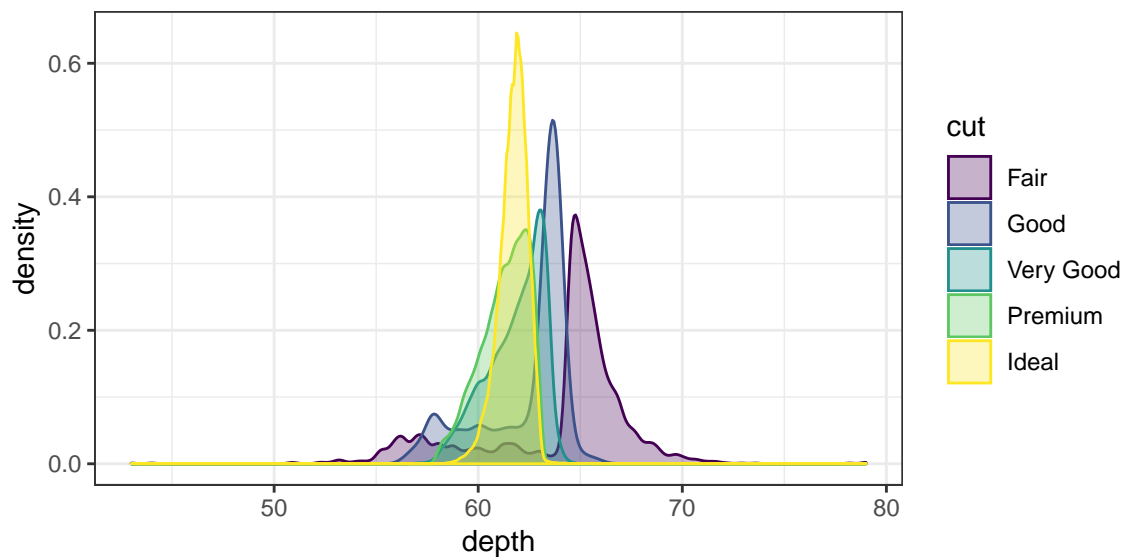


Figure 2.2: Diamond Cut Plot

3. Methodology

This section presents a layout of a simple MS-GARCH framework, as described in Hamilton (1990). This Markov-switching framework assumes two distinct states under which exchange rates evolve: a high-volatility and low-volatility. The high volatility state is denoted by

$$S_t = i \tag{3.1}$$

where $i \in \{0, 1\}$ depending on the state. 0 denotes the low volatility regime, whereas 1 denotes the high volatility regime ## Math section

Equations should be written as such:

$$\beta = \sum_{i=1}^{\infty} \frac{\alpha^2}{\sigma_{t-1}^2} \quad (3.2)$$

$$\int_{x=1}^{\infty} x_i = 1$$

If you would like to see the equations as you type in Rmarkdown, use \$ symbols instead (see this for yourself by adjusted the equation):

$$\beta = \sum_{i=1}^{\infty} \frac{\alpha^2}{\sigma_{t-1}^2} \int_{x=1}^{\infty} x_i = 1$$

Note again the reference to equation 3.2. Writing nice math requires practice. Note I used a forward slashes to make a space in the equations. I can also align equations using &, and set to numbering only the first line. Now I will have to type “begin equation” which is a native L^AT_EX command. Here follows a more complicated equation:

$$\begin{aligned} y_t &= c + B(L)y_{t-1} + e_t \\ e_t &= H_t^{1/2}z_t; \quad z_t \sim N(0, I_N) \quad \& \quad H_t = D_t R_t D_t \\ D_t^2 &= \sigma_{1,t}, \dots, \sigma_{N,t} \\ \sigma_{i,t}^2 &= \gamma_i + \kappa_{i,t} v_{i,t-1}^2 + \eta_i \sigma_{i,t-1}^2, \quad \forall i \\ R_{t,i,j} &= \text{diag}(Q_{t,i,j}^{-1}) \cdot Q_{t,i,j} \cdot \text{diag}(Q_{t,i,j}^{-1}) \\ Q_{t,i,j} &= (1 - \alpha - \beta) \bar{Q} + \alpha z_t z_t' + \beta Q_{t,i,j} \end{aligned} \quad (3.3)$$

Note that in 3.3 I have aligned the equations by the equal signs. I also want only one tag, and I create spaces using “quads”.

See if you can figure out how to do complex math using the two examples provided in 3.2 and 3.3.

4. Results

Tables can be included as follows. Use the *xtable* (or *kable*) package for tables. Table placement = H implies Latex tries to place the table Here, and not on a new page (there are, however, very many

ways to skin this cat. Luckily there are many forums online!).

	mpg	cyl	displacement	hp	drat	wt	qsec	vs	am	gear	carb
1	21.00	6.00	160.00	110.00	3.90	2.62	16.46	0.00	1.00	4.00	4.00
2	21.00	6.00	160.00	110.00	3.90	2.88	17.02	0.00	1.00	4.00	4.00
3	22.80	4.00	108.00	93.00	3.85	2.32	18.61	1.00	1.00	4.00	1.00
4	21.40	6.00	258.00	110.00	3.08	3.21	19.44	1.00	0.00	3.00	1.00
5	18.70	8.00	360.00	175.00	3.15	3.44	17.02	0.00	0.00	3.00	2.00

Table 4.1: Short Table Example

To reference calculations **in text**, *do this*: From table 4.1 we see the average value of mpg is 20.98.

Including tables that span across pages, use the following (note that I add below the table: “continue on the next page”). This is a neat way of splitting your table across a page.

Use the following default settings to build your own possibly long tables. Note that the following will fit on one page if it can, but cleanly spreads over multiple pages:

Table 4.2: Long Table Example

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
	21.00	6.00	160.00	110.00	3.90	2.62	16.46	0.00	1.00	4.00	4.00
	21.00	6.00	160.00	110.00	3.90	2.88	17.02	0.00	1.00	4.00	4.00
	22.80	4.00	108.00	93.00	3.85	2.32	18.61	1.00	1.00	4.00	1.00
	21.40	6.00	258.00	110.00	3.08	3.21	19.44	1.00	0.00	3.00	1.00
	18.70	8.00	360.00	175.00	3.15	3.44	17.02	0.00	0.00	3.00	2.00
	18.10	6.00	225.00	105.00	2.76	3.46	20.22	1.00	0.00	3.00	1.00
	14.30	8.00	360.00	245.00	3.21	3.57	15.84	0.00	0.00	3.00	4.00
	24.40	4.00	146.70	62.00	3.69	3.19	20.00	1.00	0.00	4.00	2.00
	22.80	4.00	140.80	95.00	3.92	3.15	22.90	1.00	0.00	4.00	2.00
	19.20	6.00	167.60	123.00	3.92	3.44	18.30	1.00	0.00	4.00	4.00
	17.80	6.00	167.60	123.00	3.92	3.44	18.90	1.00	0.00	4.00	4.00
	16.40	8.00	275.80	180.00	3.07	4.07	17.40	0.00	0.00	3.00	3.00
	17.30	8.00	275.80	180.00	3.07	3.73	17.60	0.00	0.00	3.00	3.00
	15.20	8.00	275.80	180.00	3.07	3.78	18.00	0.00	0.00	3.00	3.00
	10.40	8.00	472.00	205.00	2.93	5.25	17.98	0.00	0.00	3.00	4.00
	10.40	8.00	460.00	215.00	3.00	5.42	17.82	0.00	0.00	3.00	4.00
	14.70	8.00	440.00	230.00	3.23	5.34	17.42	0.00	0.00	3.00	4.00
	32.40	4.00	78.70	66.00	4.08	2.20	19.47	1.00	1.00	4.00	1.00

Continued on next page

Table 4.2: Long Table Example

mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
30.40	4.00	75.70	52.00	4.93	1.61	18.52	1.00	1.00	4.00	2.00
33.90	4.00	71.10	65.00	4.22	1.83	19.90	1.00	1.00	4.00	1.00
21.50	4.00	120.10	97.00	3.70	2.46	20.01	1.00	0.00	3.00	1.00
15.50	8.00	318.00	150.00	2.76	3.52	16.87	0.00	0.00	3.00	2.00
15.20	8.00	304.00	150.00	3.15	3.44	17.30	0.00	0.00	3.00	2.00
13.30	8.00	350.00	245.00	3.73	3.84	15.41	0.00	0.00	3.00	4.00
19.20	8.00	400.00	175.00	3.08	3.85	17.05	0.00	0.00	3.00	2.00
27.30	4.00	79.00	66.00	4.08	1.94	18.90	1.00	1.00	4.00	1.00
26.00	4.00	120.30	91.00	4.43	2.14	16.70	0.00	1.00	5.00	2.00
30.40	4.00	95.10	113.00	3.77	1.51	16.90	1.00	1.00	5.00	2.00
15.80	8.00	351.00	264.00	4.22	3.17	14.50	0.00	1.00	5.00	4.00
19.70	6.00	145.00	175.00	3.62	2.77	15.50	0.00	1.00	5.00	6.00
15.00	8.00	301.00	335.00	3.54	3.57	14.60	0.00	1.00	5.00	8.00
21.40	4.00	121.00	109.00	4.11	2.78	18.60	1.00	1.00	4.00	2.00

4.1. *Huxtable*

Huxtable is a very nice package for making working with tables between Rmarkdown and Tex easier.

This cost some adjustment to the Tex templates to make it work, but it now works nicely.

See documentation for this package [here](#). A particularly nice addition of this package is for making the printing of regression results a joy (see [here](#)). Here follows an example:

If you are eager to use huxtable, comment out the Huxtable table in the Rmd template, and uncomment the colortbl package in your Rmd's root.

Note that I do not include this in the ordinary template, as some latex users have complained it breaks when they build their Rmds (especially those using tidytex - I don't have this problem as I have the full MikTeX installed on mine). Up to you, but I strongly recommend installing the package manually and using huxtable. To make this work, uncomment the *Adding additional latex packages* part in yaml at the top of the Rmd file. Then comment out the huxtable example in the template below this line. Reknit, and enjoy.

FYI - R also recently introduced the gt package, which is worthwhile exploring too.

5. Lists

To add lists, simply using the following notation

- This is really simple
 - Just note the spaces here - writing in R you have to sometimes be pedantic about spaces...
- Note that Rmarkdown notation removes the pain of defining L^AT_EX environments!

6. Conclusion

I hope you find this template useful. Remember, stackoverflow is your friend - use it to find answers to questions. Feel free to write me a mail if you have any questions regarding the use of this package. To cite this package, simply type citation("Texevier") in Rstudio to get the citation for Katzke (2017) (Note that uncited references in your bibtex file will not be included in References).

References

Katzke, N. F. 2017. *Texevier: Package to Create Elsevier Templates for Rmarkdown*. Stellenbosch, South Africa: Bureau for Economic Research.