Impacts of macroeconomics forecast errors on volatility smile

Joseph Comisi – Paris-Dauphine University – May 2016

Abstract. In the academic world, the Black, Scholes and Merton model is the most famous and taught option-pricing model. However, this model assumes the volatility to be constant, and a short analysis of the historical volatility proves that this assumption is wrong: the volatility depends both on the option’s strike and maturity. In the professional world, the success of this model is due to its ability to obtain the implied volatilities. The aim of this dissertation is to analyse the dynamics of the volatility smile on S&P 500 3-months options. More precisely, the objective is to measure the impact of macroeconomic surprises on the level, slope, and convexity of the volatility smile. It results that many macroeconomic indexes influence these aspects. Moreover, these dimensions will react differently according to the signs of the macroeconomic surprises and the index itself. Thus, an underestimation of the inflation will expand the general level of the volatility smile, increase its trend, and diminish its convexity. In contrast, a negative surprise of the level of importation will reduce the trend and convexity. Consequently, it is possible to invest and build volatility portfolios in order to take advantages of the distorted volatility smile.

Keywords. Volatility smile, Implied volatility, Macroeconomics surprises, Principal Component Analysis.
In this report, the analysis focus on the S&P 500 3-months implied volatilities from the 5 September 2008 to the 16 March 2015. This choice is motivated by the higher liquidity of these options, and the data availability.

In order to reduce the dimension of the problem, only the first three principal components of the volatility smile are considered: the level, the slope, and the convexity of the volatility smile. These components, obtained by a principal component analysis, represent more than 85% of the total variance. The aim of this report is to analyse and measure the impact of different macroeconomic surprises on these principal components, in order to build volatility strategies.

2. Methodology

2.1. Implied volatilities

This report only focuses on moneynesses from 0.80 to 1.12. The moneyness is defined as the option strike over the underlying-asset prices \( m_t = K / S_t \).

In order to obtain the principal components, Carol Alexander [4] uses the daily variation of the difference between implied volatilities and the at-the-money implied volatilities: \( \Delta (\sigma_K - \sigma_{S,ATM}) \). Despite the advantages of this method (reduction of noise, strongest results, link with Emmanuel-Derman models), it is not possible to apply her approach. Indeed, Carol Alexander analyses the dynamics of the volatility surface over a short period, from January 1998 to March 1999. Thus, the variation of the underlying asset is limited, which allow her to work with the option strikes and not the moneynesses. The application of this method is not coherent when applied on moneynesses. Indeed, the daily variation of the deviation of the ATM implied volatility from the ATM implied volatility would always be equal to 0, which consistently impacts the results of the principal component analysis.

Therefore, the PCA is implemented on the daily variations of each implied volatility according to its moneyness: \( \Delta \sigma_{m,t} = \sigma_{m,t} - \sigma_{m,t-1} \). Carol Alexander mentioned in its article that Emmanuel Derman and Kamal [10] also used this method. Moreover, Florian Ielpo and Dominique Guegan [16] also applied this method on the interest-rate term structure.

2.2. Interpolation of missing implied volatilities

In order to interpolate missing implied volatilities among moneynesses from 0.80 to 1.12, the whole set of implied volatilities available for the specific day is used. In other words, for each day, all the implied volatilities available, including those outside the interval \([0.80,1.12]\), are used to interpolate missing implied volatilities in the interval \([0.80,1.12]\).
Uri Ron, in “A Practical Guide to Swap Curve Construction” [11], uses a consolidated method of linear and cubic interpolations. Even if he noticed that cubic interpolations are more precise and accurate than linear interpolations, cubic interpolations are ineffective for extreme values.

In this study, extreme moneyesses (and extreme implied volatilities) are moved aside, so cubic interpolation can be undoubtedly used. Francesco Audrino also strengthened this choice in his article, “Forecasting Implied Volatility Surfaces” [12], in which he used cubic interpolations to model the volatility surface. Florian Ielpo and Dominique Guégan also used cubic interpolations for missing data in the interest-rate term structure.

2.3. Principal Component Analysis (PCA)

The objective of a principal component analysis is to create independent and statistic variables that contain the leading information included in the initial plain variables. Alexander Carol ([4], page 4) highlights that “the high degree of collinearity […] occurs when there are only a few important sources of information in the data, which are common to many variables”. This high degree of collinearity is illustrated in the graph below, representing the analysed implied volatilities.

A PCA extracts the main information and incorporate it into new statistic variables, called the principal components. These new orthogonal variables are a linear combination of the initial data. The principal component \(i\) is computed as: \(pc_i = V \ast u_i\), where \(V\) represents the initial matrix containing the data, and \(u_i\) the column vector corresponding to the \(i\)th eigenvector.

Bonney, Shannon and Uys [5] remind that eigenvectors represent vectors of weights of moneyness. The eigenvectors create the linear combination between the initial data and the principal components.

They also remind that, eigenvalues are an “estimation of the variance explicated by the principal components”. The variance explicated by a principal component is defined as \(\lambda_j = \sum_{i=1}^{N} \lambda_i \), with \(N\), the number of eigenvalues, and \(\lambda_j\) the eigenvalues corresponding to the \(j\)th principal component.

“The variance-covariance matrix (or correlation matrix) of these components closely matches, if not equals, that of the original time series data where \(p \leq k\). If the information content of the \(p\) components, as measured by the correlation matrix, say, still closely resembles that of the original data structure containing \(k\) variables, then the \(p\) principal components can be used to replace the initial dataset. In this way the dimensionality of the problem may be reduced without introducing any significant information loss”. L. Bonney, G. Shannon and N. Uys 2008 [5].

In case of a covariance-PCA, data are centred. In case of correlation-PCA, the data are centred and normalised [3]. Richard A. Johnson ([8], page 435) indicates that the standardization is not without impacts on the PCA. Alexander Carol ([4], page 64) also confirm this assessment: “If PCA is performed on a correlation matrix then the results will only be influenced by the correlations of returns, but if the input to PCA is a covariance matrix then the results will be influenced by the volatility of the returns as well as the correlations of returns”.

When the analysed data are not on the same scale, Neil H. Timm ([7], page 460) and Richard A. Johnson ([8], page 435) recommend using a correlation-PCA. However, when data are on the same scale, a covariance-PCA is preferable. As the data on implied volatilities are on the same scale, and to avoid the disadvantages of a correlation-PCA, a covariance-PCA is used in this analysis. Thus, the PCA is realised on the covariance matrix \(\Sigma_{N+N}\).

Let \(T\) the number of observation, \(N\) the number of moneyness (equal to 32 in this case), and \(V_{T,N}\) the matrix to be used in the PCA, containing the variation of implied volatility deviation: \(\Delta \sigma_{m,t} = \sigma_{m,t+1} - \sigma_{m,t}\).

The PCA is realised on the moneyness space. As a covariance-PCA is used, elements of matrix \(Z\) are only centred (and not standardized): \(Z_{ij} = V_{ij} - \bar{V}_j\), where \(\bar{V}_j\) is the average of column \(j\) of matrix \(V\).

In a covariance-PCA, eigenvalues and eigenvectors are obtained by maximising the following program \(\forall i = 1, \ldots, T:\)

\[
\max_{u_i} \lambda_i = u_i^T \Sigma u_i \\
\text{s.t.} \left\{ \begin{array}{l} u_i^T u_i = 1 \\
\forall j \in \{1, i-1\}; u_j^T u_i = 0 \end{array} \right.
\]

Where \(\lambda_i\) is a scalar representing the \(i\)th eigenvalue, and \(u_i\) a column vector representing the \(i\)th eigenvector. According to the dimension, \(u_i\) is \(T \ast 1\) (observations space) or \(N \ast 1\) (moneyness space). The first constraint \(u_i^T u_i = 1\) or \(\|u_i\| = 1\), is the constraint of normalization. The second one, \(\forall j \in \{1, i-1\}, u_j^T u_i = 0\), guarantees that the eigenvectors are orthogonal.
Finally, the principal components can be obtained:

\[ f = Z \ast u, \text{ with } u_{N \times N} \text{ the set of all the eigenvectors.} \]

### 2.4. Econometric model

The aim of the econometric model is to explain the principal components (the endogenous variables) by the macroeconomic surprises (the exogenous variables).

An economic surprise is defined as the difference between the economist consensus and the released data. By following the method of Florian Ielpo and Dominique Guégan, the macroeconomic surprise of the index \( j \) at time \( t \), is computed as:

\[
S_{j,t} = \frac{R_{j,t} - C_{j,t}}{\sigma_{S_{j,t}}}
\]

Where:
- \( C_{j,t} \) is the median of the economist forecasts. Florian Ielpo and Dominique Guégan ([16], page 5) underline that “the use of the median as a measure of the expectations makes the forecast robust to the influence of badly intentioned economists that would want to shift the forecast in order to make the most of it”.
- \( R_{j,t} \) is the released value of the economic index \( j \)
- \( \sigma_{S_{j,t}} \) is the standard deviation of macroeconomic surprises \( R_{j,t} - C_{j,t} \). The surprises are normalized to make them comparable.

For every day without release of the index \( j \), its surprises are set to 0.

The selected model differentiates the surprises according to their signs. Thus, the potential impacts on the volatility smile after a surprise can be different according to an overestimation or underestimation of the index.

For each factor \( f \) with \( f = \{1, 2, 3\} \), corresponding to the different principal components:

\[
F_t^f = \beta_f + \sum_{j=1}^{n} \alpha_{j+}^f S_{j,t} 1_{[S_{j,t}>0]} + \alpha_{j-}^f S_{j,t} 1_{[S_{j,t}<0]} + \epsilon_t^f
\]

Where:
- \( P_t^f \): Value of factor \( f \) at time \( t \)
- \( \beta_f \): Y-intercept of factor \( f \)
- \( \alpha_{j+}^f \): Slope of factor \( f \) when the surprise on index \( j \) is positive
- \( \alpha_{j-}^f \): Slope of factor \( f \) when the surprise on index \( j \) is negative
- \( 1_{[S_{j,t}>0]}, 1_{[S_{j,t}<0]} \): Dummy (indicator) variables
- \( \epsilon_t^f \): Error at time \( t \) such that \( E[\epsilon_t^f] = 0 \)

According to this model:

\[
E[F_t^f | S_{j,t} > 0] = \beta_f + \sum_{j=1}^{n} \alpha_{j+}^f S_{j,t}
\]

### 3. Data

In order to measure the impact of the macroeconomic surprises on the volatility smile, an empirical analysis is performed on the S&P 500 3-months implied volatilities. The sample goes from the 5 September 2008 to the 16 March 2015.

#### 3.1. S&P 500 and options

The daily (adjusted) closed prices of the S&P 500 Index are used to compute the moneyness of the options. The analysed options are plain European vanilla options, with a maturity of 90 days, more or less 15 days.

In order to minimize the number of missing data, the analysis is performed on moneynesses that have the more data available. Thus, only the moneynesses around the at-the-money moneyness (equal to 1) will be used. In accordance with the data available, the retained sample includes the implied volatilities with moneyness from 0.80 to 1.12. Moneynesses are round to 100 basis points (0.01).

#### 3.2. Interest rates

In order to obtain the implied volatilities by the Newton-Raphson algorithm or by dichotomy, it is required to specify all the parameter of the options.

The underlying-asset value \( (S_t) \) is already collected. The maturity \( (T) \) and the strike price \( (K) \) are implicit to the optional contract. However, the risk-free interest rate \( (r) \) is not defined and can be chosen arbitrarily. In this analysis, the US 3-month Treasury-Bill yield is used. Chris Brooks [14] and Marcelo Bianconia [15] also used the Treasury bills to compute the implied volatilities on S&P500 options. Furthermore, the maturity, the geographical area, and the monetary zone of the interest-rates and the options are equal, which strengthen this choice.

#### 3.3. Independent variables

All the chosen macroeconomic indicators are well known by practitioners, and correspond to those selected by Florian Ielpo and Dominique Guégan.

The choice of the independent variables has been inspired by the calendar of US economic indexes of Bloomberg, widely followed by market operators. On the contrary of Florian Ielpo and Dominique Guégan, all the indexes are not selected, but only a part of them. Furthermore, other authors try to explain the variation of the equity returns with these variables, such as McQueen and Roley 1993,
Jensen, Mercer and Johnson 1996, and Strongin and Tarhan 1990.\(^2\)

Given the following variables:

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALANCE</td>
<td>US Trade Balance of Goods and Services</td>
</tr>
<tr>
<td>BUDGET</td>
<td>US Treasury Federal Budget Debt Summary Deficit</td>
</tr>
<tr>
<td>CONSO</td>
<td>US Personal Consumption Expenditures Nominal Dollars MoM SA</td>
</tr>
<tr>
<td>CONSUM</td>
<td>US CPI Urban Consumers MoM SA</td>
</tr>
<tr>
<td>CREDIT</td>
<td>Federal Reserve Consumer Credit Total Net Change</td>
</tr>
<tr>
<td>FDTR</td>
<td>Federal Funds Target Rate</td>
</tr>
<tr>
<td>GDP</td>
<td>GDP US Chained 2009 Dollars QoQ</td>
</tr>
<tr>
<td>HOUSENEW</td>
<td>US New Privately Owned Housing Units Started</td>
</tr>
<tr>
<td>HOUSEBUY</td>
<td>FHFA US House Price Index Purchase Only MoM% SA</td>
</tr>
<tr>
<td>HOUSESALE</td>
<td>US Existing Homes Sales</td>
</tr>
<tr>
<td>IMP</td>
<td>US Import Price Index by End Use All MoM</td>
</tr>
<tr>
<td>INCOME</td>
<td>US Personal Income MoM</td>
</tr>
<tr>
<td>INFLATION</td>
<td>US CPI Urban Consumers YoY</td>
</tr>
<tr>
<td>MICHIGAN</td>
<td>University of Michigan Consumer Sentiment Index</td>
</tr>
<tr>
<td>MORDER</td>
<td>US Manufacturers New Orders Total MoM</td>
</tr>
<tr>
<td>NFP</td>
<td>US Employees on Nonfarm Payrolls Total MoM Net Change</td>
</tr>
<tr>
<td>MNFP</td>
<td>US Employees on Nonfarm Payrolls Manufacturing Industry Monthly Net Change</td>
</tr>
<tr>
<td>PMI</td>
<td>Purchasing Managers Index</td>
</tr>
<tr>
<td>UNEMPLOY</td>
<td>U-3 US Unemployment Rate Total in Labour Force Seasonally Adjusted</td>
</tr>
<tr>
<td>WHOLEINV</td>
<td>Merchant Wholesalers Inventories Total Monthly %</td>
</tr>
</tbody>
</table>

As these indexes are released during base hour, and implied volatilities are computed thanks to the close prices, the specified model allows implied volatilities forecasting.

4. Empirical results

4.1. Principal Component Analysis

Alexander Carol [4] reminds that the standard interpretation of the first component is the trend, the second component is the tilt and the third component is the curvature of the volatility smile.

Furthermore, Ihsan Ullah Badshah [9] highlights that the first eigenvector can be interpreted as the level of the volatility smile. This vector affects completely the volatility smile in the same measure. L. Bonney, G. Shannon and N. Uys [5] explain that a “positive (negative) movements in the first component typically result in positive (negative) changes in the volatility skew - for each strike”. Thus, the impact is regular along the volatility smile.

The second eigenvector represent the slop of the volatility smile. A positive (negative) impact in the second component results in a positive (negative) change in the slope: implied volatilities with moneyness inferior to 1 will decrease (increase) and those below 1 will increase (decrease). One should notice that deep-out-of-the-money puts (with moneyness above 1.05) are more impacted by moves in the second components. Indeed, the weights associated to moneynesses above 1.05 are sharply higher than those between 1 and 1.05.

The third component can be interpreted as the curvature or convexity of the skew. The weights associated to the third component similar to those of P. Bonney, G. Shannon and N. Uys: “the coefficients of the third eigenvector […] have the same signs at both ends of the strike range and opposite signs for options in the middle of the strike range, resulting in changes in convexity of the skew surface” after a shock on the third component.

Similarly to Florian Ielpo and Dominique Guéguan, the analysis of the correlations between the factors and variations of volatility smile $\text{Corr}(F_j, \Delta \sigma_m)$ confirm the conclusion about the nature of the eigenvectors. Actually, these correlations represent the impacts of factor $j$ on the volatility smile, and the shapes of these correlations are similar to those of the eigenvectors.
Thus, the variation of implied volatility can be approximated by:
\[ \Delta \sigma_m \approx u_{m,1} * V_1 + u_{m,2} * V_2 + u_{m,3} * V_3 \]

The first component represents the major part of the explained variance, with 75.91%: parallel moves in the level of the volatility smile are the principal explanation of variations. The second component, the slope, explains 7.26% of the variance, and the convexity 2.74%. Together, the first three components of the PCA explain 85.81% of the variance of the volatility smile.

The first three eigenvalues obtained:

<table>
<thead>
<tr>
<th>Eigenvalues</th>
<th>Explained</th>
<th>Cumulated R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>52.42</td>
<td>75.81%</td>
<td>75.81%</td>
</tr>
<tr>
<td>5.02</td>
<td>7.26%</td>
<td>83.07%</td>
</tr>
<tr>
<td>1.90</td>
<td>2.74%</td>
<td>85.81%</td>
</tr>
</tbody>
</table>

The eigenvalues \( \lambda_i = Var(p_{ci}) \):

4.2. Econometric regression

Let the coefficients of determination \( R^2 \) for each factor of the model:

<table>
<thead>
<tr>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>9.26%</td>
<td>2.94%</td>
</tr>
</tbody>
</table>

Coefficients of determination

For the first model, 9.26% of the variance of the factor 1 is explained by the different macroeconomic surprises. Only 2.94% of the variance of the factor 2 is explained by the surprises, and 10.36% for the third factor.

Trend

The first factor can be interpreted as the level of the volatility smile. Many macroeconomic surprises have a significant impact on this dimension of the skew.

For instance, a positive (negative) surprise on the level of Personal Consumption Expenditures index will increase (decrease) the general level of the volatility smile. In other words, when the anticipated consumption is below the released value, the level of the volatility smile increases. A positive or negative surprise on the consumption modifies the anticipations of operators. In case of a positive surprise, market participants forecast a growing economy.

Consequently, they buy OTM puts to protect against the downside risk, ITM calls to benefit from the growing economy, and ATM options to take advantages of the rising volatility.

<table>
<thead>
<tr>
<th>Positive surprise</th>
<th>Negative surprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSO</td>
<td>+</td>
</tr>
<tr>
<td>FDTR</td>
<td>-</td>
</tr>
<tr>
<td>IMP</td>
<td>-</td>
</tr>
<tr>
<td>INCOME</td>
<td>+</td>
</tr>
<tr>
<td>INFLATION</td>
<td>-</td>
</tr>
<tr>
<td>MNFP</td>
<td>+</td>
</tr>
<tr>
<td>WHOLEINV</td>
<td>+</td>
</tr>
</tbody>
</table>

Impact on the trend of the volatility smile

The signs of the coefficients for the Fed Funds Target Rate are opposite: a positive (negative) surprise on the Fed Funds Target Rate will decrease (increase) the level of the implied volatility. Thus, a positive surprise appeases the operators, but in contrast, a negative surprise shakes the market. Similarly, a positive (negative) surprise on the Non Farm Payrolls Manufacturing Industry will also decrease (increase) the level of the volatility smile.

Surprises on the Import Price Index also impact the level of the volatility smile, but only the negative surprises have a significant and negative impact. Thus, the general level of the volatility smile is only impacted on overestimation of the index. On the contrary, negative surprises on the Personal Income index have a significant and positive impact on the trend.

Finally, all the surprises on the Merchant Wholesalers Inventories Index (positive or negative) increase the level of the volatility smile. An improvement or a deterioration of the industrial production compared to the anticipations raises the volatility.

Slope

The econometric regression of the factors on the slope of the volatility smile is not significant: none macroeconomic surprise reaches to explain the variation of the slope. All the coefficients are significantly equal to zero with an accepted risk of 5%.

However, if the accepted risk is raised a little higher, to 7%, coefficient on the inflation, for positive surprises, become significantly different of 0. Thus, when the inflation is more than expected, the slope of the volatility smile increase.

<table>
<thead>
<tr>
<th>Positive surprise</th>
<th>Negative surprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFLATION (7%)</td>
<td>+</td>
</tr>
</tbody>
</table>

Impact on the slope of the volatility smile

This conclusion and the relevance of this result have to be related to the accepted risk.
Convexity

The third factor is interpreted as the convexity or curvature of the volatility smile. Many macroeconomic surprises explain the variations of this dimension.

Negative surprises on the Trade Balance of Goods and Services of the United States of America will intensify the convexity of the volatility smile. For a negative surprise, moneyness near 1 (near the at-the-money moneyness) will shrink, and those away from 1 will grow, resulting in an increasing convexity of the volatility smile.

After a negative surprise, ITM calls and puts become more expensive as the trade balance affects the growth of the USA. The same consequences on the volatility smile occur for negative surprises on the Fed Funds Target Rate.

Multiple effects

Some surprises, on certain index, impact more than one dimension of the volatility smile.

<table>
<thead>
<tr>
<th>BALANCE</th>
<th>Positive surprise</th>
<th>Negative surprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDTR</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>HOUSEBUY</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>IMP</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>INFLATION</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>MICHIGAN</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NFP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHOLEINV</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
</table>

Impact on the convexity of the volatility smile

On the contrary, negative surprises on the Michigan Consumer Sentiment Index, and Non Farm Payroll, decrease the convexity of the volatility smile.

A positive surprise on the inflation means that the economy is growing. Thus, operators are more willing to buy call options to bet on the uprising growth. As the economy is more likely to grow, ITM call options prices increase. Furthermore, call option prices with moneyness above 1 increase more than those with moneyness below 1 because ITM calls have a positive intrinsic value.

When one or more indexes are released, it is possible to estimate the variation of each point of implied volatilities.

One should measures the variation of factors inferred by the surprises via the econometric relation, and computes the variation of a specific implied volatility point by the relation of the PCA:

\[ \Delta \sigma_m \approx u_{m,1} * V_1 + u_{m,2} * V_2 + u_{m,3} * V_3 \]

5. Extensions and applications

The first three factors of the covariance matrix are obtained via a Principal Component Analysis. These principal components can be interpreted as the trend, slope and convexity of the volatility smile. Many macroeconomic indexes, considerably followed by market operators on Bloomberg, impact these dimensions of the volatility skew. The econometric model differentiates the surprises on these indexes according to their signs.

Therefore, it is possible to build and invest in volatility strategies. One conceivable strategy is to build directional Vega portfolios after the release of an index. The directional Vega can be obtained via options, or pure volatility instruments such as variance swap.

This dissertation can be extended on some points. An analysis of the impact of the surprises on the implied volatilities with extreme moneyness can strengthen the empirical results of this study, and extend the applicability of the model.

Furthermore, the predictability of the econometric model can be improved by integrating:

- The business cycles. Florian Ielpo and Dominique Guégan take into account the business cycles by defining thresholds on one or more variables. Then, they introduce these thresholds into the model via indicator variables. According to the authors, impacts of macroeconomic surprises are different according the state the economy. Thus, there would have 4 possible and different impacts for each variable according to the conjuncture (expansion or recession) and the sign of the surprise.
- The last $p$ surprises, similarly as an autoregressive $AR(p)$ process
- The last $q$ errors, that is a Moving Average $MA(q)$ part
6. References


Data: Bloomberg, Yahoo Finance
7. Appendix

7.1. Results of the PCA

<table>
<thead>
<tr>
<th>Eigenvalues</th>
<th>Explained (%)</th>
<th>Moneyness</th>
<th>Eigenvector 1</th>
<th>Eigenvector 2</th>
<th>Eigenvector 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>52.42</td>
<td>75.81%</td>
<td>0.80</td>
<td>0.180</td>
<td>-0.107</td>
<td>0.252</td>
</tr>
<tr>
<td>5.02</td>
<td>7.26%</td>
<td>0.81</td>
<td>0.186</td>
<td>-0.103</td>
<td>0.243</td>
</tr>
<tr>
<td>1.90</td>
<td>2.74%</td>
<td>0.82</td>
<td>0.185</td>
<td>-0.093</td>
<td>0.293</td>
</tr>
<tr>
<td>0.93</td>
<td>1.35%</td>
<td>0.83</td>
<td>0.184</td>
<td>-0.092</td>
<td>0.238</td>
</tr>
<tr>
<td>0.84</td>
<td>1.21%</td>
<td>0.84</td>
<td>0.178</td>
<td>-0.109</td>
<td>0.248</td>
</tr>
<tr>
<td>0.71</td>
<td>1.02%</td>
<td>0.85</td>
<td>0.179</td>
<td>-0.101</td>
<td>0.188</td>
</tr>
<tr>
<td>0.66</td>
<td>0.96%</td>
<td>0.86</td>
<td>0.185</td>
<td>-0.096</td>
<td>0.122</td>
</tr>
<tr>
<td>0.59</td>
<td>0.86%</td>
<td>0.87</td>
<td>0.185</td>
<td>-0.081</td>
<td>0.034</td>
</tr>
<tr>
<td>0.46</td>
<td>0.66%</td>
<td>0.88</td>
<td>0.185</td>
<td>-0.088</td>
<td>0.068</td>
</tr>
<tr>
<td>0.43</td>
<td>0.62%</td>
<td>0.89</td>
<td>0.181</td>
<td>-0.098</td>
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### 7.2. Results of the regressions

Dependent Variable: FACTEUR_1

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- R-squared: 0.092615
- Mean dependent var: -4.91E-16
- Adjusted R-squared: 0.064059
- S.D. dependent var: 7.240372
- S.E. of regression: 7.004629
- Akaike info criterion: 6.761771
- Sum squared resid: 62361.40
- Schwarz criterion: 6.923624
- Log likelihood: -4394.722
- Hannan-Quinn criter.: 6.822471
- F-statistic: 3.243228
- Durbin-Watson stat: 2.239636
- Prob(F-statistic): 0.000000
Dependent Variable: FACTEUR_2

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R-squared 0.029477  Mean dependent var -9.48E-17
Adjusted R-squared -0.001067 S.D. dependent var 2.241280
S.E. of regression 2.242476 Akaike info criterion 4.483790
Sum squared resid 6391.475 Schwarz criterion 4.645643
Log likelihood -2900.366 Hannan-Quinn criter. 4.544490
F-statistic 0.965066 Durbin-Watson stat 3.022901
Prob(F-statistic) 0.533585
Impacts of macroeconomics forecast errors on volatility smile

Joseph COMISI – Paris-Dauphine University – May 2016

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Dependent Variable: FACTEUR_3

<table>
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<tr>
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R-squared 0.103654 Mean dependent var -2.98E-17
Adjusted R-squared 0.075445 S.D. dependent var 1.377331
S.E. of regression 1.324356 Akaike info criterion 3.430481
Sum squared resid 2229.231 Schwarz criterion 3.592334
Log likelihood 0.72209.396 Hannan-Quinn criter. 3.491181
F-statistic 3.674482 Durbin-Watson stat 2.848375
Prob(F-statistic) 0.000000