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Global FX Strategy

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14 July 2021

FX Derivatives Research Note

Distance measure for quantifying market regimes for FX vol trading

- We discuss a method for quantifying the perpetual dilemma: which historical periods are similar. We say that market conditions for two time periods are similar if the Mahalanobis distance between them is small.
- The Mahalanobis distance, a commonly used metric, is essentially a multi-dimensional z-score with the multi-dimensional vector being a difference between a reference (e.g. today) and another date, and where the components of the vector are various market and economic data points at time T.
- We justify the use of Mahalanobis versus, for example, Euclidean distance in Mahalanobis inherently incorporating PCA and thus automatically suppressing impact of highly redundant timeseries.
- As a proof-of-concept we apply the framework on seven baskets: global risk basket, positioning basket, economics/broad market backdrop basket, three FX vol baskets (USD, EUR and JPY vs G10) and the overall basket that incorporates variables from other six baskets, overweighting FX vols.
- Constraining the Mahalanobis distance to 10%-tile, we then generate a visualization of the similarity between today's market vs. history going back to 2006. Intuitively correct, we find the current broad market conditions to have smallest distance to the pre-GFC, 2014, 2017-2019 (with interruptions) and finally the late 2020 period.

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Our team would greatly appreciate your support in the Quantitative Analysis category and the Currency & Foreign Exchange category in Institutional Investor's 2021 Global Fixed Income Research poll. We have worked hard this year to provide a quantitative edge when expressing our FX vol view and finding trade opportunities, and hope that you have found that work and insights useful. Click here to vote.

The usually sparse summer calendar was rudely interrupted earlier today by the US CPI print. Our earlier analysis (see *here*) which looked at pre/post FX vol calendars has highlighted CPI alongside Fed meetings as worth watching on the back of solid historical performance. A follow-up *study on Jackson Hole* was more mixed but the event premium (event risk 1-day vol net of normalized 1-day vol) outlined the potential for financing higher beta with JPY vols. The push/pull on yen was clearly on display today and we expect similar vol dynamic to continue to play out. Useful in trading event risk, such studies are narrowly focused, lacking a broader backdrop.

An example of such broader backdrop is a basket of FX vols, VXY-GL, which is only ~0.3vol pts off the June low. In terms of 10-year historicals that's equivalent to the bottom 9%-tile. Even more extreme pricing is seen for VXY-G10 (5%-tile). During that 10-year stretch FX vols were similar or marginally lower only briefly in 2014 during the V-shape vol price action in the year of two halves and in the immediate pre-COVID period. Those previous episodes tended to only last ~2 months. The state of FX vols is somewhat at odds with the

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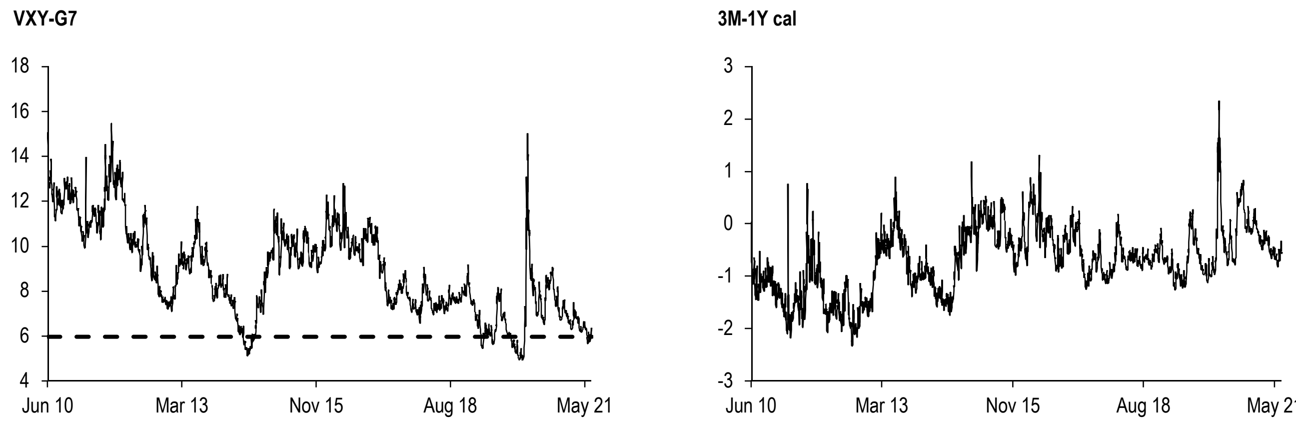
reaction of FX markets to data surprises and VXY-G10 vol curve which is only modestly steep and suggests longer-term depressed G10 FX vols (Exhibit 1).

The oddities raise the bigger question, a perpetual dilemma, on **which historical periods are similar** and thus provide meaningful insight into what to expect. It's a complex question that incorporates one's expectations. We attempt here to answer the simpler version which only deliberates about similarities with other historical periods. Even that tends to be very subjective and, beyond memorable historical landmarks in past market events, there can be quite some disagreement as to what construes similar periods.

Thus **the necessary first step is to quantify a measure of similarity. We say that market conditions for two time periods are similar if the Mahalanobis distance between them is small. The Mahalanobis distance, a commonly used metric, is essentially a multi-dimensional z-score with the multi-dimensional vector being a difference between a reference (e.g. today) and another date, and where the components of the vector are various market and economic data points at time T.**

Exhibit 1: VXY-G10 vols at 5%-tile and 3M-1Y vol curve flatness suggests that the depressed FX vol levels may be with us for longer.
VXY-G10 is a weighted basket of 3M ATM USD/G10 vols. The corresponding Bloomberg ticker is <JPMVXYG7 Index> and for 1Y version <JPMVG71Y Index>. See here for latest rebalancing.



Source: J.P. Morgan

The distance measure – the definition

We use a **distance measure which is adjusted for the statistical properties of the components**. To implement this we first compute the covariance matrix **S** of the data points. We use the Mahalanobis distance function:

$$\mathbf{d}(\mathbf{x},\mathbf{y}) = \sqrt{(\boldsymbol{x}-\boldsymbol{y})^T \boldsymbol{S}^{-1}(\boldsymbol{x}-\boldsymbol{y})}$$

There are several reasons that we use this particular distance function. First, when trying to compute a distance between two dates using a large number of variables, we will run into the issue that some variables may be highly correlated. So, for example, consider if there are several similar variables for which the difference between each variable over the two dates is large. If we were using standard Euclidean distance then the distance might become much smaller if we were to remove one of those variables. However, with the Mahalanobis distance, the fact that the variables are correlated is accounted for in the $\boldsymbol{S}^{-1}$ term.

Readers familiar with PCA might wonder how this Mahalanobis distance function is related to PCA since the two ideas seem so similar. **In particular, both PCA and the Mahalanobis distance are concerned with measuring the 'important directions' of a dataset. It turns out that the Mahalanobis distance is actually equivalent to the Euclidean distance on the PCA-transformed dataset.** Note that this means we must also scale during the PCA transformation and not solely rotate the coordinates. In fact, we originally set out to define our distance formula through the PCA method but ultimately found the Mahalanobis expression to be cleaner and more straightforward to work with.

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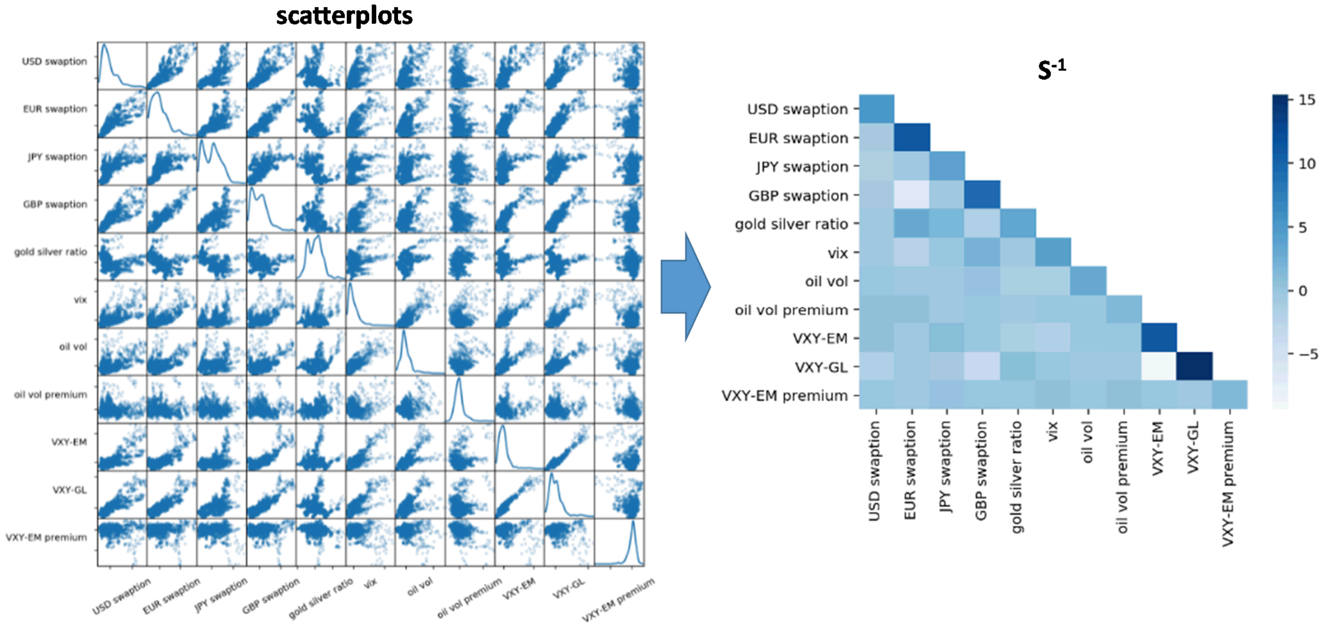
Exhibit 2: An example of an S^{-1} matrix on an 11 variable basket (aka Global risk markets basket). The strongly negative term in S^{-1} matrix offsets the combined effect of the highly correlated VXY-EM and VXY-GL. A similar though somewhat less detrimental case is seen for EUR and GBP swaptions.



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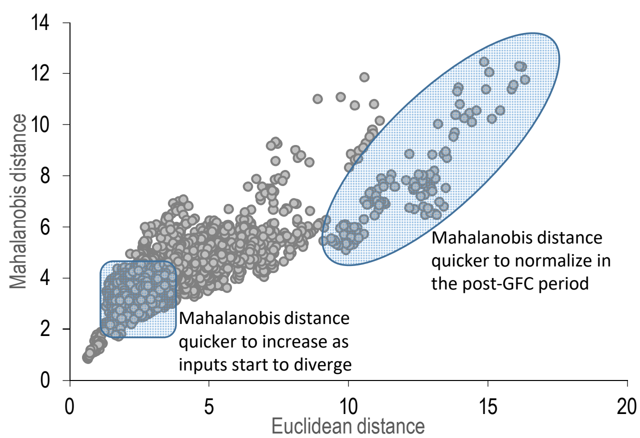
Empirically, for a basket containing 11 global risk variables Exhibit 3 compares Euclidean and Mahalanobis distance and finds that Mahalanobis distance is quicker to mean-revert from high / low regimes. Essentially the $\boldsymbol{S}^{-1}$ term acts to suppress the effect of the historically correlated timeseries resulting in the distance measure being based on less correlated market variables.

Exhibit 3: As inputs start to diverge Mahalanobis distance is quicker to react than Euclidean.

11 variable basket (aka Global risk markets basket) used to illustrate the difference.



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Another reason to use this distance function is the difference in variance among the variables. By multiplying by the inverse of the Covariance matrix, we are essentially rescaling the data so that a variable with a relatively large variance will not dominate the resulting value.

Of course there are also some shortcomings to this distance function. The key one is that **the covariance is fixed (at least in this implementation) rather than time varying, thus risking going stale if the relationships change over time. Also, there is still the 'outlier problem' since this is a quadratic distance formula.** An extreme value in a single component can cause the distance to be extreme which may or may not be a desired

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part of the model. If this feature is not desired, the individual components of (x-y) can be capped with a 'min' function or smoothed with a sigmoid function though such an approach may prove cumbersome to implement.

The distance measure – the intuition

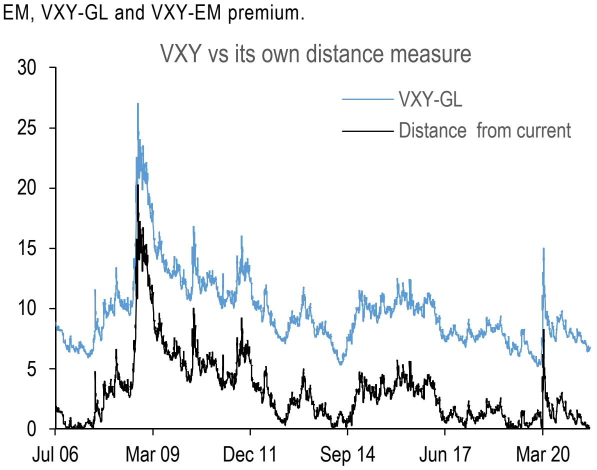
Before diving into analysis of a broad backdrop (market and economic), we need to convince ourselves that the proposed measure makes intuitive sense. The simplest, but also too trivial, case would be the one of market environment consisting of only one market variable, VXY-GL (yes we are biased to FX, but the framework is applicable more broadly). As per previous section, the distance measure is simply an absolute difference between the reference and historicals levels (i.e. $|VXY(t_{ref}) - VXY(t)|$). With the FX vols at near the historically depressed levels for the reference chosen to be the current level of VXY (i.e. we are interested how similar the current environment is to the historicals), the distance operation largely replicates the shape of the VXY itself (Exhibit 4 – LHS).

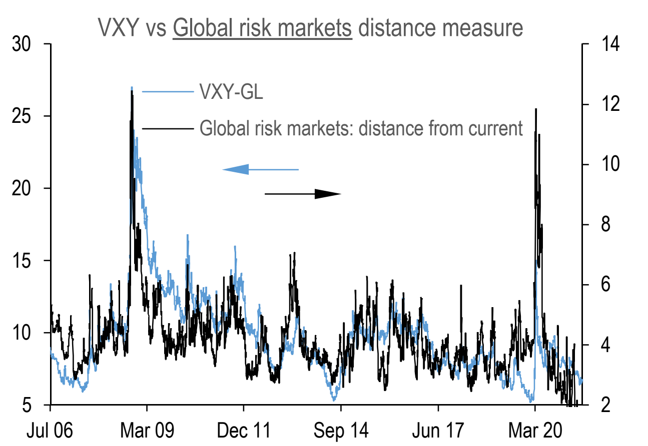
Building on the previous, we consider a modestly more complicated case, namely a basket of global risk markets variables. The basket consists of: 3Mx10Y swaptions in majors (USD, JPY, EUR and GBP), gold/silver price ratio, VIX, Brent 3M vol, Brent vol premium, VXY-EM, VXY-GL and VXY-EM basket premium, overall 11 (somewhat arbitrary) market variables that constitute a multi-dimensional vector. Average base metals vols and US credit would make good additions (though base metals vol timeseries do not go far back enough). We then calculate the distance measure in that 11 dimensional space and compare it with the VXY-GL index (Exhibit 4 – RHS). Two more clarification points: 1) One additional step we make is to calculate distance as an average of the most recent 1-month of data. That smooths out the timeseries, though not dramatically. 2) We measure the distance on the historical z-scores as the original variables (all are vols except gold/silver ratio), while largely stationary, are on very different scales. Exhibit 5 lists the variables and the transformations more broadly.

The timeseries distance chart shows that global risk markets were starkly different than currently in 2008/2009 and during the COVID-19 episode but similar in Q1 and Q4 of 2012, mid-2014 and during the long (though often interrupted) stretch from 2017 to 2020. We see that when our variables are vol / vol premia / risk-off indicators (as in the Global risk markets basket), the resulting distance measure is similar to the 1-D case of VXY itself. Clearly, we won't be able to pull such a simple parallel once the market dimension increases or as the variables become more diverse as we add higher-order option markets greeks, correlations, and economics variables.

Exhibit 4: (LHS) Under special conditions of currently depressed FX vols, the distance measure (vs the current level of FX vols) largely replicates the shape of the VXY. (RHS) Global risk markets were starkly different in 2008/2009 and during the COVID-19 episode but similar in 2013, 2014 and during the long (3x interrupted) stretch from 2017 to 2020. Similar message given by the VXY.

"Global risk markets" variables: 3Mx10Y swaptions in majors (USD, JPY, EUR and GBP), gold/silver price ratio, VIX, Brent 3M vol, Brent vol premium, VXY-EM, VXY-GL and VXY-EM premium.





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Current backdrop within distance framework across market baskets

Having familiarized ourselves with the workings of the framework, we now turn to an actual proof-of-concept of the Mahalanobis distance applicability across various baskets (so far we only touched on the Global Risk Markets slice). Exhibit 5 summarizes the baskets and their corresponding variables & transformations used. The baskets are by no means optimized though we think they are quite relevant and hit the key market aspects that FX option watchers may like to consider.

Exhibit 5: Composition of various baskets of market & economic variables.

Global Risk Markets	zscores	**Econ backdrop**	
US, EU, JP and UK 3Mx10Y swaptions		IMM: USD,EUR,JPY,GBP,AUD,CAD,CHF,MXN	zscore
Gold/Silver price ratio		Global PMI	Outright & 3-mo chg
VIX		Sentiment: Consumer, Mnfc, non-Mnfc	None
Oil 3M vol		yoy CPI	None
Oil vol premium		1y recession probability	None
VXYs: EM & GL		EASIs: G10, EM, US, EU, JP	None
VXY - EM premium		FRIs: Global, DM, EM, US, EU, JP	1-y zscore of 3-mo chg
Positioning	zscores	**FX vols**	1y-zscore & w/w chg in zscore
IMM: USD,EUR,JPY,GBP,AUD,CAD,CHF,MXN		USD, EUR and JPY / G10	
USD,EUR,JPY,GBP / G10 pairwise average FX corr		RR and RR/ATM	
Corr premium		BF and BF/ATM	

Source: J.P. Morgan

Namely, we apply the framework on seven baskets. Three are broad(er) baskets: 1) global risk basket, as already introduced; 2) positioning basket which comprises major IMMs (in form of z-scores) as well as FX correlations—here FX correlations (USD/G10, EUR/G10 and JPY/G10) and the corresponding correlation premia are meant to capture broader, more persistent shifts that tend to translate into prolonged themed FX markets moves and can exacerbate positioning pressures; 3) economics/broad market backdrop basket, which contains global PMI (level and 3-mo change), three economic sentiment indicators, CPI, major EASIs and FRIs (1-yr z-score of 3-mo change) and adds a component of FX by including IMMs.

The other three baskets are strictly FX vol based. But, instead of focusing on broad FX vol dynamics typically captured via VXYs (which we already included in the global risk basket), FX vol baskets aim to capture very granular market characteristics (i.e. currency level vols). USD/G10, EUR/G10 and JPY/G10 basket each contain 9 currency RR, RR/ATM ratio, BF and BF/ATM ratio timeseries that are given in form of 1-y z-scores and w/w change in z-score. In total, each basket consists of 72 timeseries. The baskets overlap as USD/JPY, EUR/JPY and EUR/USD are all found in two out of three baskets. With a 72 dimensional space per basket Mahalanobis is the key in suppressing the redundancies.

Finally we also construct the overall basket. Note that taking the distance is not a linear operation, thus the overall basket is not a simple sum of the individual baskets as we see in Exhibit 6. The exhibit shows historical periods which Mahalanobis distance finds to be the closest to the current backdrop. In calculating the distance instead of taking a point measurement, we average over the last 1-mo period to smooth out the daily changes. The “spectral lines” chart identifies the dates that fall into bottom 10%-tile for each of the series. We truncate the date-axis with January 2021 as, naturally, the distance rapidly declines as it gets within the last 3-4 months from the reference date T.

Going down the list, the **positioning basket** distance is the lowest in pre-GFC, mid- to late 2009, Q3 2013, narrowly in late 2017 / early 2018 and in 2020. With the USD positioning since recently normalized, the comparable historical backdrops are harder to pinpoint. In 2009 and 2013 the dollar positioning was consolidating from the local highs and just flipping short but in 2017/2018 was similarly rebounding from multi-year shorts. This highlights the lack of variables that identify the direction of change alongside the levels (z-scores). The **global risk basket**, as earlier stated, is largely in sync with broad market vol indices, such as VXYs. Comprising a diverse set of variables, the **econ basket** low distance points turned quite distributed with, for example, 2007, 2013, 2015 and 2017 helped by the similar state of sentiment indicators. Being at

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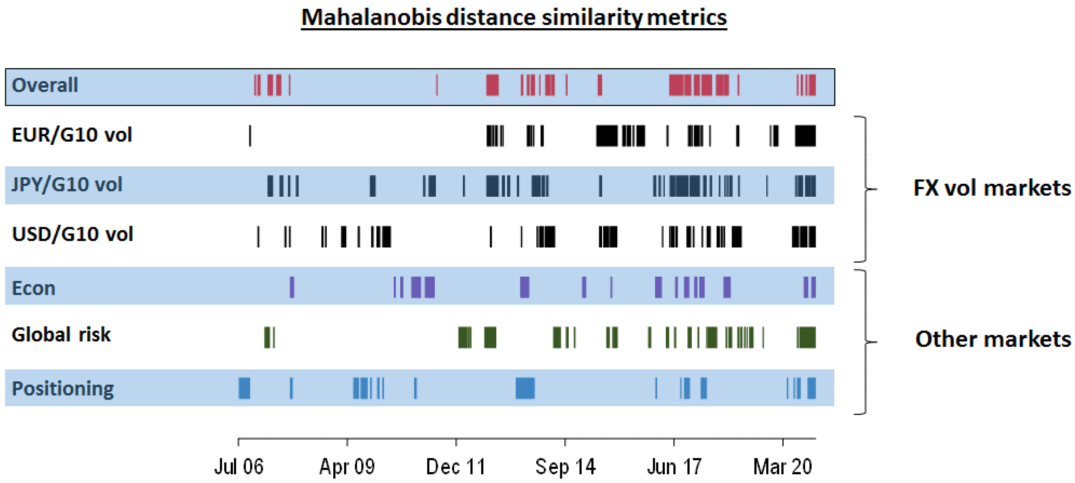
unprecedented levels and by large margin away from the recent historicals, yoy core CPI is currently not playing the role.

The overall basket highlights similarity of the current backdrop with the pre-GFC, 2104, 2017-2019 (w/ interruptions) and finally the late 2020 period. With FX vols participating with three baskets, **FX vols are overweight in the Overall basket** even though Mahalanobis framework tends to suppress redundancies.

Exhibit 6: The overall basket highlights similarity of the current backdrop with pre-GFC, 2104, 2017-2019 (w/ interruptions) and finally late 2020. Note that FX vols are overweight in the Overall basket even though Mahalanobis framework tends to suppress redundancies.

Doubles removed from the Overall basket



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Recap

We introduce a framework for quantifying similarity between market backdrops (actual or forecasted) and apply it on FX vols. We state that market conditions for two time periods are similar if the Mahalanobis distance between them is small. **Inherently incorporating PCA and thus automatically suppressing impact of highly correlated timeseries, Mahalanobis has an edge over simpler measures such as Euclidean distance or out-of-box clustering methods.** As a proof-of-concept we apply the framework on seven baskets: global risk basket, positioning basket, economics/broad market backdrop basket, three FX vol baskets (USD, EUR and JPY vs G10) and the overall basket that incorporates variables from other six baskets, overweighting FX vols. **Having constrained the Mahalanobis distance to 10%-tile, we find the current market conditions to have smallest distance to the pre-GFC, 2014, 2017-2019 (w/ interruptions) and finally the late 2020 period.**

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