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Eurozone Real Output and Covered Interest Parity Deviations: Can Stronger Real Output Lessen the Deviations?

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Abstract

Evidence shows that covered interest parity deviations have expanded over time in the EUR/USD cross currency basis swap market – the world’s largest basis swap market – even across the less erratic long-end of the basis swap curve. We analyze the long-run impact and dynamic interdependencies of eurozone macroeconomic factors on the long-end of the EUR/USD cross-currency basis swap spread, utilizing quarterly data from 2003–2018. Our stylized model predicts that a rise in euro area real output relative to the US would lead to a tighter euro basis swap spread; however, an increase in euro area money supply relative to the US as well as a depreciation of the euro would widen the euro basis in the long run. Our model suggests that the magnitude of the effect of real output on the basis is particularly more pronounced than the magnitude of the individual or combined effect of money supply increases and euro depreciation on the basis. Interestingly, our empirical results are consistent with these predictions. In addition, after examining convergence to long run, we find that among the eurozone variables, it is the cross-currency basis that is the predominant adjusting variable in the event of a divergence from the estimated long-run relation. Finally, using accumulated impulse response, we show that shocks to the exchange rate which strengthen the US dollar have permanent effects on the basis.

Keywords: eurozone, exchange rates, money supply, real output and euro cross-currency basis

JEL Classifications: E4, E5, E6, F3, G1, G2

I. Introduction

A major shift in the global financial markets over the last decade - one which has added an important variable to the list of carefully monitored indicators in the financial markets - is the persistent breakdown of covered interest parity (CIP). At its core, the CIP is a no arbitrage condition. In simple terms¹, it states that, given two currencies \$ and €, the income realized when a \$ holder invests in a € fixed income security and exchanges the € proceeds to \$ must be equivalent to the income generated had the \$ holder invested in a similar \$ security domestically. This also implies that when a euro entity issues in \$ and exchanges the cost of the \$ funds raised to €, this cost must be equal to that

¹ How a pure arbitrage profit from CIP deviations - manifested as a negative cross-currency basis between the euro and U.S. dollars – can be made. We start by assuming the arbitrageur has no dollar in hand. To arbitrage in the euro market, the U.S. dollar arbitrageur borrows one \$1 at the interest rate i and converts the \$1 into euro at a rate of \$1 to S euro. This gives S euro. The arbitrageur then approaches the euro zone financial market, lends out the euro at the prevailing euro market interest rate i^* , and then signs a forward contract on the same date to convert the euro proceeds to the U.S. dollar at a future date when the deal expires, i.e. at maturity or end of investment horizon. At maturity, which is at the end of the investment horizon n , the arbitrageur receives $Se^{ni^*} \approx S(1 + i^*)^n$ in euros, and converts this sum into $Se^{ni^*}/F = S(1 + i^*)^n/F$ U.S. dollars due to the forward contract F . At the end of the investment horizon, the arbitrageur’s \$1 debt in the U.S. dollars together with the accrued interest would be e^{ni} . The arbitrageur repays this debt in U.S. dollars from Se^{ni^*}/F which is the sum in U.S. dollars realized from investing in the euro market. The arbitrageur is then left with a profit of $(Se^{ni^*}/F - e^{ni})$ which is equal to the absolute value of the euro cross-currency basis. Thus, the more negative is the euro cross-currency basis, the greater the arbitrage profit that new arbitrage positions can generate for the arbitrageur. In summary, the arbitrageur has made a profit from owning. The arbitrageur starts out by borrowing dollars, exchanging to euro, going long in the euro asset (and shorting the dollar), with the euro cash flow fully hedged back to dollars using forwards.

incurred had the euro entity issued a similar product domestically in €. Otherwise, it would be possible to raise cheaper € funds via issuing in \$ or obtain a higher income in \$ via €, with currency risk fully hedged. The CIP breakdown became most visible in the last crises and has since persisted – offering the possibility to access cheaper funds or make arbitrage profits than would have been possible had the CIP remained largely unbroken. The CIP breakdown is encoded in what has now been known as the cross-currency basis swap spread. If CIP existed, this spread would be zero. Thus, the non-zero nature of the spread captures the magnitude or extent of CIP breakdown. This variable also indicates the level of stress in the financial market. For the euro basis, it is highly negative across maturities, including at the low volatility and less erratic long end of the basis curve which is the focus of this paper.

Much of the recent studies on cross-currency basis swap spreads have been skewed towards explaining why risk-free arbitrage still exists and why the spreads have not fizzled out, what the spreads imply about the credit risk in currencies, how they relate to the general demand for dollar-based assets and how post-crisis regulations - which impose balance sheet constraints that limit the size of exposures that banks and non-banks can take - have impacted the basis spreads. One of the major findings in the literature is that the CIP breakdown persists because banks, and other financial institutions that depend on them, are constrained, by increase regulations post crisis, from exploiting the opportunities which the CIP breakdown affords. As a result, the opportunities remain, because they have not been fully exploited, and the euro cross-currency basis remains deeply negative across maturities. But how do macroeconomic factors contribute to the persistence of the cross-currency basis? The role of macroeconomic factors in the persistence of the euro cross-currency basis has remained largely ignored in the literature. Since financial markets necessarily rely on benign macroeconomic conditions, then information on cross-currency basis swap spreads should be contained in some macroeconomic factors. The focus of this paper, therefore, is on what we can learn about the euro cross-currency basis swap spread from macroeconomic factors in the euro area.

Another motivation for this study is that the limited existing literature on CIP breakdown has focused almost exclusively on the strength of the dollar exchange rate as a major mechanism responsible for driving the cross-currency basis wider, in line with the findings by Avdjiev et al. (2017). Although this is true and is confirmed in our study, we believe this does not tell the full story. First, whilst it is true that an increase in dollar strength could reduce the amount of dollar flows to other countries or dollar lending activities as the fear of potential default increases as a stronger dollar burdens the ability of borrowers or counter parties to meet obligations, which would slow cross-border dollar flows and appetite for non-dollar assets, it is also important to note that other factors, such as a more favorable economic performance exist that could raise cross border dollar flows even amid an increasing dollar strength. As such, the dollar will be dominant and exert the most considerable influence on the cross-currency basis swap spreads only when other indicators of financial and economic health are less benign. Second, an exclusive focus on the dollar neglects the potentially substantial impact of broader economic drivers on the cross-currency basis swap spreads, an effect already emphasized by the low coefficient of determination for the dollar as the main driver of the basis in existing studies. We seek to address these highlighted gaps in the literature by emphasizing the role played not only by the exchange rate but also by the real and monetary aspects of the economy in determining the long-run behavior of the cross-currency basis swap spreads.

To understand the impact of eurozone macroeconomic factors on the euro cross-currency basis, we construct a model relating the euro cross-currency basis with standard macroeconomic factors – exchange rate, money supply and real output representing relative currency prices, monetary policy and performance of the real economy, respectively. We model the cross-currency basis as a deviation from CIP, in line with the standard definition. Our model predicts a tightening of the euro cross-currency basis in the long run when real output increases in the eurozone relative to the U.S., but a widening of the basis following a rise in euro area money supply and a depreciation of the euro exchange rate. We take these predictions to a euro data set and directly investigated their implications for the euro cross-currency basis. We do this to make sure that our theoretical results are not a mere coincidence and that they adequately fit and are consistent with the euro data. We first examine the non-stationarity and cointegration property of the euro data. Our results show that the macroeconomic variables and euro cross-currency basis swap are cointegrated, implying the existence of an estimable long-run relationship in levels. To estimate the long-run relationship, we employ appropriate estimators for cointegrated time series such as dynamic OLS, fully modified OLS and canonical cointegrating regression.

After estimating the coefficients on the macroeconomic variables, we find that our results are consistent with the predictions of our model in that they show an economically and statistically significant long run relationship between macroeconomic factors in the euro area and euro cross-currency basis swap spreads. The major finding of our paper is that the theoretical model is strongly supported by euro area data. The key message from the model and data is that macroeconomic factors play a significant role in the behavior of the euro cross-currency basis spreads in the long run. In particular, we find that real output, money supply and the exchange rate are linked in the long run; the linkage is such that i) an increase in Euro area output relative to US real output tightens the euro basis, ii) an increase in euro money supply relative to US money supply widens the basis and iii) a depreciation of the EURUSD exchange rate also widens the basis. We find that these results are generally true across all estimators employed. Thus, in the long-run, deviations from CIP in the eurozone turn on the strength of the dollar relative to the euro and the scale of money supply in the Euro area. When eurozone money supply increases and the dollar strengthens relative to the euro, deviations from CIP become larger and the euro cross-currency basis swap spreads tend to widen in the long run.

Our point estimates across all estimators considered indicate that, other things being equal, a 1 basis-point increase in the eurozone real output relative to the U.S tightens the 10-year euro cross-currency basis by 7.70 – 9.44 basis points per quarter, while a 1 basis-point depreciation in the EUR/USD exchange rate and an increase in euro area broad money supply widens the 10-year euro cross-currency basis by 1.07 – 2.98 basis points and 2.32 – 5.11 basis points, respectively. This indicates that in the long run, most of the tightening in the long end of the euro basis is driven by an improvement in real output in the eurozone. Not only is this important, it is able to offset the widening pressure from currency depreciation and money supply increases as our point estimates have shown.

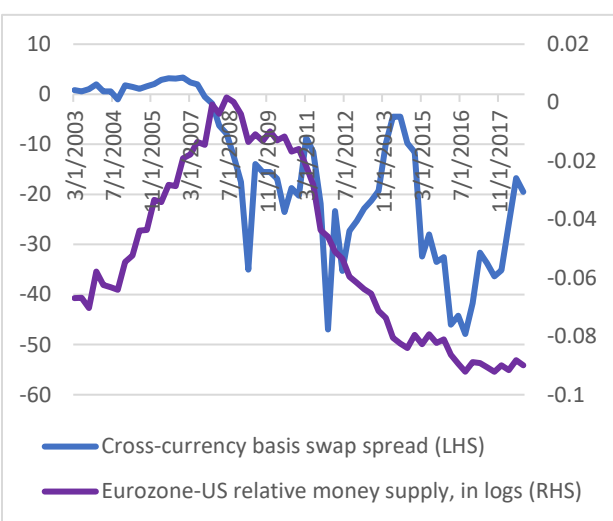
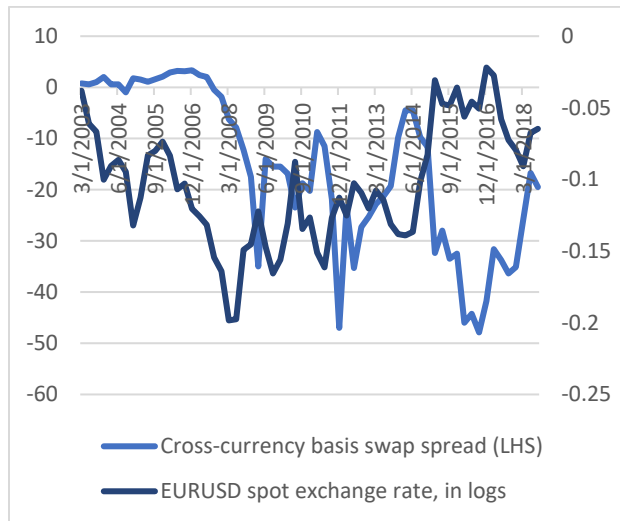
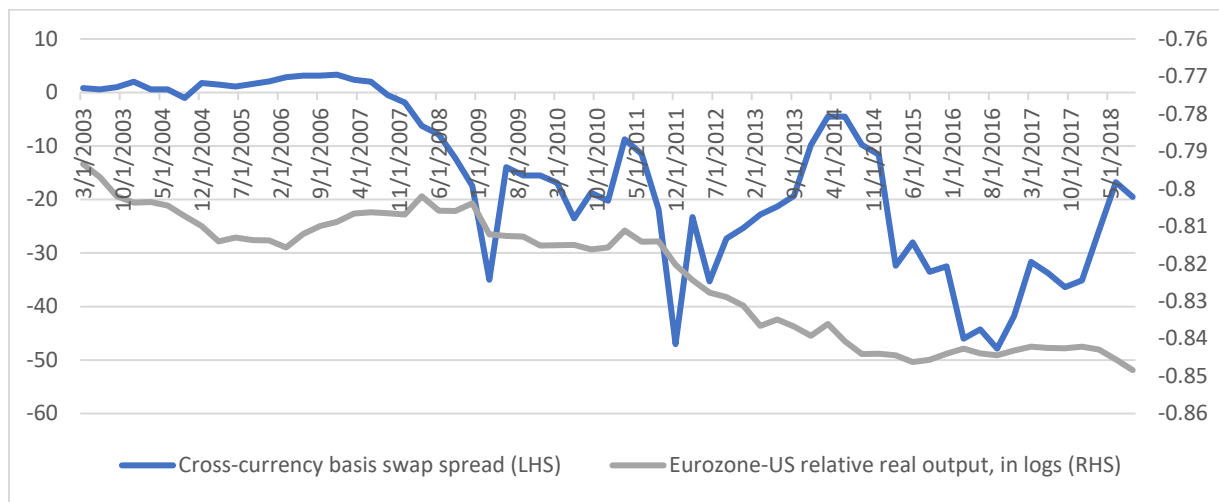
We also investigate the dynamic impact of the error correction term on the changes of each of the variables in the cointegrated vector in order to get a sense of the adjustment back to equilibrium following a temporary deviation. We find that it is mainly the euro cross-currency basis that predominantly adjusts to restore equilibrium. The associated speed

of adjustment implies a half-life for cross-currency misalignments of just over 5 quarters. With respect to the macroeconomic variables, the error correction variable has either no explanatory power for their dynamics or yields a positive sign unsupportive of convergence. Lastly, we show that shocks to the exchange rate, which strengthen the US dollar, have permanent effects on the basis.

We have focused on the euro area for several reasons. First, there has been a significant increase of international bond issuance in the euro since the launch of the European monetary union, Hale and Spiegel (2012). Also, Avdjiev et al. (2017) find evidence that the euro has started to exhibit characteristics of a global funding currency. This makes a study examining the link between eurozone macroeconomic factors and the EUR/USD cross-currency basis very important especially given that the euro proceeds obtained are often of intermediate importance and the final currency of need for a large amount of these issues, especially for large multilateral development institutions, is often in a different currency from the euro and often swapped to a different currency, mostly the US dollars. Second, euro cross-currency basis swap market is the most active basis swap market, accounting for 46% of volumes (see Barnes (2017)). The EUR/USD basis is the largest cross-currency swap market. Moreover, the EUR/USD is a very liquid currency pair and is the most traded foreign exchange pair among the G10 currencies, accounting for over 20% of the total volume of transactions in the forex market, thus providing adequate and required variability in the data for analysis. Third, the eurozone is the largest and best known monetary union which affords the region with macroeconomic scale and size, a broader based, synchronized monetary policy, and increases the internationalization of the euro in global payments and foreign exchange settlements.

To provide a graphical illustration of what turns out to support our model and empirical finding, Figure 1 below plots the cross-currency (in blue) paired with the relative real output (ash), relative money supply (purple) and exchange rate (black) over time. A cursory look at the graphs suggest that when the ash line goes down, which means the eurozone real output underperforms the US output, the cross-currency basis (blue line) tends to widen. We also see that when the purple line increases, which means that the eurozone money supply increases relative to the US money supply, the cross-currency basis tends to widen. In fact, as it can be seen, the cross-currency basis, by and large, is often the mirror image of the relative money supply. Lastly, the plot of the EUR/USD exchange rate are shown below in black. When the lines go up, the dollar strengthens (or the euro weakens) and when they go down, the euro strengthens, or the dollar weakens. Again, as with money supply, we see that the euro cross-currency basis is the mirror image of the euro weakness or dollar strength. When the euro weakens (or the dollar strengthens), the cross-currency basis spreads widen.

Figure 1a: 10-year cross-currency basis paired with relative output, money supply, spot and forward exchange rate



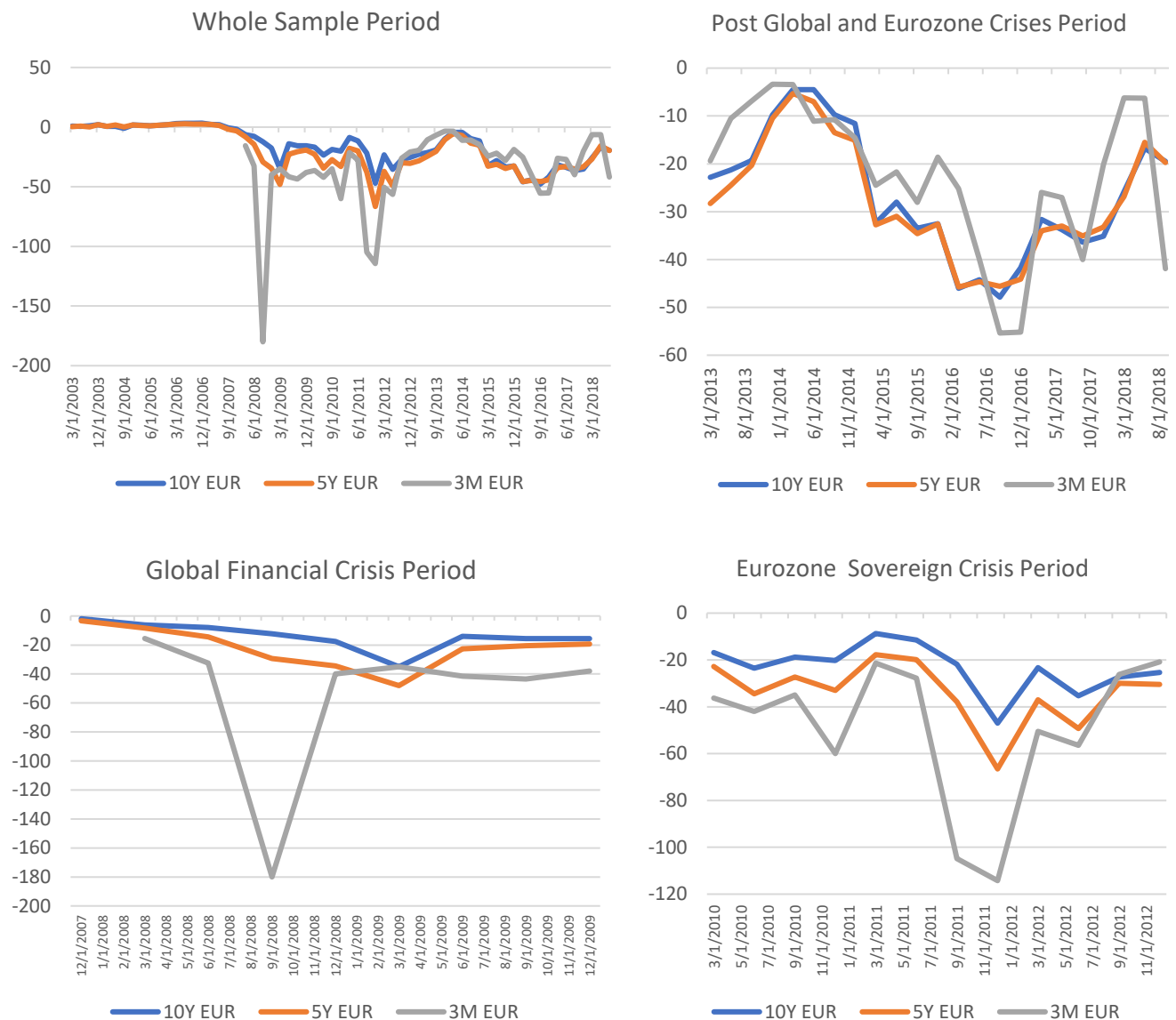
The rest of the paper is organized as follows. Section II reports some stylized facts about the euro basis while Section III presents the baseline model framework which forms the basis of subsequent empirical analysis. Section IV explains the data, empirical methodology as well as the empirical result while Section V analyzes the convergence to long run via error-correction analysis. Section VI presents the dynamic interdependencies using VAR, and Section VII provides a comparison with other empirical studies. The last section concludes.

II. The EUR Basis – Stylized Fact

Here, we present some stylized facts on the euro cross-currency basis swap spreads. We take a cursory look at the basis at the 3-month, 5-year and 10-year maturity buckets and across notable periods over the past decades. The tables below summarize the quarterly behavior of the basis across the three maturities over the i) whole sample period (2013 to 2018), ii) global financial crisis period (2007 to 2009), iii) eurozone sovereign crisis period (2010

to 2012), iv) combined crisis periods (2007 to 2012) and, finally, v) the period post crisis (2003 to 2018), respectively.

Fig 1b: Evolution of the euro cross-currency basis swap spreads



We begin with the whole sample period. In this case, across the three maturities, the 3-month euro basis is the widest, on average, and has the highest volatility. This is followed by the 5-year euro basis while the 10-year euro basis is the tightest and has the least volatility across the three maturities. The 3-month EUR basis seems to diverge significantly from the 5-year and 10-year basis, both of which appear to be well synchronized. The correlation analysis presented below confirms this observation quite well.

Table 0a: Summary Statistics – Whole Sample Period

	<i>10 EUR</i>	<i>5 EUR</i>	<i>3M EUR</i>
Mean	-12.88	-15.62	-35.76
Median	-7.04	-9.37	-27.75
Standard Dev	14.63	17.09	32.16
Range	51.21	69.33	176.63
Minimum	-47.87	-66.55	-180.00
Maximum	3.34	2.78	-3.36

Notes: The table provides summary statistics for Q1 2003 to Q3 2018. The mean values show that there was tighter basis in the 10Y (Longer end basis) while 3M (short end basis) recorded the widest basis. Under the same period, we notice that 3M EUR is the most volatile (using the value of its standard deviation) compared to 10Y and 5Y. The highest value of 3.34 occurs in Q4 2006 for the long-end basis while the lowest value occurs in Q3 2008 for the short-end basis.

Correlation - Whole Sample Period

	<i>10Y</i>	<i>5Y</i>	<i>3M</i>
10Y	1.00		
5Y	0.96	1.00	
3M	0.19	0.49	1.00

In the above correlations, the 5-year and 10-year basis swap spreads have the highest correlation of 0.96, compared to the correlation between the 3-month basis and each of the 5-year and 10-year basis of 0.49 and 0.19 respectively, which are significantly smaller, confirming the weak harmonization between the short end of the basis (3-month) and those at the longer end (10-year and 5-year).

Turning now to the two crises periods – that is, the global financial crisis and the eurozone sovereign crisis – the account is largely similar. The short end of the basis curve is, on average, several times wider than the long end and has the highest volatility in both periods of crises. The short end of the euro basis is the most volatile and widest relative to the long end - which remains tighter, on average, and has the least volatility. The observed low correlation pattern between the short and long end of the basis is also supported by the correlation values for both periods of crises. In fact, the 3-month basis behaves so differently that its correlation with the 10-year basis turns negative in the global financial crisis period, suggesting that there is some substitutability between the 3-month versus the 10-year basis which also implies that the basis swaps could serve as a hedge for one another. For basis trading, this outcome suggests the existence of a hedging opportunity for the euro basis with itself, where one basis is hedged with another drawn from the short and long end when basis swaps are traded across maturities.

Table 0b: Summary Statistics - Global Financial Crisis and Eurozone Crisis Periods

	Global Financial Crisis			Eurozone Crisis Period		
	<i>10Y</i>	<i>5Y</i>	<i>3M</i>	<i>10Y</i>	<i>5Y</i>	<i>3M</i>
Mean	-13.96	-22.24	-53.25	-23.30	-33.86	-49.62
Median	-13.95	-20.55	-39.00	-22.57	-31.74	-39.12
Standard Dev	9.39	13.65	51.95	10.23	13.42	30.88
Range	33.12	44.70	164.50	38.28	48.80	93.41
Minimum	-35.00	-48.00	-180.00	-47.00	-66.55	-114.25
Maximum	-1.87	-3.30	-15.50	-8.71	-17.75	-20.83

Notes: The above summary represents the period of Global Financial Crisis (Q4 2007 to Q4 2009) and European Sovereign Crisis (Q1 2010 to Q4 2012)

	Correlation			Correlation		
	Global Financial Crisis			Europe Sovereign Crisis		
	<i>10Y</i>	<i>5Y</i>	<i>3M</i>	<i>10Y</i>	<i>5Y</i>	<i>3M</i>
10Y	1			10Y	1	
5Y	0.92	1		5Y	0.95	1
3M	-0.083	0.22	1	3M	0.62	0.79

Interestingly, however, the correlation between the basis, particularly between the short and long end, rises several times more in the eurozone crisis period compared to the global financial crisis period, suggesting that the association of the euro basis across maturities in the eurozone sovereign crisis period is not exactly the same as in the global financial crisis period. Nonetheless, in both instances, the previous theme remains – that there is a relatively low correlation between the short end and long end of the euro basis.

The above pattern remains true when we look at the combined crisis period – that is a combination of the global crisis and eurozone crisis periods as a whole –, see Table 0c, although the correlation between the short and long end drops significantly, reflecting the relatively lower correlation in the global financial crisis period compared to eurozone crisis period.

Table 0c: Summary Statistics - Combined Crisis Period

	<i>10Y</i>	<i>5Y</i>	<i>3M</i>
Mean	-19.29	-28.88	-51.0736
Median	-17.50	-29.25	-39.00
Standard Dev	10.73	14.43	39.36

Range	45.125	63.25	164.5
Minimum	-47.00	-66.55	-180
Maximum	-1.87	-3.30	-15.50

Notes: The above summary statistics is a combined period of Global Financial Crisis and European Sovereign Crisis (which covers Q4 2007 – Q4 2012). From the table we notice that 5Y and 10Y tend to behave alike while 3M differs with the most volatile data and has the widest cross currency display.

Correlation – Combined Crisis Period

	<i>10Y</i>	<i>5Y</i>	<i>3M</i>
10Y	1		
5Y	0.95	1	
3M	0.23	0.44	1

However, some slight changes seem to have occurred since after both crises. Indeed, looking at the after-crisis period, the long end of the basis now appears slightly wider than the short end. Nonetheless, the evidence that the short end has a higher volatility is unaltered as the basis continues to be more volatile in the short end than in the long end. Moreover, the correlation between the basis at the long end remains larger than the correlation between the short and long end of the basis, suggesting that the initial evidence that the correlation between the long and short end of the basis is relatively low remains true. Despite this, it is also important to note that the correlation between the short and long end has increased noticeably since after the crisis period. In fact, the behavior of the euro basis post crisis is similar to that in the eurozone crisis period.

Table 0d: Summary Statistics - After-crisis period

	10Y	5Y	3M
Mean	-26.47	-27.52	-22.44
Standard Error	2.72	2.56	3.21
Median	-28.00	-31.00	-20.15
Standard Dev	13.04	12.30	15.41
Range	43.38	40.45	52.01
Minimum	-47.88	-45.75	-55.37
Maximum	-4.50	-5.30	-3.36

Notes: The above summary statistics is for the post global crisis and eurozone crisis periods (which covers Q1 2013– Q3 2018). From the table we notice

Correlation – After-crisis period

	<i>10Y</i>	<i>5Y</i>	<i>3M</i>
10Y	1		
5Y	0.98	1	
3M	0.75	0.75	1

In all, some interesting stylized facts arise from the summary statistics. First, the correlation between the short and long end of the euro basis is relatively lower than the correlation between the long end. Second, the short end of the basis is more volatile than the long end and has a mostly wider mean value relative to the long end. Third, the behavior of the euro basis across maturities in the post crisis period is generally similar to the behavior in the eurozone crisis period. If the long end of the euro basis behaves similarly and are more synchronized, do they also respond to similar macroeconomic factors? We now move to the next section where we investigate the baseline model that explains how macroeconomic factors drive the observed behavior of the basis at the long end.

III. Baseline Theoretical Model

To illustrate how relative real output, money supply and spot exchange rate may influence the long-term euro libor cross-currency basis swap spread, we consider a continuously compounded n -year risk-free interest rates quoted in U.S. dollars and the euro – which is the foreign currency. Let i and i^* be the continuously compounded n -year risk-free interest rates at time t in the U.S dollars and euro, respectively. Let S be the EURUSD spot exchange rate at time t , where S is expressed as the number of units of the euro per unit of the U. S dollars, so an increase in S is understood as an appreciation of the U.S. dollar or a depreciation of the euro, i.e. the U. S. dollar is the numeraire currency. Furthermore, let F denote the n -year forward exchange rate in euro per U. S. dollar at time t . Before we proceed, let us consider two useful results which will be used to support our exposition.

1. Lemma

By definition, $\log(1 + \delta) = \int_1^{1+\delta} \frac{1}{\theta} d\theta$, and $\delta \approx 0$ such that δ is in the interval $0 < \delta < 1$, then $\frac{1}{\theta} \approx 1$ for $1 < \theta < 1 + \delta$. Hence, $\log(1 + \delta) \approx \int_1^{1+\delta} d\theta = \delta$. Moreover, $(1 + \delta)^n \approx e^{n\delta}$ for each real n . Hence, for ease of computation, the amount realized from continuously compounding a risk-free interest rate i , $0 < i < 1$, after n periods is approximated as $(1 + i)^n \approx e^{ni}$. The same identity holds abroad, i.e. $(1 + i^*)^n \approx e^{ni^*}$.

2. Lemma

If both the U.S. and Euro securities are risk-free and the forward contract bears negligible counter party risk, then both strategies are the same and thus should yield equivalent payoffs, i.e.

$$e^{ni} = \frac{e^{ni^*} S}{F}$$

This is called the no-arbitrage, CIP assumption. In logs, this expression becomes

$$\frac{1}{n}(f - s) = i^* - i$$

where f and s are log values.

Thus, if CIP holds, the equality in the above lemma must hold and the cross-currency basis swap spread is trivially zero. On the other hand, suppose, however, that the CIP fails to hold. Then there is a deviation from covered interest rate parity and $\frac{1}{n}(f - s) \neq i^* - i$. This means that \exists an $x \neq 0$, representing the deviations from CIP, such that

$$\frac{1}{n}(f - s) = (i^* - i) + x \quad (1.0)$$

x is known as the cross-currency basis.

Now, continuing with our previous exposition, suppose there are no barriers to cross border capital and assets flows between the euro area and the U.S., and a representative agent, with investible U.S. dollars, seeks to exploit the markets to optimize her financial outcomes. For ease of exposition, let the investible dollars available to the agent be \$1. Two outcomes are possible. First, at time t , she could invest the \$1 domestically and generate a total amount of e^{ni} U. S. dollars n years from now. Second, she could exchange her \$1 for the euro at the spot exchange rate S , enter a swap contract agreement and then invest the S euro in the eurozone market. At the end of the n years, she would own a total of $e^{ni^*} S$ euros. When she swaps the amount realized in the euro back to the U. S. dollars at the forward rate F previously agreed at time t , this amounts to $e^{ni^*} S / F$ in U. S. dollar terms. This is called synthetic US dollars.

Meanwhile, suppose that the demand for real money balances in the U.S. and eurozone is characterized as a standard function of real output and nominal interest rate, where for simplicity, we assume that the nominal interest rate is the same as the US and euro risk-free interest rates i and i^* quoted at date t in US dollars and euro. The standard monetary model can be written as –

$$m - p = \psi_1 i + \psi_2 y \quad (1.1)$$

$$m^* - p^* = \psi_1 i^* + \psi_2 y^* \quad (1.2)$$

where m , p , i , and y denote domestic money supply, price level, interest rate and output respectively in the U.S., while asterisks denote variables for the euro area. ψ_1 and ψ_2 denote interest rate semi-elasticity of money demand and income elasticity of money demand, respectively, where $\psi_1 > 0$ and $\psi_2 > 0$ in line with Frankel (1979). Except for interest rates, all other variables are expressed in logarithm.

Taking the difference between (1.1) and (1.2) yields

$$(m^* - m) - (p^* - p) = \psi_1(i^* - i) + \psi_2(y^* - y) \quad (1.3)$$

Meanwhile, standard purchasing power parity implies that, if s is the spot exchange rate, then

$$s = p^* - p, \quad (1.4)$$

Combining (1.0), (1.3), and (1.4), we obtain

$$x = \left(\frac{1}{\psi_1} - \frac{1}{n} \right) s - \frac{1}{\psi_1} (m^* - m) + \frac{\psi_2}{\psi_1} (y^* - y) + f f_t \quad (1.5a)$$

which links our variables of interest to the euro cross-currency basis swap spread, x . The model provides a simple theoretical framework that leads to testable implications for the long-run relation between the euro cross-currency basis swap spreads and macroeconomic indicators – relative money supply, relative real output and spot exchange rate.

First derivative of the model with respect to our variables of interest yields

$$\frac{\partial x}{\partial s} = \left(\frac{1}{\psi_1} - \frac{1}{n} \right), \quad \frac{\partial x}{\partial (m^* - m)} = -\frac{1}{\psi_1}, \quad \frac{\partial x}{\partial (y^* - y)} = \frac{\psi_2}{\psi_1} \quad (1.5b)$$

Equation (1.5a) is the model governing the dynamics of the long run links between the euro cross currency basis and the macroeconomic variables. The dependence of the euro basis swap spreads on the dollar spot exchange rate is in line with the mirror effect of the dollar on the basis, first emphasized empirically by Avdjiev et al. (2017). However, apart from Ibhagui (2018), we are not aware of any other studies that link the other variables, i.e. real output and money supply dynamics, to the basis. Thus, our model simultaneously captures important potential drivers of the euro basis, some of which have not been investigated for the eurozone in the extant literature.

Assume that² $\psi_1 > 0$, and $\psi_2 > 1 > 0$, we have

$$\frac{\partial x}{\partial s} = \left(\frac{1}{\psi_1} - \frac{1}{n} \right) << 0, \quad \frac{\partial x}{\partial (m^* - m)} = -\frac{1}{\psi_1} < 0, \quad \frac{\partial x}{\partial (y^* - y)} = \frac{\psi_2}{\psi_1} > 0, \quad (1.6)$$

implying that, ceteris paribus, an increase in relative money supply would worsen CIP deviations in the eurozone and widen the euro cross-currency basis swap, an increase in relative real output would tighten the deviations while euro depreciation would either widen or tighten the cross-currency basis swaps. Also, as $\psi_2 > 1$, we have $\left| \frac{\psi_2}{\psi_1} \right| > \left| \frac{1}{\psi_1} \right| > \left| \frac{1}{\psi_1} - \frac{1}{n} \right| > 0$, suggesting that the magnitude of the impact of real output on the euro basis should be greater than the impact of either money supply or exchange rate or the sum of both.

The empirical specification associated with our simple model can be written as

$$x = \beta_0 + \beta_1 s + \beta_2 (m^* - m) + \beta_3 (y^* - y) + \varepsilon f_t \quad (1.7)$$

² See Frankel (1979), Isaac and de Mel (2001), Setzer and Wolff (2009), and Nakashima and Saito (2009)

where $\beta_1 < 0$, $\beta_2 < 0$ and $\beta_3 > 0$. Equation (1.7) forms the basis for our empirical analysis to test the hypothesis implied by the model.

IV. Data and Empirical Methodology

a. Data

The data for this study consists of quarterly observations for the cross-currency basis, the nominal exchange rate (euro per U.S. dollar), the euro area money supply relative to the U.S., and euro real output relative to the U.S. from Q1 2003 to Q3 2018, selected based on data availability for all variables. The cross-currency basis and nominal exchange rate series are from Bloomberg data manager, and the money supply and real GDP series are from the Federal Reserve Economic Data (FRED) economic data. Except for the cross-currency basis, all variables are measured in log-levels.

b. Empirical Methodology

We focus on the long-run relation between our variables of interest – which are the macroeconomic factors – and the long end of the euro cross-currency basis. In our time series analysis, we first provide exhaustive evidence that a cointegrated relation exists among the components of the vector $[x, s, (m^* - m), (y^* - y)]$ which enables us to estimate and uncover the long-run relation among the variables, particularly how the macroeconomic factors impact the euro cross-currency basis swap spreads in the long run. We estimate the cointegrating equation using the appropriate time series estimators for cointegrated system of variables. These are the dynamic ordinary least squares (DOLS), fully modified ordinary least squares (FMOLS) and canonical cointegrating regression (CCR). We also include the ordinary OLS for comparison.

We begin the empirical analysis by first investigating the integration properties of our series.

c. Unit roots

We first investigate the integration properties of $[x, s, (m^* - m), (y^* - y)]$ using the well-known augmented dickey fuller (ADF) unit root test, as well as the DF-GLS and MZ_α unit root tests which have been shown to have good size and power properties Ng and Perron (2000). Table 1 reports the results for the unit root tests. Column (1) of the first row of Table 1 shows the variable tested in levels; column 2 of the first row shows whether a linear trend was included in the unit root tests while the second row reports the first difference. All our specifications include a constant term.

We designate the variables in Table 1 as I(1) or I(0) using the following decision rule: If at least two of the tests reject the null hypothesis of nonstationarity at the 10 percent significance level or better, or if one test rejects at the

5 percent significance level, then we designate the corresponding variable I(0). If at least two of the tests do not reject the null hypothesis of nonstationarity at the 10 percent level or better, we designate the variable as I(1).

Table 1: Unit root test results

Variable in level	ADF	DF-GLS	MZ_{α}	Variable in level (with trend)	ADF	DF-GLS	MZ_{α}	Decision
x	-0.59	-1.34	-3.63	x	-1.71	-2.54	-12.91	I(1)
s	-2.27	-1.59	-4.42	s	-2.66	-1.94	-6.08	I(1)
$m^* - m$	-0.15	-0.33	-0.39	$m^* - m$	-1.92	-0.85	-0.88	I(1)
$y^* - y$	-0.91	0.96	0.63	$y^* - y$	-1.64	-1.61	1.29	I(1)
Variable in first difference	ADF	DF-GLS	MZ_{α}	Variable in first difference (with trend)	ADF	DF-GLS	MZ_{α}	
x	-3.34***	-10.09***	-28.45***	x	-3.31***	-10.09***	-28.45***	I(0)
s	-7.67***	-6.11***	-28.77***	s	-7.71***	-7.43***	-30.36***	I(0)
$m^* - m$	-2.84***	-2.86***	-8.90***	$m^* - m$	-3.23***	-3.17***	-10.01***	I(0)
$y^* - y$	-7.43***	-3.57***	-16.59***	$y^* - y$	-7.35***	-7.00***	-30.08***	I(0)

*, **, *** indicate significance at the 10, 5, and 1 percent levels, respectively; (trend) indicates test allows for both a constant and stationarity around a linear trend.

1. ADF critical values at the 10, 5, and 1 percent critical values are -2.59, -2.91 and -3.56, respectively; when a linear trend is included, the 10, 5, and 1 percent critical values become -3.17, -3.48 and -4.12, respectively.
2. DF-GLS critical values at 10, 5, and 1 percent levels are -1.61, -1.95 and -2.60; with linear trend included, they become -2.86, -3.15 and -3.73 respectively.
3. MZ_{α} critical values at 10, 5, and 1 percent levels are -5.70, -8.10 and -13.81; with linear trend included, they become -14.20, -17.30 and -23.80 respectively
4. H_0 in each case is the null hypothesis of nonstationarity or unit root.

Based on the unit root test results in Table 1, we conclude that all four of the variables, $[x, s, (m^* - m), (y^* - y)]$ are I(1). In this scenario, our long-run model strictly requires cointegration between the integrated variables over our sample. Since these variables are all I(1), in the next subsection, we test for a cointegrating relationship among these four variables. We report cointegrating estimates for the variables in Table 2.

d. Cointegration test results and coefficient estimation

Table 2 reports the Johansen trace and maximum eigen value cointegration tests. The test clearly indicates that the null hypothesis of no cointegration is rejected, suggesting cointegrating relationship for the cross-currency basis and exchange rate, relative money supply and relative real output.

Table 2: Johansen Cointegration tests

No trend					
H_0	Trace Statistic	5% Critical Value	Maximum Eigen Statistic	5% Critical Value	
$r = 0$	57.22***	47.21	37.86***	27.58	
$r \leq 1$	28.25	29.68	19.25	21.13	
$r \leq 2$	11.64	15.41	1.69	14.26	
$r \leq 3$	1.00	3.76	2.82	3.84	
With trend					
H_0	Trace Statistic	5% Critical Value	Maximum Eigen Statistic	5% Critical Value	
$r = 0$	51.14***	54.64	38.82***	32.12	
$r \leq 1$	27.86	34.55	24.92	25.82	
$r \leq 2$	15.35	18.17	10.18	19.38	
$r \leq 3$	5.05	3.74	4.32	12.52	

r denotes the number of cointegrating vectors. The optimal lag lengths for the VARs were selected by minimizing the AIC. At this lag, the VAR produces results that exhibit no serial correlation. *** indicates rejection of the null hypothesis of no-cointegration at 5% level of significance or better.

Table 3 - Estimation of Coefficient of Cointegrating Equation

	DOLS	FMOLS	CCR	Static OLS
s	-2.98*** (2.62)	-1.87*** (2.46)	-1.77*** (2.47)	-1.07** (2.25)
$m^* - m$	-5.11*** (2.56)	-3.39** (2.49)	-3.34*** (2.68)	-2.32*** (3.18)
$y^* - y$	9.44*** (3.21)	7.70*** (3.64)	7.79*** (4.05)	8.32*** (12.16)
R^2	0.75	0.43	0.33	0.52

Figures in brackets are t-statistics. (***) and (**) indicate statistical significance at the 1% and 5% level, respectively. Results are reported in per basis point change in each of the original independent variable so that a 100 basis points change (a percentage change) in the original independent variable will correspond to the reported estimated coefficients multiplied by 100. We specific DOLS (-1, 1).

Table 3 presents the empirical results for the estimation of the coefficients of the regressions, based on the specification in equation (1.7). Overall, a number of stylized features of the data, consistent with our original model, emerge from these regressions. First, there is a positive and strongly significant long-run relation between the cross-currency basis swap spread and relative real output in the euro area, providing support for the existence of a tightening effect of real output increases on the long-end of the euro basis. The magnitudes of the coefficients across the different estimators are remarkably similar and in line with those predicted by the benchmark model. The size of the relative real output effect on the basis is economically and statistically significant: according to the estimated point coefficients, a 10-basis point increase in euro real output relative to the US implies a long-run basis tightening of about 77 to 94 basis points. Second, the relation between cross-currency basis and relative real output is stronger than the relation between cross-currency basis and each of nominal exchange rate and euro area relative money

supply, again confirming the deduction from our simple model. This can be seen to be true across all estimators employed, even across the OLS estimator which is especially the least efficient of all the estimators.

The results also show that there is a significant negative effect of euro depreciation on the cross-currency basis and this result stands for the entire estimators, suggesting that a 10-basis point depreciation of the euro would widen the cross-currency basis by about 11 to 30 basis point in the long run. In fact, the negative relation turns out both statistically and economically very significant. Finally, relative money supply increases are associated with basis spread widening as seen in Table 3, and the relation is economically and statistically significant. A 10-basis point rise in euro money supply relative to the US would widen the euro cross currency basis by about 23 to 51 basis points in the long run.

As a robustness check, we replace the 10-year basis with 5-year basis and re-estimate the model to check whether our main results are robust to the choice of the long end of the euro basis. The result, reported in Table 4, shows that previous findings are unaltered as all effects preserve their previous inclination and remain very significant statistically and economically. Also, the magnitude of the effect of relative real output continues to be greater than the magnitude of relative money supply, exchange rate as well as their sum, suggesting that an increase in relative real output in the euro area is responsible for most of the tightening in the long end of the euro basis in the long run and more than offsets the combined widening pressures from money supply increases and currency depreciations.

Table 4: Robustness with an alternative long end basis – 5-year

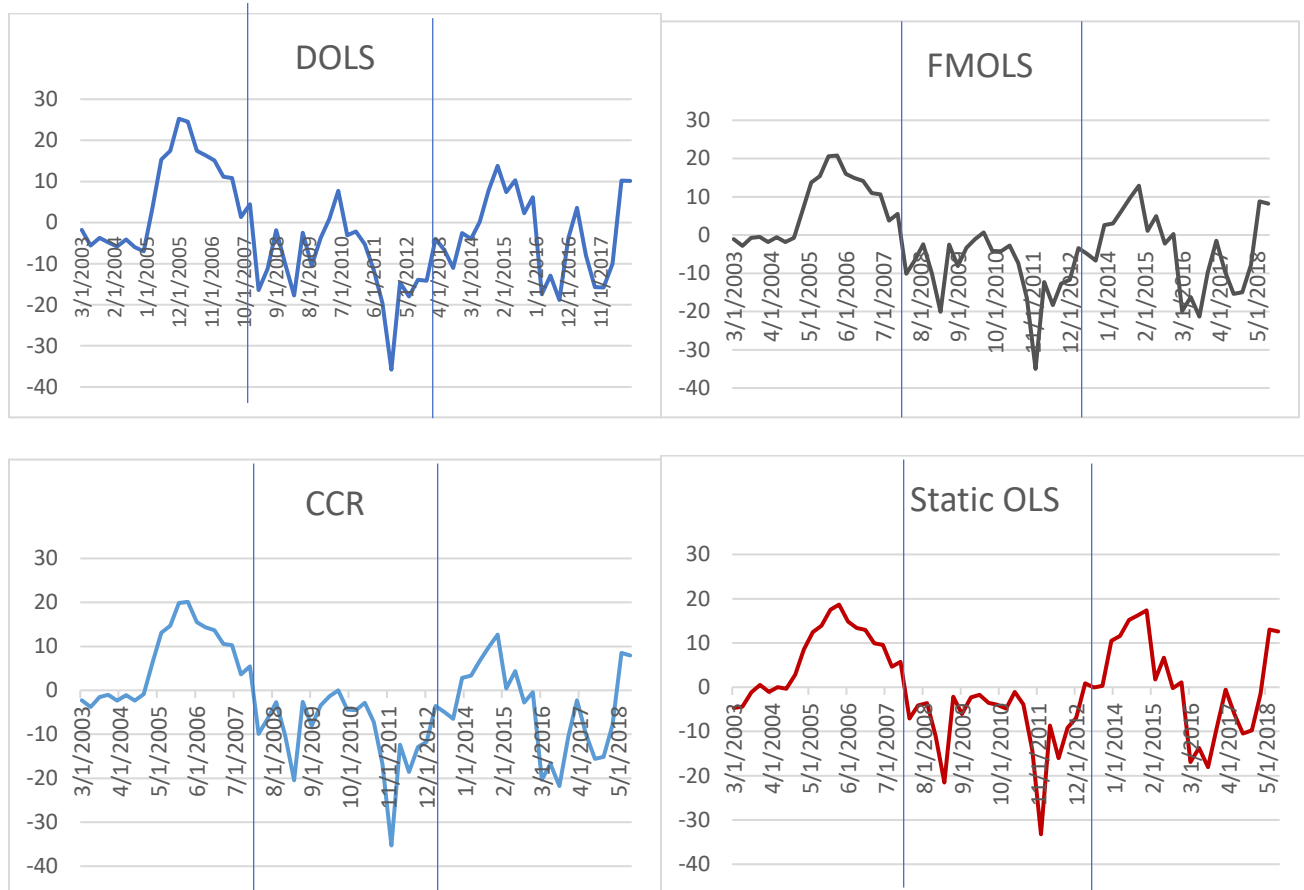
	DOLS	FMOLS	CCR	OLS
<i>s</i>	-3.28*** (3.21)	-1.67** (2.16)	-1.66** (2.14)	-0.97 (1.50)
<i>m* – m</i>	-6.73*** (3.75)	-4.27*** (3.05)	-4.38*** (3.20)	-3.50*** (3.01)
<i>y* – y</i>	10.01*** (3.79)	8.23*** (3.80)	8.40*** (4.24)	9.41*** (5.58)
<i>R</i>²	0.75	0.33	0.33	0.38

Figures in brackets are t-statistics. (***) and (**) indicate statistical significance at the 1% and 5% level, respectively. Results are reported in per basis point change in each of the original independent variable so that a 100 basis points change (a percentage change) in the original independent variable will correspond to the reported estimated coefficients multiplied by 100.

Fig. 2 presents graphs of the euro basis deviations from the level implied by our simple model for the four estimators reported in Table 3. Vertical lines are drawn for the periods Q4 2007 and Q4 2012 to roughly depict different historical regimes in the global financial markets: i) commencement of the global financial crisis and thereafter the euro crisis, and ii) the end of the euro crisis and global financial crisis. The deviations based on each estimator have a strong tendency for mean-reversion as shown in Fig 2. It is also from Fig 2 that the deviations from the level implied by the identified macroeconomic fundamentals can be sizeable. However, except in few instances, they are generally not very persistent. Consequently, it is plausible to detect the long-run relationship between the cross-currency basis and our chosen macroeconomic variables with data inclusive of most period represented in the data.

Note that the period prior to the global financial crisis, particularly the 2004 to the 2006 period, stands out in Fig 2 as a period where the euro cross-currency basis diverges considerably from the underlying macroeconomic fundamentals in our model. The euro cross-currency basis was little and mostly positive during this period, as is widely known in the literature. Also, the deviations tend to be quite substantial and persistent, on average, in this period and towards the end of the eurozone crisis. Because of this, it will be tough attempting to detect the long-run relationship between the cross-currency basis and macroeconomic fundamentals using data from these periods alone.

Fig 2: Deviations of the basis from the long run level implied by our simple model



Note: Vertical lines are drawn for the periods Q4 2007 and Q4 2012 to roughly depict different historical regimes in the global financial markets: i) commencement of the global financial crisis and thereafter the euro crisis, and ii) the end of the euro crisis and global financial crisis

To summarize the results of this section, we find considerable support for the predictions of our simple stylized model of the long-run impact of macroeconomic fundamentals on the euro cross-currency basis swap spreads. Also, Fig. 1 suggests that long data spans, which include substantial periods of negligible and less persistent deviations from the identified macroeconomic factors, will generally be important to successfully detect the long-run equilibrium relationship between macroeconomic variable and the basis implied by our stylized model.

We now provide some views on the process through which the identified macroeconomic factors influence the euro basis in the long run. The tighter basis from increased eurozone real output suggests that in the long run, when eurozone real output improves relative to the US, the eurozone becomes an attractive investment destination which in turn induces demand for euro securities, particularly from US dollar entities. The demand for euro assets from US dollar-based entities – with proceeds hedged into US dollar libor – encourages the issuance of euro denominated bonds which accelerates the issuance of euro liabilities – i.e. reverse yankee bonds – by foreign issuers who subsequently swap the euro liabilities into US dollars.

As demand for euro assets increases, euro spreads tend to shrink, and the basis tightens. From the supply side, this encourages the issuance of euro liabilities as a combination of lower spreads and tighter basis is favourable to euro issuers looking to swap to US dollars as this reduces their funding costs. Although the demand for euro assets stokes issuance of euro denominated bond, our results suggest that in an improving eurozone economy, the issuance of euro denominated bonds tends to fall behind the overall demand for euro assets hedged to dollars. The relatively lower barrier could be driven by barriers to issuance which foreign entities often face. It could also be driven by strategic decisions to limit issuance amid rising demand for euro securities – it is well known, issuers do not respond proportionately to all demand for euro assets. Thus, supply of hedging activities – associated with demand for dollar-hedged euro assets – outstrips demand for hedging activities, associated with issuance of euro liabilities swapped into dollars, consequently tightening the cross-currency basis.

In all, our results reveals that even though tighter cross-currency basis should increase funding activities in the euro area for foreign entities seeking dollars as it becomes cheaper to obtain dollars via euro, if the eurozone real output remains relatively more favourable, then demand for euro assets hedged to dollars would rise at a faster pace than issuance or funding in euro, causing the basis to tighten. This mechanism plausibly explains how an increase in eurozone real output relative to the US can tighten the euro cross-currency basis.

Turning to relative money supply, a rise in eurozone money supply relative to the US, which signals a more accommodative or less restrictive monetary stance in the eurozone, narrows eurozone spreads. This increases/induces an increase in funding activities as foreign issuers increase the issuance of euro liabilities to latch on the lower cost of euro debt. The relative abundance of money in supply attracts the interest of issuers who seek easy access to abundant euro. Euro-based issuers might issue locally to take advantage of the abundant and cheaper euro for onward carry trades and other high-return investments, with proceeds hedged into euro. Foreign issuers whose end currency is the US dollar, would issue with the sole aim of swapping to the final currency of choice, mostly the US dollar. Both activities would elevate demand for hedging activities

As the euro liabilities are swapped to the dollar, this increases the demand for hedging activities and puts a downward pressure on the euro cross-currency basis swap spread. The increased issuance of euro liabilities is not driven by demand for euro securities. Instead, it is driven by the availability and perceived reduction in the cost of euro debt on the back of an accommodative monetary stance which increase money supply.

Since the supply of hedging activities, i.e. demand for euro assets hedged to dollars, becomes limited, this creates an imbalance wherein demand for hedging dominates supply of hedging. The demand for euro assets hedged to dollars, and hence supply of hedging activities, shrinks because the loose monetary stance generally makes it unattractive for US dollar-based investors to demand or hold euro assets hedged into dollar libor. This lowers their demand for euro securities as they seek better returns elsewhere. In this instance, the imbalance tilts towards a much higher demand for hedging activities from the euro liability issuers relative to the supply of hedging activities from US dollar-based holders of euro assets. Consequently, the euro cross-currency basis widens.

If the euro basis widens considerably, this may increase the funding cost associated with swapping euro into dollars which, all else unchanged, should limit the issuing and swapping of the euro and possibly stabilize or even tighten the basis. However, if the relative money supply continues to rise, credit spreads would tighten further, issuers would remain attracted to funding via the euro, and the euro basis would continue to widen.

Moving now to the exchange rate, the result is in line with the view that an appreciation of the dollar is associated with a wider cross-currency basis. Viewed from the perspective of supply of hedging activities (that is, the demand for foreign assets), Avdjiev et al. (2017) argues that the US dollar serves as a risk barometer, "... the dollar is a key barometer of risk-taking capacity in global capital markets". A stronger dollar reduces cross-border lending in dollars as the risk of lending in dollars increases when the dollar strengthens relative to foreign currencies. This is because a stronger dollar means foreign, non-dollar, entities become more burdened and could fail to meet maturing dollar obligations; the dollar obligations become elevated in foreign currency terms even when the value of the obligations in dollars remains unchanged. This reduces cross-border dollar lending and hence reduces demand for euro securities, lowering supply of hedging activities.

From the issuance side, because of the appreciation of the dollar, more euro liabilities would need to be issued and dollar-swapped to get the same amount of dollars. This increases the issuance of euro denominated bonds and puts upward pressure on demand for hedging activities. In this scenario, demand for hedging dominates supply of hedging as there are more euro liabilities being created (to be swapped for the same amount of dollars) than assets being demanded (given lower dollar inflows and lower cross-border lending in dollars), resulting in lower demand for euro assets from US dollar investors and consequently widens the euro basis.

V. Convergence to Long Run- Error-correction Mechanism

In this section, we seek to gain insight into how the long-run equilibrium is restored between the basis and the identified macroeconomic variables by estimating vector error-correction models. By the Granger representation theorem, the residual from the cointegration equation must forecast changes in at least one of the four variables x , s , $(m^* - m)$, $(y^* - y)$. For instance, if the residual is positive (the basis is tighter than its long-run value), either the basis must widen or one of the macroeconomic factors must shift in order to drive the relation back to its long-

run value. Accordingly, by inspecting the error correction mechanism (ECM), insight is gained into which variables endogenously adjust to ensure convergence to the long-run relation.

Table 5: Error correction coefficients (ECM) estimate

	(1)	(2)	(3)	(4)
A. 10-year basis				
	x	s	$m^* - m$	$y^* - y$
ECM	-0.1382*	-0.0002	0.0001	0.0001***
	(1.78)	(1.13)	(1.10)	(4.29)
R²	0.05	0.04	0.11	0.32
B. 5-year basis				
	x	s	$m^* - m$	$y^* - y$
ECM	-0.1377*	-0.0002	0.0001*	0.0001***
	(1.71)	(1.11)	(1.73)	(4.54)
R²	0.05	0.04	0.14	0.34

Note: *, **, *** indicate significance at the 10, 5, and 1 percent levels, respectively. A. is based on the 10-year basis and B. the 5 year basis

Table 5 reports the dynamic impact of the error correction term on the changes of each of the variables in the cointegrated vector. We can see that for both the 5-year and 10-year basis, which are our measures for the long-end of the euro basis, it is the euro basis that is the only predominant adjusting variable. In both cases, the error-correction coefficient is negative and significant while for the other variables, the coefficients are mostly insignificant. This implies that the macroeconomic variables are weakly exogeneous for the euro and when deviations from the implied long-run equilibrium occur in the Eurozone, it is predominantly the basis, and not the macroeconomic factors, that adjusts to restore long-run equilibrium over our sample period. In both cases, the speed of adjustment implies a half-life for basis swap equilibrium misalignments of about 5 quarters, meaning that it should take around 5 quarters for one half of shifts away from the equilibrium implied by our model to be restored. With respect to the other variables, the ECM variable has no explanatory power for the dynamics of the relative money supply and exchange rate positions, and actually has a positive sign in relative money supply and real output equation. Overall, the similar adjustment mechanisms at work for both tenors over the last decade reflect robustness of our findings for the long-end of the euro basis.

VI. Dynamic Interdependencies using Vector Autoregressions

After establishing the long-run relationship between the euro basis and exchange rate, relative real output and relative money supply, we now turn to the last part of our analysis where we investigate the dynamic interdependencies between the euro basis and each of the identified drivers. Thus, in this section, we want to study the effects of exchange rate shocks, money supply shocks and real output shocks on the cross-currency basis swap spread. We do not impose any specific restrictions in our VAR. Instead, we allow the variables to speak for themselves. We consider different orderings of our variables in a generalized impulse response (GIRF) framework which yields results invariant to the chosen ordering. One major merit of the GIRF is that it generates unique impulse responses and singles out shocks without resorting to restrictive identifying restrictions.

In order to explore the dynamic interdependencies between the basis and the main variables of interest, we estimate a 4-variable VAR for $Z_t = [\Delta x_t, \Delta s_t, \Delta(y_t^* - y_t), \Delta(m_t^* - m_t)]'$, specified as

$$A_0 Z_t = B(L)Z_{t-1} + CX_t + u_t \quad (1.8)$$

where Z_t is a 4-variable vector of our endogenous variables, where the endogenous variables are as previously defined, A_0 is the matrix of contemporaneous coefficients, $B(L)$ is a polynomial of lagged coefficients, X_t is a vector with intercepts and linear trends, and u_t is a vector of structural innovations.

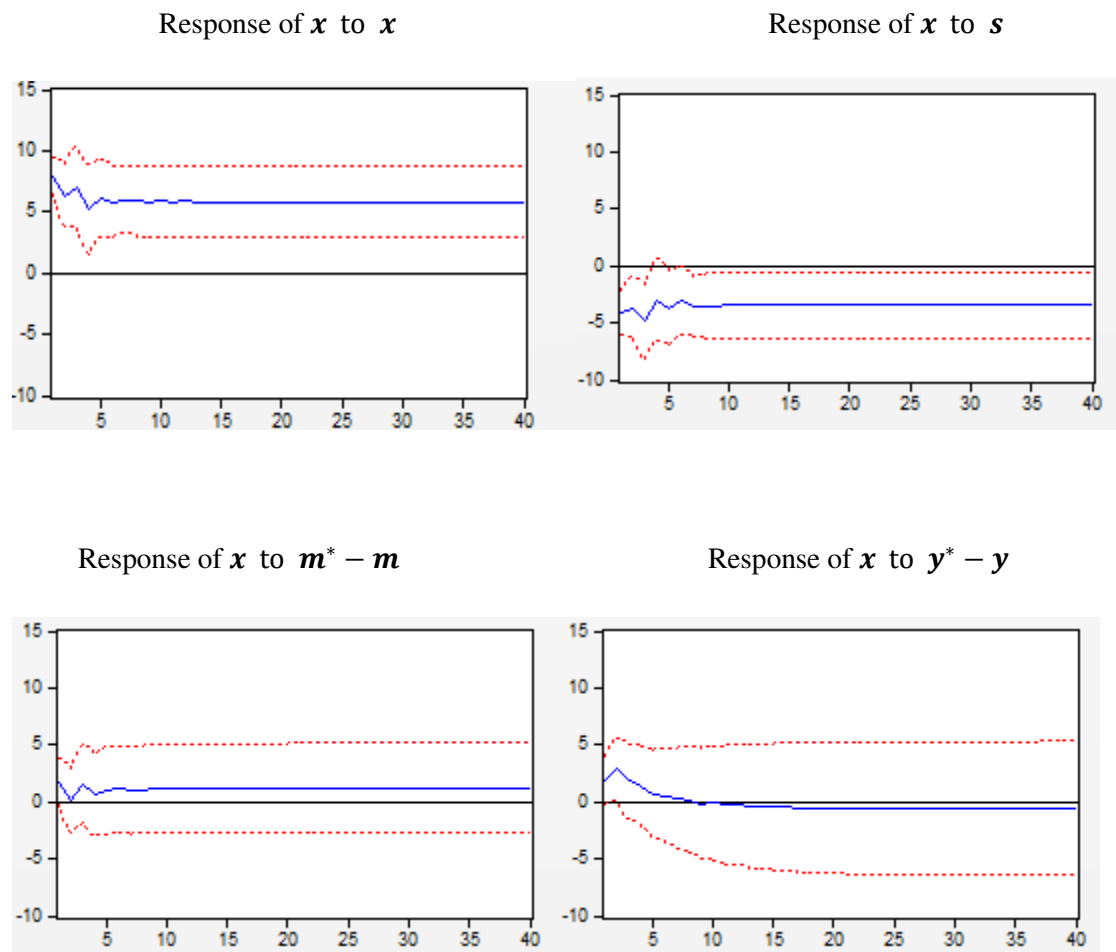
Pre-multiplying by A_0^{-1} gives the model in reduced form as

$$Z_t = J(L)Z_{t-1} + KX_t + v_t \quad (1.9)$$

where $J(L) = A_0^{-1}B(L)$, $K = A_0^{-1}C$, $v_t = A_0^{-1}u_t$

Figure 5 reports the cumulative response for a one-time shock to changes in exchange rate, relative real output and relative money supply. In general, the impulse responses are quantitatively different. Figure 5 displays the cumulative impulse responses from our 4-variable specification and shows the effect of a positive shock to exchange rate, interpreted as a stronger dollar or weaker euro, widens the basis. The cumulative impulse response function plots the accumulation of the impact of the shock to our variables across time, unlike the impulse response function which provides the impact of a shock at a single point in time. We concentrate on the dynamics of the shocks to the macroeconomic variables on the basis.

Figure 5: Cumulative impulse response functions of EUR/USD cross-currency basis spread (x) to a shock in US dollar exchange rate (s), relative money supply ($m^* - m$) and relative real output ($y^* - y$)



The top left graph shows that the basis is positively affected by a one standard deviation shock of itself upon impact. It tightens on impact. As time progresses, the basis continues to be positively affected by this one-time shock on itself. The top right graph shows that the basis is negatively affected by a one standard deviation exchange rate shock upon impact, and as time goes on the basis continues to be negatively affected by the shock. The responses show that the exchange rate has a persistently negative and significant impact on the basis on impact and these negative dynamics accumulate over time. This result is robust to alternative ordering of the variables estimated by the generalized impulse response. The estimated negative impact is visible and remains significant for several quarters after the occurrence of the shock. The bottom left, and right graphs show the effect on the basis of a shock to relative real output and money supply, respectively. The real output shock positively affects the basis and this benefit is marginal, quickly levels off about 6 quarters after the shock and largely unchanged over time. The money supply shock initially relates positively with the basis on impact until after 6 quarters when the effect turns negative and over time

continually remains in the negative. Both money supply and real output shocks have a statistically negligible effect on the basis even on impact.

In all, we have shown that the exchange rate shock decreases the basis permanently while shocks to real output increases the basis. We also see that the basis first increases in response to a money supply shock but falls below zero, eventually decreasing the basis over time. In general, a shock to the exchange rate tends to produce a higher, significant and more persistent negative effect on the basis than a shock to either of the other variables. These results are largely robust to alternative ordering of the variables and the inclusion a deterministic time trend. In general, the generalized impulse responses, which we employed, are invariant to the order of the variables in the VAR system. Our main conclusion in this exercise on the dynamic interdependencies is that that irrespective of the component, the response of the basis due to exchange rate shocks is more significant and persistent than those caused by real output or money supply shocks and factors driving fluctuations are potentially largely external. Juxtaposing with the long run evidence, our result proposes that while exchange rate has the least effect on the long-end of the euro basis in the long run, the basis effects of exchange rate shocks in the short run appear to be more persistent and relatively more pronounced.

VI. Relation to other studies

Although to our knowledge, there are no studies that have specifically addressed the links between our identified macroeconomic variables and the cross-currency basis in a major monetary union such as the eurozone, we would attempt to make a comparison of our findings with those obtained by the few related studies available.

Using a collection of G10 countries, Avdjiev et al. (2017) estimated a panel regression of the cross-currency basis on the dollar exchange rate, with the variables expressed as changes in levels over the sample period. They obtained a strong evidence of a wider basis when the dollar appreciates, with a significantly negative coefficient across most currencies. In this paper, we have estimated the long-run links not only between exchange rate and cross-currency basis for a longer span but also, we have done this in the presence of plausible macroeconomic drivers of the basis. This enables us to control, as suggested by our theoretical model, for the effects of relative money supply and relative real output. This is important, especially in view of the links between these variables and the exchange rate, the strong and significant effect of relative money supply and relative real output on the euro basis at the long end, and the fact that dollar exchange rate is not necessarily the only important driver for the basis in the long run. This is relevant as it enables us to obtain the effect of each variable on the cross-currency basis whilst controlling for the presence of the other variables. We found the effect of relative real output on the basis to be much stronger, and the effect of relative money supply and exchange rate to be much weaker in our framework

With respect to long-run cointegrating relation, Baran and Whitzany (2017) estimates the long-run drivers of the euro cross-currency basis, including in their cointegrating vector the exchange rate, measures of credit risk, volatility index and credit spreads. They find that the cross-currency basis tends to be tighter in the long run when the euro strengthens relative to the dollar. However, their study excludes standard macroeconomic variables as have been considered in this paper and are difficult to interpret comparatively given the discrepancy in the unit of measures for

the variables included in their cointegrating vectors as potential drivers of the basis. Du et al. (2017) estimate the effect of regulation on cross-currency basis and find that the more stringent regulation that followed the crisis explains why the cross-currency basis has persisted, and CIP deviations have not been arbitrated away. The key issue in these studies is the complete neglect of the effects of other plausible macroeconomic factors on the cross-currency basis. Moreover, ignoring these factors have possibly been responsible for the often-low explanatory power of the drivers of the basis advanced so far in the literature.

Our paper is the first that directly studies the long-run relationship between the euro cross-currency basis and standard macroeconomic variables in the eurozone. The only other paper that we are aware of, that specifically studies the long-run drivers of the euro basis, is Baran and Whitzany (2017). However, their framework is purely empirical, focuses on the short to mid end of the euro basis and does not provide a theoretical motivation. We present instead a new empirical evidence motivated by a simple theoretical framework which enables us to directly test the implications of our hypothesis without losing much degree of freedom in an environment of limited data, as that would be the case if we aimlessly handpicked regressors as potential drivers of the basis. In a recent work, Ibhagui (2018) derives a model based on the standard monetary model. This paper, which focuses on the eurozone, rather than on a panel of countries like Ibhagui (2018), draws from that model as a benchmark to investigate the significance of the identified macroeconomic factors for the euro basis in the long run. Thus, our results are specific to the eurozone and we make no claim that they extend to other countries or currencies given the heterogeneity among countries, even those with developed financial markets.

Finally, this paper has investigated long-run relations between the basis and macroeconomic factors, with a focus on the eurozone. Our promising results suggest directions for future research. Thus, our next line of action would be to extend this country specific research to include other G10 currencies and the broader emerging markets even as we also seek to analyze the short run dynamic linkages between the basis and their associated macroeconomic drivers. In countries for which there is support for our model, it would be interesting to compare the similarity of the support to the eurozone and to examine the dynamics of the adjustment process to the long-run equilibrium relation implied by the model by studying metrics such as the panel impulse responses and variance decompositions for the cross-currency basis and macroeconomic fundamentals in these countries. It would also be interesting to undertake a research to build a dynamic stochastic general equilibrium (DSGE) model that can replicate the dynamics of these variables and extend this line of research to emerging market economies. However, the task could be complicated by patchy data as the derivatives markets of some of these EM economies are much less developed. This paper has taken the U.S. as the numeraire. Future research could utilize other major countries variables or even the eurozone as the numeraire and investigate whether our model has support as a long-run anchor for characterizing the cross-currency basis. Finally, it is plausible that the divergence of the basis from the identified underlying macroeconomic factors could exhibit nonlinearity in reversion to mean. Thus, issues pertaining to exploring this possibility for the euro zone and other countries for which we find support for our model have major relevance for derivatives policy makers and rank high in the priority list for future research efforts in untangling the long-run macroeconomic anchors for the cross-currency basis.

VII. Conclusion

Among major economies, the EUR/USD cross-currency swap market stands out as the largest cross-currency swap market, accounting for around 46% of market volumes. Expectedly, there is a growing literature which so far has focused on studying the characteristics and market drivers of the euro basis. However, very little has been done to assess the significance of economic factors as potential long-run drivers of the euro basis – that is, to assess whether and how eurozone economic conditions influence the euro basis in the long run. The potential long run relationship between eurozone macroeconomic variables and the euro cross-currency basis, especially at the long end of the euro basis which is the most active, is thus a major unanswered question in the literature since the emergence of CIP deviations.

In this paper we have presented evidence for a long-run relationship between the euro basis at the long end and the eurozone macroeconomic variables. First, our result suggests that eurozone relative real output has a positive and pronounced effect on the euro basis. This means that when the eurozone real output relative to US real output increases, the euro basis tends to tighten. Second, we find that exchange rate and relative money supply have important and economically significant effects on the euro basis in the long-run relation. Increases in relative money supply and euro depreciation both widen the euro basis. Furthermore, we show that the magnitude of the effect of relative real output on the euro cross-currency basis dominates the combined effect of exchange rate and relative money supply, so that a tightening of the basis from an increase in relative real output in the eurozone can considerably offset the effect of a wider basis from exchange rate depreciation and money supply increases. We also find that when there is a divergence from the estimated equilibrium relationship, it is predominantly the cross-currency basis that adjust to ensure a return to equilibrium.

Finally, using accumulated impulse response, we show that shocks to the exchange rate which depreciate the euro and strengthen the US dollar have permanent effects on the euro basis. On the whole, although our theoretical framework is quite stylized, our result suggests that any theoretical or empirical model investigating the dynamics and drivers of the cross-currency basis ought to incorporate features that allow for the effects of macroeconomic factors. An exclusive focus on the dollar exchange rate as the key driver of the basis is unsatisfactory and may not fully capture the evolution of the basis in the long run.

Regarding financial market policy, the existence of a long-run relation between relative real output, exchange rate, relative money supply and cross-currency basis suggests that a sustainable increase in euro real output position relative to the US will eventually trigger a tighter cross-currency basis, with the magnitude of tightening dominating the inevitable occurrence of a widening emanating from exchange rate depreciation and rises in money supply. Thus, policies that considerably stoke real output in the eurozone will eventually put a floor on the widening of the euro basis in the long end and hence limit CIP deviations.

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