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US and EA yield curve persistence during the COVID-19 pandemic

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ABSTRACT

This paper investigates changes in persistence caused by the COVID-19 pandemic in the US and EA yield curves. We extract the long-term, short-term and medium-term factors and proxy the persistence by estimating the autoregressive coefficient of each factor. To examine the time-varying effects, we employ a local linear estimation. Our findings suggest that, during the first phases of the pandemic, the US long-term and short-term factors exhibited explosive behaviour while, at the same time, the EA factors diminished in persistence, making the EA yield curve more predictable even though the EA countries were hit by the pandemic somewhat earlier than the US.

1. Introduction

An increasing volume of studies has attempted to shed light on the effects of the recent COVID-19 pandemic in the economic and financial systems. Most studies focus on stock market reactions, liquidity, volatility, policy and cryptocurrencies. It is beyond our scope to provide an in-depth review but see some indicative references such as Li et al. (2020), Caferra and Vidal-Thomás (2021), and Xu (2021), among many others, for an introduction to this literature.

In contrast, little attention has been paid to the reaction of yield curves during the COVID-19 pandemic. We shed light in this area by investigating the change in persistence in the long-term, short-term and medium-term factors of the US and Euro Area (EA) yield curves. Our contribution is threefold. First, we investigate the yield curves’ behaviour, employing the Diebold and Li (2006) framework, and thus start a new topic which extends the COVID-19 discussion on the fixed-income literature. Second, in an effort to estimate the time-varying change in persistence of the yield curve factors, we apply the local linear framework of Cai (2007); to the best of our knowledge, this is the first time that a time-varying kernel-based framework has been used to examine the yield curve persistence. Our third contribution is to provide a comparative analysis of the US and EA yield curves and highlight common facts and differences.

Our empirical evidence suggests that there are differences in the persistence of the factors during the pandemic which, in turn,
affect the predictability of the curves. For both the US and the EA, we observe a decline in persistence towards the end of 2019, making the yield curve factors and, therefore, the yield curves more predictable. However, during the pandemic, the US long-term and short-term yield curve factors have presented evidence of explosive behaviour. In contrast, the EA yield curve factors have shown less persistence, making the EA yield curve more predictable even if the EA countries, e.g., Italy, had to enter a lockdown earlier than the US did.

What does our analysis imply for the fixed-income investor? In a nutshell, our evidence suggests that, since a yield curve becomes

Fig. 1. US and EA yield curves (daily frequency). All maturities are expressed in months. Dashed lines indicate the 2020-01-02 and 2020-04-30 dates (Incubation to Rebound COVID-19 pandemic phases).
unpredictable for a specific period of time, the investor should consider hedging. This can be done by diversifying across other asset classes (e.g., commodities, equities, or even cryptocurrencies) or, as our results show, across other government securities. In our case, a US Treasury investor could benefit by hedging with EA fixed-income securities since the EA curve is less persistent during the COVID-19 turbulent times.

The paper is organised as follows. Section 2 discusses the data, descriptive statistics and the phases of the pandemic. Section 3 compares the US and EA yield curve factors. Section 4 discusses the time-varying effects in the persistence of these factors. Finally, Section 5 presents the concluding remarks. Our Online Appendix offers additional results.

2. Data & descriptive statistics

Our sample consists of yields for maturities of 1- to 30-year zero-coupon bonds (expressed in months, i.e. 12 to 360 months). We use the zero-coupon spot rates as provided by the Federal Reserve Board (FED) and the European Central Bank (ECB) for the US and EA cases respectively.\(^2\) We collect daily data from 2019-01-02 to 2021-01-29 (\(T = 520\)) and 2019-01-01 to 2021-02-05 (\(T = 549\)) for the US and EA respectively.

Following Ramelli and Wagner (2020) and Capelle-Blancard and Desroziers (2020), we define the following pandemic phases: (i) Incubation (from 2020-01-02 to 2020-01-17) which includes the first announcements in Wuhan and the closing of the Seafood Wholesale Market, (ii) Outbreak (from 2020-01-20 to 2020-02-21) when the Chinese authorities confirmed the transmission of the virus and WHO published its first report, (iii) Fever (from 2020-02-24 to 2020-03-20) with the first lockdown in Italy, and (iv) Rebound (from 2020-03-23 to 2020-04-30) with the FED intervention and the stock market rebound.

Figure 1 provides an illustration of the two curves across time and maturities. The red dashed lines indicate the beginning of the Incubation (2020-01-20) phase and the end of the Rebound (2020-04-30) phase. We can already notice the difference in the behaviour of the two curves. During the pandemic, the level in the US decreases and the slope increases. However, only the slope seems to be more affected in the EA curve.

Table 1 presents the descriptive statistics for all observed rates. The only similarity is in the sample means. The average yield increases at longer maturities, for both curves, reflecting the premium associated with the maturity risk. However, (i) negative rates exist for the EA and non-zero rates exist for the US, (ii) short-term yields are more volatile than long-term yields for the US (std. dev. is 0.943 for the 12-month yield and it increases to 0.576 for the 30-year yield) but the opposite is true for the EA (std. dev. is 0.132 for the 12-month yield and it increases to 0.488 for the 30-year yield), (iii) US yields, in general, are more persistent than EA yields (note that, across maturities, the autocorrelation coefficient from lag 1 to lag 100 decreases from about 0.99 to 0.37 for the US, whereas for lag 100 the short-term and medium-term yields for the EA have an autocorrelation which is close to zero), and (iv) short-term yields are more persistent in the US (autocorrelation declines as the maturity increases) whereas the opposite is true for the EA (autocorrelation increases as we move to longer maturities).

The above details provide a clear overview of the underlying dynamics affecting the two curves. To name a few, consider the road to the national elections and Trump administration in the US, and the Brexit discussions in the EA. However, we see a convergence towards the end of the period under investigation. It is therefore important to investigate and compare how each yield curve reacted during the COVID-19 outbreak.

3. Yield curve factors

To examine the reaction of the yield curves to the COVID-19 effects, we extract the long-term, short-term and medium-term yield curve factors following Diebold and Li (2006); which are an “incarnation” of the Nelson-Siegel factors. In particular, we have:

\[
y_i(\tau) = \hat{\beta}_{1t} + \hat{\beta}_{2t} \left( \frac{1 - e^{-\lambda_1 \tau}}{\lambda_1 \tau} \right) + \hat{\beta}_{3t} \left( \frac{1 - e^{-\lambda_2 \tau}}{\lambda_2 \tau} - e^{-\lambda_1 \tau} \right),
\]

(1)

where \(y_i(\tau)\) is the yield of the bond with maturity \(\tau\) at time \(t\) for \(t = 1, 2, ..., T\). \(\hat{\beta}_{1t}, \hat{\beta}_{2t}, \hat{\beta}_{3t}\) and \(\lambda_1, \lambda_2\) are the three latent curve factors and \(\lambda_1\) controls for the exponential decay. Small values for \(\lambda_1\) provide a better fit for the curve at long maturities, whereas large values provide a better fit at short maturities. The three latent factors can be viewed as the long-term, short-term and medium-term factors and can be interpreted as proxies for the level, slope and curvature of the yield curve (see Diebold and Li (2006) for more details). For each observed day, \(t\), we estimate the vector of parameters by applying nonlinear least squares.\(^3\)

Figures 2 and 3 illustrate the estimated time series for the four parameters, i.e. \(\hat{\beta}_{1t}, \hat{\beta}_{2t}, \hat{\beta}_{3t}\) and \(\lambda_1\). The red dashed lines correspond to the beginning of the Incubation phase (2020-01-20) and the end of the Rebound phase (2020-04-30). We can already observe important differences between the US and EA yield curves.

The long-term factor for the US, \(\hat{\beta}_{1t}\), starts to decline in 2020 and spikes during the Fever phase, whereas it remains at a high level during the Rebound.

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1. We use all government yields, not only the AAA-rated ones.
2. See Díaz et al. (2019) for details of the FED methodology for zero-coupon yields.
3. Diebold and Li (2006) use an easier solution, fixing \(\lambda_1\) at a pre-specified value, such that the loading on the medium-term factor achieves its maximum, i.e. \(\lambda_1 = \lambda = 0.0609\), and then applying OLS. We choose to adopt a more data-dependent approach by optimising the whole vector of parameters on each day.
Table 1: Descriptive statistics for US and EA bond yields at different maturities (daily frequency). $\hat{\rho}(k)$ denotes the autocorrelation coefficient at lag $k$. All maturities are expressed in months. US Sample: 2019-01-02 to 2021-01-29 ($T = 520$). EA Sample: 2019-01-01 to 2021-02-05 ($T = 549$).

| Maturity | US Mean | Std. Dev. | Min. | Max. | $\hat{\rho}(1)$ | $\hat{\rho}(10)$ | $\hat{\rho}(20)$ | $\hat{\rho}(50)$ | $\hat{\rho}(100)$ |
|----------|---------|-----------|------|------|----------------|-----------------|-----------------|----------------|----------------|
| 12       | 1.194   | 0.943     | 0.095| 2.596| 0.967          | 0.906           | 0.740           | 0.454          | -0.424         |
| 24       | 1.149   | 0.900     | 0.108| 2.591| 0.966          | 0.902           | 0.726           | 0.427          | -0.358         |
| 36       | 1.155   | 0.864     | 0.127| 2.600| 0.955          | 0.900           | 0.719           | 0.414          | -0.295         |
| 48       | 1.189   | 0.834     | 0.169| 2.615| 0.955          | 0.900           | 0.717           | 0.406          | -0.230         |
| 60       | 1.237   | 0.807     | 0.222| 2.635| 0.952          | 0.900           | 0.715           | 0.402          | -0.160         |
| 72       | 1.291   | 0.783     | 0.281| 2.659| 0.951          | 0.900           | 0.714           | 0.397          | -0.086         |
| 84       | 1.348   | 0.763     | 0.341| 2.685| 0.951          | 0.900           | 0.712           | 0.392          | -0.008         |
| 96       | 1.405   | 0.745     | 0.402| 2.713| 0.951          | 0.899           | 0.710           | 0.387          | 0.071          |
| 108      | 1.461   | 0.729     | 0.462| 2.741| 0.950          | 0.898           | 0.707           | 0.382          | 0.150          |
| 120      | 1.514   | 0.715     | 0.520| 2.770| 0.949          | 0.897           | 0.704           | 0.377          | 0.228          |
| 132      | 1.566   | 0.702     | 0.577| 2.798| 0.948          | 0.895           | 0.700           | 0.373          | 0.305          |
| 144      | 1.615   | 0.690     | 0.632| 2.826| 0.948          | 0.894           | 0.697           | 0.369          | 0.380          |
| 156      | 1.662   | 0.679     | 0.686| 2.857| 0.947          | 0.892           | 0.694           | 0.366          | 0.451          |
| 168      | 1.707   | 0.668     | 0.738| 2.889| 0.946          | 0.891           | 0.691           | 0.363          | 0.519          |
| 180      | 1.750   | 0.659     | 0.782| 2.919| 0.946          | 0.889           | 0.689           | 0.362          | 0.584          |
| 192      | 1.791   | 0.649     | 0.817| 2.947| 0.945          | 0.888           | 0.687           | 0.361          | 0.645          |
| 204      | 1.830   | 0.641     | 0.853| 2.975| 0.945          | 0.887           | 0.685           | 0.361          | 0.702          |
| 216      | 1.868   | 0.633     | 0.888| 3.001| 0.944          | 0.886           | 0.683           | 0.361          | 0.756          |
| 228      | 1.904   | 0.625     | 0.924| 3.026| 0.944          | 0.885           | 0.682           | 0.362          | 0.807          |
| 240      | 1.938   | 0.618     | 0.958| 3.050| 0.943          | 0.885           | 0.682           | 0.363          | 0.855          |
| 252      | 1.971   | 0.612     | 0.992| 3.073| 0.943          | 0.884           | 0.681           | 0.365          | 0.900          |
| 264      | 2.003   | 0.606     | 1.025| 3.096| 0.943          | 0.883           | 0.681           | 0.367          | 0.942          |
| 276      | 2.034   | 0.600     | 1.057| 3.117| 0.942          | 0.883           | 0.681           | 0.369          | 0.981          |
| 288      | 2.063   | 0.595     | 1.088| 3.138| 0.942          | 0.882           | 0.681           | 0.370          | 1.018          |
| 300      | 2.092   | 0.591     | 1.117| 3.158| 0.941          | 0.882           | 0.682           | 0.372          | 1.052          |
| 312      | 2.119   | 0.587     | 1.146| 3.178| 0.941          | 0.882           | 0.683           | 0.374          | 1.084          |
| 324      | 2.145   | 0.583     | 1.174| 3.198| 0.940          | 0.881           | 0.683           | 0.376          | 1.115          |
| 336      | 2.171   | 0.580     | 1.200| 3.216| 0.940          | 0.881           | 0.684           | 0.377          | 1.143          |
| 348      | 2.196   | 0.578     | 1.226| 3.235| 0.939          | 0.880           | 0.685           | 0.378          | 1.170          |
| 360      | 2.219   | 0.576     | 1.250| 3.253| 0.939          | 0.880           | 0.686           | 0.379          | 1.195          |
before declining during the Fever and Rebound phases for the EA. The short-term factor, $\hat{\beta}_{2t}$, is inversely proportional when we compare the two curves: it declines for the US during the four pandemic phases whereas it increases, at the same time, for the EA. Finally, a similar effect is observed for the medium-term factor of both curves, $\hat{\beta}_{3t}$, which declines in the first half of the pandemic and then increases.

Diebold and Li (2006) forecast the yield curve in two steps: (i) they model the latent factors and obtain forecasts for each factor separately, and (ii) using these estimates, construct the forecast for the yield curve. It is obvious that if the factors follow a unit root, then they are unpredictable and, therefore, the best model will be naïve forecasting. However, if the persistence in the time series of these factors declines, it will make the time series covariance stationary, and, in that sense, more predictable.

On this basis, how does the persistence of the yield curve factors change before and during the pandemic? Is there a period where these factors are more predictable? Are there periods in which these series become strongly persistent or even explosive? These questions are of particular importance to the fixed-income investor who will need to form investment decisions based on the most accurate yield curve forecasts. We attempt to provide empirical evidence to answer the above questions with the time-varying framework that we employ below.

4. The effects of COVID-19 pandemic on the persistence of yield curve factors

Diebold and Li (2006) attempt to capture the underlying dynamics of each yield curve factor employing a first order autoregressive model, AR(1). Our aim is to use the estimated autoregressive coefficient to proxy the persistence in each factor and, thus, indirectly proxy the persistence of the yield curve.

We extend Diebold and Li (2006) employing a time-varying (TV) framework which allows us to investigate how the autoregressive coefficient changes across time; particularly before and during the pandemic. This allows us to understand how the persistence in each curve changes and, therefore, how predictable each curve is; or, in particular, how predictable each long-term, short-term and medium-term part of each curve is. The model is given by:

$$x_t = \phi_0 t + \phi_1 x_{t-1} + \epsilon_t,$$

with $t = 1, 2, \ldots, T$ and is estimated using the local linear approach with $\epsilon_t$ satisfying the standard assumptions. This methodology fits

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4 This is indeed the conclusion in Diebold and Li (2006) for short-term horizons, e.g., one-step ahead.

5 See Cai (2007) for a detailed discussion on assumptions and estimation and Casas and Fernández-Casal (2019) for an implementation in R. See also Giraitis et al. (2014) for details on time-varying autoregressive models.
a set of weighted local regressions with a chosen window size. The windows look “both ways”; i.e. at time $t$, we estimate the parameters using the observations before and after $t$ with the appropriate weighting. The size of these windows and the weighting are controlled by the bandwidth parameter $b$ and the selected kernel function. In our calculations for both US and EA yield curves, we use the Epanechnikov Kernel with $b = 0.05$ bandwidth and construct the 95% wild bootstrap confidence intervals.

Figures 4–6 present the time-varying estimation of the autoregressive coefficient for the yield curve factors for the US and EA curves. The red vertical dashed lines indicate the pandemic phases and correspond to 2020-01-02, 2020-02-21, 2020-03-20 and 2020-04-30, which mark the beginning of the Incubation, the end of the Outbreak, the end of the Fever and the end of the Rebound phases respectively.

As expected, in Fig. 4 we see that the persistence of the long-term factor for the US remains relatively stable during 2019, indicating that the factor is close to a unit root. Towards the end of 2019, there is a gradual decline in the persistence since the autoregressive coefficient changes from about 1 to about 0.5. It fluctuates around this level during the end of 2019 and until the beginning of the Incubation in 2020. This drop in persistence and, therefore, the change of $\hat{\beta}_{1t}$ from the unit root boundaries to weak stationarity indicates a change in the underlying dynamics, making the long-term factor more predictable during this period. It remains at around this level in 2020 but suddenly increases to about 1.5 towards the end of the Outbreak phase indicating explosive behaviour. Then it returns to the unit root stability levels, as in the pre-pandemic, 2019, period.

At the same time, the autoregressive coefficient for the long-term yield curve factor for the EA exhibits a different behaviour. We observe a more “cyclical” pattern in the persistence during 2019, which, however, is not stable at the unit root region, indicating that the long-term factor of the EA curve is generally more predictable. As we enter the COVID-19 Incubation and Outbreak phases, the persistence in the long-term factor gradually declines and remains around 0.5 during the Rebound phase. This is totally different from its behaviour in the US, indicating that the long-term factor for the EA yield curve is more predictable and less affected by COVID-19, even though Italy and other EA countries entered lockdown earlier than the US did.

A similar conclusion holds for the short-term factors as seen in Fig. 5. For the US we again have a decline in persistence towards the end of 2019, a gradual increase during the first two phases of the pandemic with a period of explosive behaviour and a return to the
Fig. 4. Time-Varying AR(1) estimation for the US and EA long-term yield curve factor, $\hat{\beta}_{1t}$. Red dashed lines correspond to 2020-01-02, 2020-02-21, 2020-03-20 and 2020-04-30. They mark the beginning of the Incubation phase, the end of the Outbreak phase, the end of the Fever phase and the end of the Rebound phase during the COVID-19 pandemic respectively. Light blue lines indicate the 95% wild bootstrap confidence intervals.
pre-pandemic unit root levels in the last two phases of the pandemic and the whole of 2020. Instead, the short-term factor of the EA curve gradually loses persistence from the beginning of 2020 until the middle of the year, when its intervals include the unit root boundaries. Therefore, this evidence again suggests that the short-term factor for the EA curve is more predictable than that of the US. This is partially surprising as one would have expected to observe explosive behaviour, at least, during the Fever phase of the pandemic with Italy’s lockdown and the dramatic death toll in EA countries, e.g., Italy and Spain.

Finally, Fig. 6 presents the time-varying estimation of the autoregressive coefficient for the medium-term factor. For both curves, the persistence of the medium-term factor goes down towards the last quarter of 2019. Next, it gradually increases for the EA during the first two phases, whereas it becomes more volatile for the US. After the Rebound, the autoregressive coefficient stabilises at around 0.5 for the EA, whereas it fluctuates between 0.5 and 1 for the US.

The above analysis concludes that, before the pandemic, the persistence in all three factors gradually declines for both curves. However, in the first two phases of the pandemic, the long-term and short-term factors present explosive behaviour for the US. During these pandemic phases, persistence declines for the EA factors, making the yield curve more predictable, even though the EA countries, e.g., Italy, Spain and France, entered lockdown earlier than the US did. For an investor, this provides an opportunity to turn to securities of a less persistent and, thus, more predictable yield curve.

5. Conclusion

This paper investigates the change in persistence in the US and EA yield curves caused by the COVID-19 pandemic. We extract the Diebold and Li (2006) long-term, short-term and medium-term incarnation of the Nelson-Siegel parameters and apply a local linear time-varying approach to estimate changes in their persistence.

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10 This finding is also evident for the long-term and short-term factors even in a “backward” looking rolling OLS exercise that a researcher could apply in real time; see the Online Appendix for more details.
Our evidence suggests that during the pandemic there are differences in the persistence of these factors which, in turn, affect the predictability of these curves. For the US we observe a decline in persistence towards the end of 2019, whereas during the pandemic period the US long-term and short-term yield curve factors present evidence of explosive behaviour, making the curve unpredictable. At the same time, the EA yield curve factors decline in persistence, making the EA yield curve more predictable even though the EA countries had to enter lockdowns earlier than the US.

CRediT authorship contribution statement

Fotis Papailias: Conceptualization, Methodology, Software, Validation, Formal analysis, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration.

Supplementary material

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