BI Norwegian Business School - campus Oslo

GRA 19502

Master Thesis

Component of continuous assessment: Thesis Master of Science

Assessing Predictability of the Tendencies in Economic Activity Using the Yield Curve

[redacted]

Start: 02.03.2017 09.00

Finish: 01.09.2017 12.00

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Hand-in date:
31.08.2017

Programme:
Master of Science in Business with major in Finance

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Abstract

We study the power of the yield curve to predict changes in economic activity in countries at different stages of economic development. Using the yield spread, we assess the relationship between the slope of the yield curve and cumulative and marginal real GDP growth in highly developed (U.S., Norway) and emerging (Russia, Ukraine) countries. Within- and out-of-sample models are constructed to evaluate the explanatory and predictive power of this relation respectively. We find the overall significance of the yield spread in explaining subsequent economic growth across all the countries contingent on a specific time horizon. The results of forecasts evaluation for the U.S., Norway and Russia demonstrate the rationality of using the yield spread models in highly developed countries as opposed to emerging ones where naïve autoregressive models are preferred. The thesis highlights the potential of further investigation in the post-soviet region.

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1. *Introduction*

The prediction of fluctuations in economic activity across various countries is one of the topical scientific problems. In this framework, the yield curve analysis has been proven to have a significant predictive power on economic output. Herewith, especially robust forecasting results were obtained for the countries with highly developed financial markets. However, there is still a question whether this method can be efficiently applied in various economies disregarding the level of their economic development.

In particular, evidence for emerging economies has not been sufficiently covered in the literature, for the very reason that their bond markets have become available for analysis only since the beginning of the 21st century with the opening of emerging markets for international capital flows. In addition, there has been no extensive research made in this field for the countries from the post-soviet world, which 25 years after the collapse of USSR have become possible and necessary to analyze, to our opinion. An absence of corresponding research and attention to this question in literature creates a scientific gap that this master thesis is aimed to cover.

Thus, researching the effectiveness of the yield curve analysis in post-soviet emerging countries (e.g. Ukraine, Russia) compared to highly developed ones (e.g. Norway, U.S.) is highly demanded. Moreover, the time period analyzed by most of the recent studies discussing this topic was very limited. It was either the period before the world financial crisis in 2007-2008 or the short period after it, due to the need to avoid biases while analyzing periods together. Nowadays, in 2017, there is again a sufficiently long timeframe since the last financial crisis to both re-examine the predictive power of the yield curve in industrialized countries and complete an objective demand for analogous research in emerging countries.

The research puzzle of this master thesis questions the importance of examining changes in the spread between long-term and short-term government bonds' yields of various countries for predicting the impending shifts in economic growth of short-listed economies of our high interest.

The thesis is organized as follows. The scientific gap and motivation to examine the spread-GDP relation for short-listed counties is described in Section 2 through analyzing the methodology, geographic coverage and results of the previous research. Section 3 provides a brief theory of the yield curves as well as explains the main terms used. In Section 4, the selected two-step methodology is reasoned and described in detail. The results of within-sample regressions and out-of-sample models performance for the U.S., Norway, Russia and Ukraine are presented in Section 5. Section 6 summarizes authors' findings and suggests the area for further research.

2. *Background and Literature Review*

The role of the yield curve in predicting economic cycles has been widely discussed in the literature since the 1960s. Specifically, Kessel (1965) was first to make a specific reference towards the evidence that in the times of economic cycles' peaks term spreads tend to be negative. Having examined the relationship between short- and long-term debt instruments over the time period of 1857-1961 in the United States, he showed the tendency of the yield curve to be most positively sloping at the beginning of economic expansions and most negatively sloping before the recessions. In a further research by Fama (1986), a particular role was assigned to the study of changes in short-term interest rates, which were found to be declining at the beginning of economic downturn and started to rise, forerunning the economic expansion; while long-term yields remained relatively stable throughout different business cycles.

Following this study, next major research in this field were conducted at the end of the 1980s by Harvey (1988), Laurent (1988,1989) and Stock and Watson (1989) and were concentrated on examining the ability of the slope of the yield curve to predict various macroeconomic indicators using mostly U.S. financial data. Specifically, addressing consumption-based capital asset pricing model, Harvey (1988) was the first to found a strong connection between the negative yield spread – a difference between the long- and short-term zero-coupon government bond rates – and upcoming recessions in the U.S. in terms of consumption level. Noting that by CCAPM cyclical movements in personal consumption should be reflected in cyclical movements of expected return, his paper finds that there are information and predictive ability about future consumption growth in the real term structure. At the same time, Laurent (1988, 1989) denoted the importance of the term spread (between the federal funds' rate and 20-year Treasury bills' yields) in predicting GNP growth.

The further contribution of Stock and Watson (1989) in the aforementioned topic is significant in terms of developing a sophisticated framework for evaluating the indicators used to forecast the state of macroeconomic activity. Revising the set of indexes of coincident (CEI) and leading economic indicators (LEI), they include the yield spread in the latter one and recognize the slope of the yield curve as one of the most useful factors for forecasting domestic inflation and growth. After over 30 years Stock and Watson still include the given spread as a powerful predictor in their studies and forecasting models (2012).

Subsequent studies of Estrella and Hardouvelis (1990, 1991), Chen (1991) and Mishkin (1990, 1991) have also challenged the predictive power of the yield curve and proved the existence of correlation between the U.S. yield curve's slope and change in aggregate GNP, investment level and inflation, among others suggesting that an inverted yield curve could be a signal of an impending recession. In this context, Estrella (2005) showed that every post-war recession in the U.S. could have been predicted by the yield curve slope, with the only "false" signal in the late 1960s. However, despite an extensive amount of the literature proving the forecasting power of the yield curve, this statement has been challenged at first by Bernanke (1990) who disagreed that the term spread was the best predictor of real output, suggesting the usefulness of the paper spread (difference between commercial paper and public securities) instead under assumption of a constant monetary policy across various monetary regimes. Nevertheless, in the subsequent paper, applying a nonlinear model, Bernanke and Blinder (1992) demonstrate that the real output can be better predicted by exactly the yield spread rather than other monetary aggregates.

The predictive content of the yield spread for inflation was examined firstly by Mishkin (1990) for US domestic inflation and further by Mishkin (1991) for 10 other industrial economies, where it was found to be significant. The intuition behind this expected relation is based on the Fisher equation, saying that the nominal interest rates reflect market expectations regarding both real rates for a given maturity and future inflation. However, having not controlled for the lagged inflation, which would reduce the significance of results, these studies were criticized by few later ones, including the one of Stock and Watson (2003).

While early studies were primarily concentrated on U.S. market and U.S. financial data, subsequent research of Harvey (1991), Estrella and Mishkin (1997) and Estrella, Rodrigues and Schich (2003) examined if the relationship between the yield spread and future economic growth held up outside the U.S. The findings showed that to some extent predicting ability was present, being however unstable over time and demonstrating a poor forecasting performance. Similarly, Chinn and Kucko (2010), while having found the yield spread to have a significant predictive power on such economic indicator as industrial production growth in the U.S., came to a conclusion that usefulness of the yield spread for forecasting macroeconomic situation in the countries other than U.S. is much smaller and tends to be declining over longer time-horizons. Challenging the predictive power of the yield spread, in such a way, scientists pay attention to the need to extend and refine the previous studies, whose vast majority is based on the US market and a handful of industrialized countries, such as: Germany, France, U.K., Italy, Canada, Sweden, Japan etc.

The recent research of Mehl (2006) is one of the first attempts to investigate if the slope of the yield curve can be used as a predictor of both inflation and growth in emerging countries rather than the industrialized world. The importance of this study is that while by Chinn and Frankel (2003) the effect of US interest rates on highly developed countries had been already studied, Mehl raises a question of spillover effects of the monetary and financial conditions in the U.S. or Euro area to emerging markets, as well as testing the predictive ability of the yield curves of the latter ones on local domestic markets, extending the geography of research to 14 emerging countries. Key findings are that the yield curve contains information for both short and long inflation and growth forecast horizons in almost all researched countries, with differences being seemingly linked to the level of countries' market liquidity. The summary of other recent (after the 2000s) papers assessing the predictive power of the yield curve in the countries other than U.S. is presented in Appendix: Table 1.

Finally, the recent research of the relation between the yield curve and the state of economy that are worth mentioning include the one of Cooper and Priestley (2008) exploring the output gap in the U.S. economy and using it to forecast the excess holding period return of long-term bonds over the short-term rate, supporting by these findings liquidity preference theory. Another interesting study in this field was made by Cochrane and Piazzesi (2008) who constructed a model to decompose the yield curve into expected interest rate and risk premium components and showed that those risk premia are forecastable by term-structure factors. These findings are important in terms of interpreting abnormal yield curves and extracting from them the information regarding real expectations of the interest rates dynamics and the fraction of risk premia required by investors in a specific country, which outlines an area for further research in this field.

3. *Theory Description*

The central object of the whole yield curve analysis is yield itself, specifically a yield to maturity on zero-coupon bonds, and its meaning for the economy overall and economic forecasts. The yield curve represents then a dependence between the time to maturity and the yield, that in the case of zero-coupon bonds is an objective interest rate reflecting the real market situation.

There exist several economic theories explaining the change of the yield depending on the maturity of bonds: expectations theory, segmented market theory and the liquidity preference theory.

The first one states that the yield curve depends on investors' expectations of the future interest rates such that a long-term interest rate is simply a geometrical mean of the short-term rates sequence. Expectation theory, however, assumes, that any long-term instrument may be reconstructed with several short-term instruments, which is usually not that likely in reality, assuming the risk aversion of investors – yields do not always tend to move together for different durations.

The segmented market theory considers instruments with different maturities as separate instruments with their own markets, supply and demand. Supporters of this hypothesis divide the debt market into short-, middle- and long-term segments as most of the investors have set preferences for the maturities. Following this logic instruments with different maturities may be considered separately and then the prominence of the yield curve may be explained. Unfortunately, the theory fails when it comes to the fact that the change in a yield of an instrument with the specific maturity spills the effect for the instruments with other maturities.

Finally, the liquidity preference theory states that the main difference between the yields for different maturities lies within the fact that investors prefer to keep their savings liquid and would prefer longer term debt instrument when the price for it would be low enough (i.e. the yield would be higher). This stands for the liquidity premium and explains the possible upward slope of the curve.

Following the expectations and liquidity preference theories, it can be assumed that the shape and the slope of the yield curve may be used to investigate investors' beliefs about the market. The last ones are known to be the main market drivers for changes in an economy.

The generalized formula for the long-term rate under the expectation (with liquidity premium equal to 0) and liquidity preference theory:

$$i_{n,t} = \frac{i_{1,t} + i^e_{1,t+1} + \cdots + i^e_{1,t+n-1}}{n} + lp_{n,t} \qquad (1)$$

where $i_{n,t}$ – long-term interest rate – is the weighted geometrical average of future short rates and the liquidity premium $lp_{n,t}$ requested by investors for investments in bonds of the longer term.

In reality, three types of curves may be observed. In most of the cases, a normal (upward-sloping) curve is observed with short-term rates lower than the long-term ones. This slope has many explanations: the expectations of the interest rates to rise, high demand on the short-term debt instruments or even a preceding inflation. In a general case, such shape of the yield curve is treated as a good sign and is usually present in countries demonstrating the economic growth. However, a steeply increasing yield curve could be also noticed at the moment of expected economic deterioration due to the default risk increasing with time to maturity.

In some rare cases the yield curve may be flat, which may be the result of pure investors' beliefs that the future interest rates would remain the same (or lower for the amount of the liquidity premium). The flat yield curve may be also just an occurrence when the curve changes its shape from normal to inverted.

An inverted yield curve exists when the short-term rates are higher than the long-term ones. This may be the result of active investment into long-term debt instruments (hence, high bond prices and low yields) to "lock" the savings for better times. In other words, short-term investments are less demanded, as higher risks (e.g. default risk for certain countries) are associated with the near future horizon. Such a declining yield curve mostly indicates a forthcoming recession. However, in reality, the tendency to invest for a long-term while expecting recession may be also misleading since if really significant risks, such as country's default, are expected soon, there might be no reason to invest in the long-term bonds as well. In such a way, an inverted yield curve may be a result of investors flawed expectations.

In this particular research, it should be also highlighted that, assuming that liquidity and other risk premia are always non-negative (greater/equal to zero), the recession expectations may be considered to exist even if the yield curve is flat or even upward sloping. The reason for this is that investors' required risk premia may be so high that their effect may offset the expected interest rates decrease, covering it with the "cap".

All of the abovementioned gives reasons to consider the yield spread (i.e. the difference between the long- and short-term yields) as a good measure for tracking yield curve changes, which in their turn are expected to contain a useful information for predicting changes in countries' economic growth.

4. *Research Methodology*

In this research, we concentrate on investigating the specifics of the predictive power of the yield curve in a real economic growth of chosen countries with inverted yield curves compared to the usual cases of highly-developed countries. Particularly, our area of interest covers emerging countries of former USSR, since to our knowledge no study regarding yield curves and their meaning for prospective economic conditions of these countries has been conducted before. Besides, we identified the lack of sufficient research covering this issue both in the case of

Norway and the U.S. after the last financial crisis. Therefore, having defined the existing scientific gap we shortlisted the sample of analyzed countries to the U.S., Norway, Russia and Ukraine.

The complexity of investigating the latter countries lies in the availability of adequate data on debt securities' yields over the sufficient time period. Since the aforementioned countries became independent only in 1991, their domestic bond markets started to deepen significantly only after the 2000s. In such a way, dealing with a restricted sample of the volatile data, a contribution of this research lies mainly in examining whether the yield spread in Ukraine and Russia contains information about the subsequent real economic growth, which would potentially let predict the tendencies for their economic expansion or recession in the following years.

In the literature on the researched topic most studies were looking into the relation between the yield curve slope and such indicators as GDP, industrial production and consumption growth, and inflation. Considering rather an agricultural specialization of Ukraine and high dependence of Russia on oil and gas industry, it was decided that industrial production growth is not a comparable index in the given case. Additionally, the adequacy of a consumption growth data is being questioned, as well as the one for an inflation rate (which has risen dramatically since 2014 and is presumably explained much more by other economic and political factors rather than the yield spread). Therefore, the indicator that is going to be looked at is real GDP and its dynamics in relation to the change in the yield spread.

In order to compare the findings about the yield curves in emerging countries mentioned above, we're making the same investigation and refine previously made findings on the predictive power of the yield curve in the U.S. and Norway, relying on the most recent data. Choosing the U.S. as one of the research objects we aim to explore if the predictive power of the yield curve is still strong in the country where it consistently showed the highest forecasting performance. Norway was chosen as a developed industrialized country regarding which little research has been made in this field. Additionally, considering recent oil prices drop and devaluation of Norwegian krona, the research aims to examine if the change in real GDP growth is reflected in Norway's yield curve. In such a way, the example of the U.S. and Norway is used to show the relation between the yield spread and subsequent real economic growth in developed countries true for the last data available and the ability to use it in forecasting.

Using the same approach and restricting our sample to the time frame of the last 15 years (2002-2017), we aim to compare the estimation results of the constructed models over defined horizons among the short-list of countries at different levels of economic development, as well as evaluate their forecasting power.

The methodology applied in this study is a combination of frameworks developed by Stock and Watson (2003) and Estrella and Hardouvelis (1991) as they both were proved to be reliable in published research papers on this topic. It implies outputs of two econometric approaches to be analyzed, specifically, within-sample regression models and out-of-sample forecasting models.

Within-Sample Estimation:

Method of within-sample regression is mainly taken from Estrella and Hardouvelis (1991) and is based on estimating Ordinary Least Squares (OLS) regressions of the real GDP growth and the yield spread between the long-term and short-term government bonds.

The yield spread for all countries is calculated using the formula:

$$Spread_t = r_t^l - r_t^s \quad (2)$$

For the U.S., Norway and Russia the yields on 10-year and 3-month government bonds were taken as proxies for the long-term (r_t^l) and short-term (r_t^s) interest rates respectively. In the case of Ukraine representative proxies for this research were obtained using the yields on bonds with shorter maturities (discussed in more details in Section 5.1).

As we deal with time series that is often non-stationary, a proper way to investigate the effect of the yield spread on economic activity requires GDP level data to be transformed to GDP growth data (i.e. log-data). There are two ways of computing yearly growth in GDP: for *k* periods ahead (cumulative approach) or from *k-j* to *k* period (marginal approach). As GDP level data is quarterly, the aforementioned variables are computed in the following way:

$$Cumulative\ Growth_{t,t+k} = \frac{400}{k}\ ln(GDP_{t+k}/GDP_t) \quad (3)$$

$$Marginal\ Growth_{t+k-j,t+k} = \frac{400}{j}\ ln(GDP_{t+k}/GDP_{t+k-j}) \quad (4)$$

In such a way, both measures of GDP growth have the same forecasting horizon *k*, while estimating the GDP change on a yearly basis for different periods: from *t* to *t+k* for cumulative and from *t+k-j* to *t+k* for marginal growth.

To examine the relation between the yield curve slope and GDP growth two types of regressions are run: simple factor regressions (5), (7) and alternative regressions that include a first-order autoregressive component (6), (8):

$$Cumulative\ Growth_{t,t+k} = \alpha_0 + \alpha_1 Spread_t + \varepsilon_{t+k} \quad (5)$$

$$\text{with } H_0: \alpha_0 = \alpha_1 = 0$$

$$Cumulative\ Growth_{t,t+k} = \gamma_0 + \gamma_1 Spread_t + \gamma_2 (L1) Growth_{t,t+k} + \varepsilon_{t+k} \quad (6)$$

$$\text{with } H_0: \gamma_0 = \gamma_1 = \gamma_2 = 0$$

$$Marginal\ Growth_{t+k-j,t+k} = \beta_0 + \beta_1 Spread_t + u_{t+k} \quad (7)$$

$$\text{with } H_0: \beta_0 = \beta_1 = 0$$

$$Marginal\ Growth_{t+k-j,t+k} = \delta_0 + \delta_1 Spread_t + \quad (8)$$

$$+ \delta_2 (L1) Growth_{t+k-j,t+k} + u_{t+k}$$

$$\text{with } H_0: \delta_0 = \delta_1 = \delta_2 = 0$$

T-stats of obtained regressions should be inflated accounting for the heteroscedasticity and autocorrelation where it is needed as data overlapping issue arises. Hence, Newey-West correction with the lag of k is applied where both heteroscedasticity and autocorrelation are observed according to Durbin-Watson and White's tests (Newey, 1994). For regressions with insignificant autocorrelation tests only White's corrections are used.

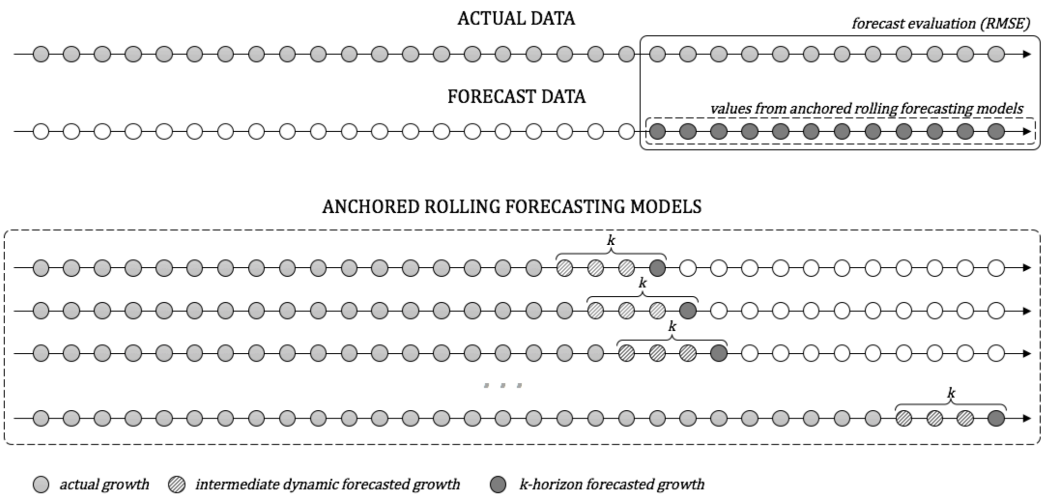
Finally, the assessment of predictability is conducted through computing R^2 (goodness of fit) and SER (standard error of regression) to choose the best model for each country and compared them with each other.

Out-of-Sample Forecasts Modeling:

Method of out-of-sample forecasting used is the one developed by Stock and Watson (2003) and assumes evaluation of forecasting performance of selected models in comparison with a naïve benchmark, that is simple AR(1) model.

To complete this stage, for each model that is to be evaluated the estimation of several anchored rolling (recursive) regressions is required. Using the estimated coefficients, k-step-ahead dynamic forecasted values of growth are calculated such that we end up with a sequence of estimated values for the chosen forecasting period. In this way, we get a fair forecasting assessment, as only the data that is available up to pseudo-forecasting is used.

The algorithm of generating and evaluating k-step-ahead dynamic forecasts is summarized in the following scheme:



This approach is also known as cross-validation procedure, or evaluation on a rolling forecast period with k-steps ahead forecasts, which was mainly taken in a framework described by Hyndman (2014).

Forecast evaluation is conducted through calculating RMSE (Root Mean Squared Error) for each selected forecasting model and respective benchmarks:

$$RMSE = \sqrt{MSE} = \sqrt{\frac{\sum_{t=1}^{n}(GDP\ growth_f - GDP\ growth_{act})^2}{n}} \quad (9)$$

Further, RMSE of selected forecasting models and benchmarks are compared and checked for the significance of the equality of provided forecasts using the method developed by Diebold and Mariano (1995), that is by estimating Diebold-Mariano (D-M) statistics against insignificance:

$$H_0: \mathbb{E}(MSE^{f1} - MSE^{f2}) = 0 \quad (10)$$

As we use small data samples, HLN (Harvey, Leybourne and Newbold, 1987) correction is applied to deflate t-statistics.

If RMSE of a selected forecasting model was lower than the one for naïve AR(1) forecasting model and Diebold-Mariano statistics indicated significance, then selected forecasting model was considered to have a sufficient predictive power and vice-versa.

The empirical estimation of within-sample regressions and out-of-sample forecasts evaluation in this research is conducted using eViews statistical package.

5. Empirical Model and Results

5.1. Data

The data used in this research include series of three variables for the U.S., Norway, Russia and Ukraine. The summary of the data collected is presented in the table below:

		United States, Norway, Russia	**Ukraine**
1 - GDP	*Description*	GDP level in constant 2010 local currency units	GDP level in constant 2010 local currency units
	Source	The World Bank Database	The World Bank Database
2 - Short-term interest rates	*Description*	3-month government bonds yields	averaged yields on bonds with the time to maturity ranging from 1 to 6 months traded during the last 3 trading days of the quarter
	Source	OECD Database	CBonds – financial news agency and data vendor in CIS countries
3 - Long-term interest rates	*Description*	10-year government bonds yields	averaged yields on bonds with the time to maturity over 3 years traded during the last 3 trading days of the quarter
	Source	OECD Database	CBonds – financial news agency and data vendor in CIS countries
	Period	(2000:Q1; 2017:Q1)	(2010:Q1; 2017:Q1)
	Frequency	quarterly	quarterly
	Observations	69	29

Data collection for Ukraine was highly restricted by the availability of reliable interest rates. It may be explained by the fact that Ukrainian bond market remained on the very low level of development until 2010. If some earlier records are available, they are usually very volatile and provide a low level of trust. Moreover, accounting for the country's economic position and risks, we assume that investors' uncertainty results in relatively short bond lives and, hence, short YTM observed in the market. To fill the data gaps an alternative self-evaluated approach was applied to obtain near-realistic results.

For other countries yield spread as a difference between the yields on 10-year and 3-month government bonds was chosen as the indicator which was proven by previous studies to be the most relevant for our kind of investigation.

As follows from descriptive statistics and variance tests (see Appendix: Table 2), in all GDP data signs of a unit root can be observed. Such a problem is not surprising for economic level data and is eliminated through computing logarithms as described in Section 4 of this research. The same applies to some interest rates data: series itself may keep a near-root feature that is, however, unobservable when dealing with the yield spreads that are the differences of rates series.

5.2. Within-Sample Regressions

The within-sample modeling of the spread-GDP relation for all countries is conducted over varying time horizons. For regressions (5), (6), which are expected to explain the cumulative change in GDP, forecasting horizon is set to $k = 1, 2, 4, 6, 8$ and 12 quarters ahead. For regressions (7), (8), with the marginal GDP change as a dependent variable, the following parameters are set: $j = 1$ for $k = 1, 2, 4$, $j = 2$ for $k = 4, 6, 8$ and $j = 4$ for $k = 6, 8, 12$.

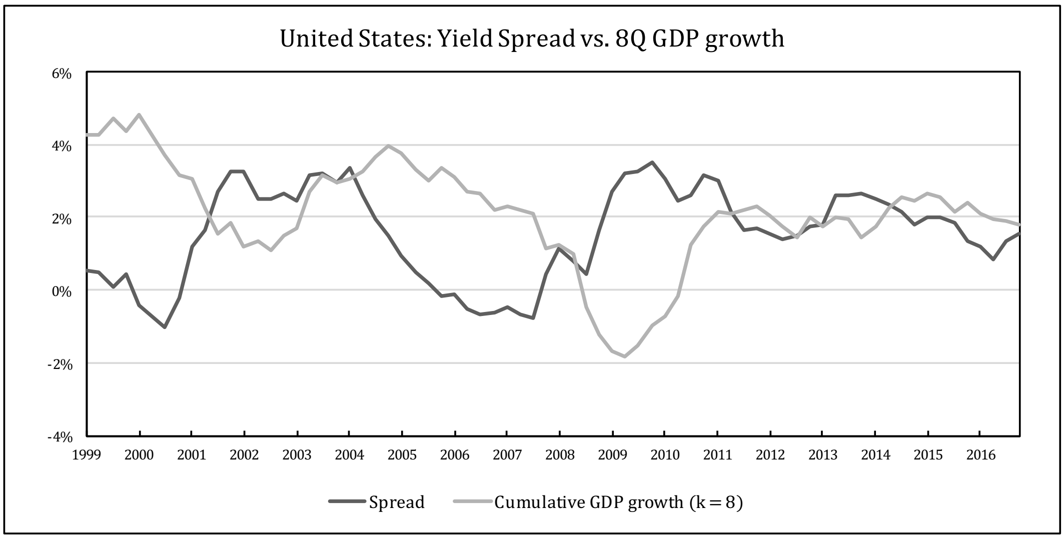
The data on growth computed over the period of 2002:Q1 to 2017:Q1 was used in models for the U.S., Norway and Russia so that all within-sample models kept an equal number of observations and provided comparable results. However, accounting for limited data available, all models for Ukraine were estimated over the maximum time range and hence numbers of observations used in regressions vary among models with different forecasting horizons.

As can be seen from the regressions estimates presented in Appendix (Tables 3-6), in all countries we can observe a proof of existing relationship between the GDP growth and the yield spread, which however demonstrates the best performance for each country at the specific different horizon. Overall, the effect of spread appeared to be stronger in cumulative GDP growth models rather than marginal ones. Similarly, adding an auto-regressive component as a factor substantially increased the explanatory power of the models.

All models with AR(1)-term – (6), (8) – explained the growth variable better (in terms of substantially higher R^2), where an auto-regressive component was found to be highly significant in nearly all cases and at all horizons. This finding is expected while dealing with relatively high-frequency time series.

Specifically, turning to the results of the *U.S.* (Appendix: Table 3), the yield spread has performed the best in the models with 8 quarter forecasting horizons for cumulative growth. Marginal growth model with *j* = 4 has most usefulness due to a good performance of 4-quarter cumulative model, which still appears to be effective in a couple of periods ahead.

Overall, the yield spread has high significance in the majority of models constructed for the U.S., increasing with time horizon and diminishing only after 8-th quarter. Comparing to other countries, it has quite a high usefulness in marginal GDP growth models as well. The representation of the strong relation between 8-quarter cumulative GDP growth and the yield spread is shown on the graph below.

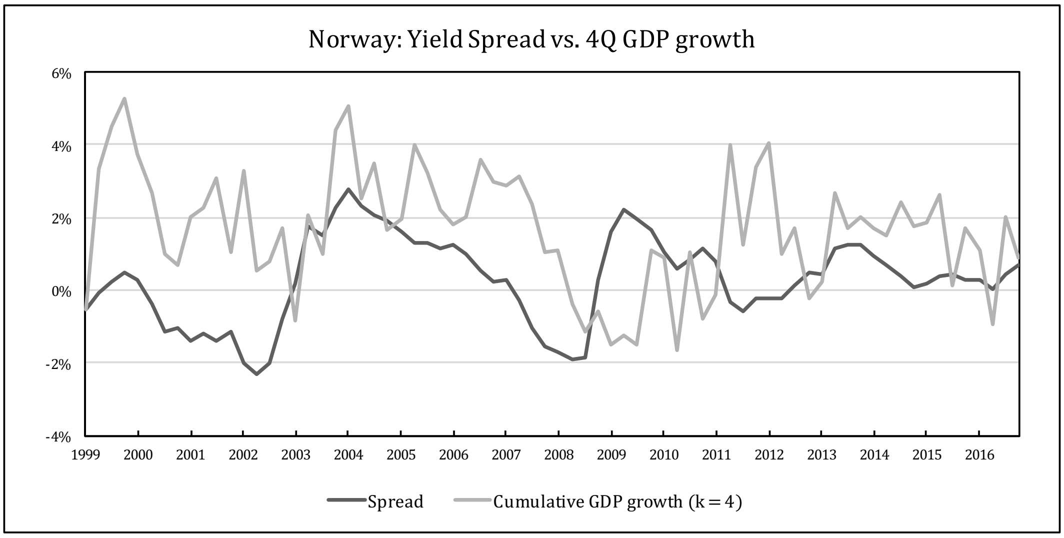


It's worth mentioning that as we can observe from the graph above starting from the 2000s indeed periods of economic downturn were preceded by inversion of the yield curve around 8 quarters before.

Looking at the results of regressions estimation for *Norway* (see Appendix: Table 4), we see that unlike in the case of U.S. constant appeared highly significant in most models, which signals that there are other important factors influencing GDP growth that are not included in the model. This has its reflection in generally lower explanatory power and higher SER of Norway's models as opposed to the ones of the U.S.

Overall, we can notice that spread has shown lower significance in case of Norway. Marginal models here have very poor performance compared to the U.S.: only 1-to-2-quarter marginal model (k = 2, j = 1) when combined with AR(1) term has a significant spread coefficient and provides a sufficiently high explanatory power. However, we still can conclude that the most acceptable models for Norway are the ones explaining cumulative growth, with the best model of the 4-quarter horizon.

From the graph below we can get an insight of the correlation between the yield spread and 4-quarter growth of Norwegian real GDP, which is actually visible.

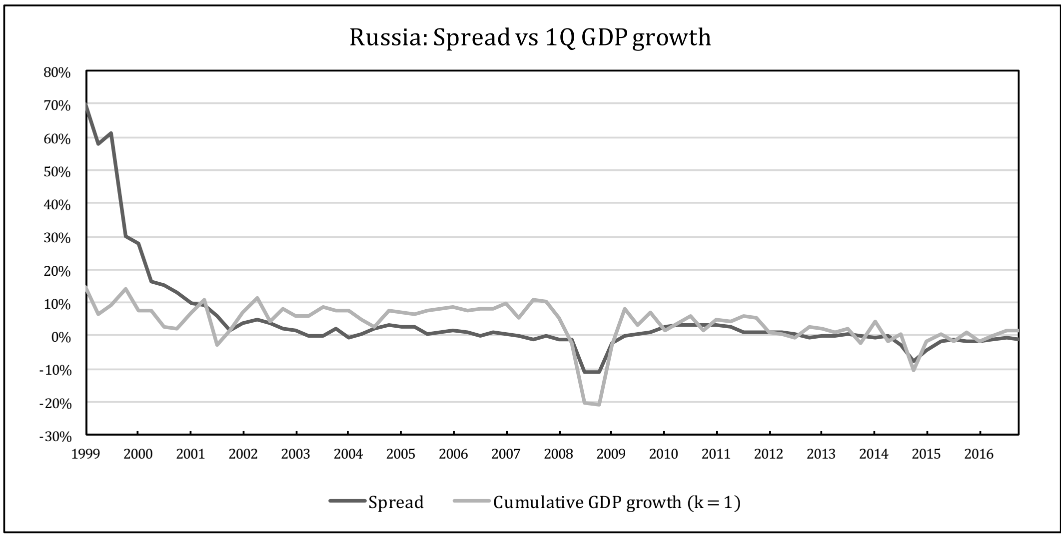


Moving forward to the sample of ex-communist emerging countries in our research, we must say that the results obtained for them were surprisingly encouraging.

Despite the high volatility of growth, in the case of *Russia* (see Appendix: Table 4), the yield spread performed relatively well, showing the significance of its coefficients over all horizons in the models of cumulative GDP growth and giving generally higher R^2 than, for example, the same models for Norway. Nevertheless, at highest-order horizons a too high significance of spread looks suspicious and gives an impression of spurious results, presumably, due to the high data volatility in a relatively short sample, since taking into account dynamics of actual data there is no economic logic behind such indication.

The marginal models showed better results than in the case of Norway as well, specifically 1-to-2-quarter and 2-to-6-quarter models demonstrated highest R^2 and significant spread coefficient, which is logical, since in cumulative terms 1-quarter and 4-quarter models performed better than others. However, constant term was found to be significant at all horizons, signaling the importance of omitted variables, and adding an AR-component to the models elevated the R^2 drastically, leaving an autoregressive term the only significant variable. In such a way, we have noticed that AR-models (simple or combined with other factors) have strong explanatory power in the case of Russia, which may tell us that there is a certain pattern in Russian growth (being highly volatile but around certain mean) that can be captured by AR model better than by the yield spread.

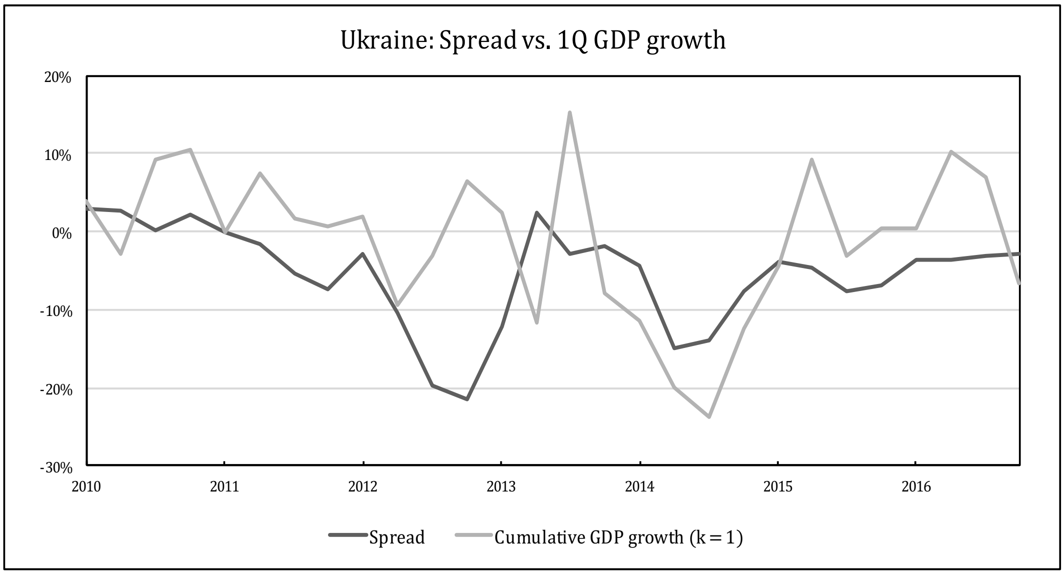
The strongest relation between the yield spread and GDP growth for Russia is captured by the simple factor model of 1-quarter cumulative GDP growth. The graphical representation of this relation is shown below.



Looking at the graph, we indeed can track the similarity in dynamics of both variables, however it seems that investors in Russian economy change their expectations in response to declining or increasing GDP growth straight away, or that’s the yield spread that reflects their expectations in such a way, which puts under the question the adequacy of the interest rates data and the relevance of using it in economic growth forecasting.

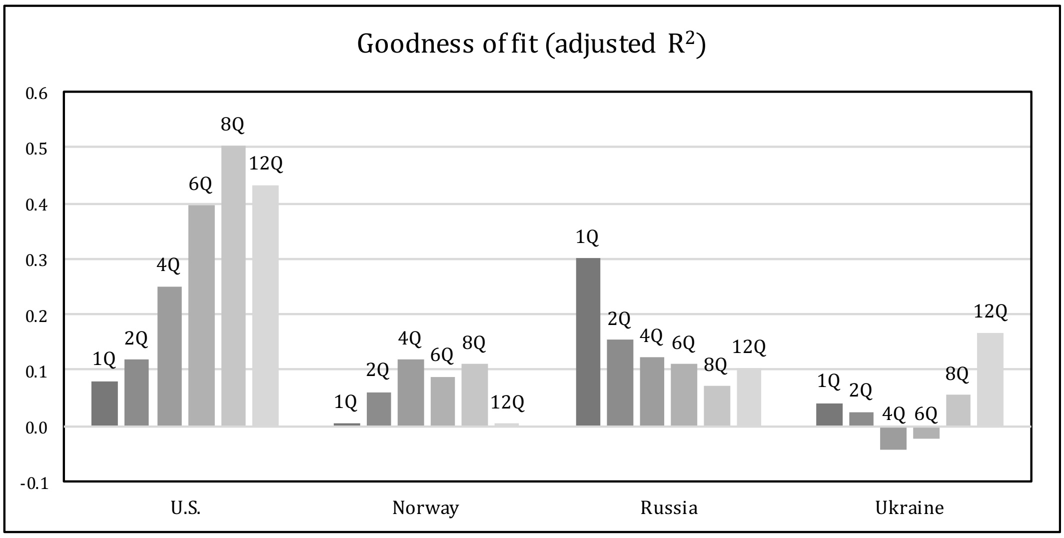
Finally, turning to the results of *Ukraine* (see Appendix: Table 6), we should point out that despite all the complexity connected with under-development of Ukrainian financial market and overall limited data availability and accessibility, having analyzed the sample from 2010:Q1 to 2017:Q1, we can conclude that there actually is an interrelation between the economic growth and the slope of the yield curve in Ukraine.

Models with AR component demonstrate much higher R^2, similarly to Russia, as well as here we can also observe extremely low p-values of the spread coefficients at the high-order horizons, which seem spurious and rather senseless when based on such a small sample size. Nevertheless, significance of the single spread factor in a 1-quarter model for cumulative GDP growth seems to be adequate, and observing this relation on a graph below gives an evidence of the fact that with more new data available it may actually be useful to include the yield spread of Ukrainian bonds in growth forecasting models.



We realize that in both Ukraine and Russia results may be biased, accounting for the lack of quantity and moderate quality of data on the bonds' yields and considering as well current unstable economic and political situation in both countries, which affected the change in GDP growth in recent years, but as long as financial markets will be developing and opening for international investors, the yield curve is expected to become a more significant predictor of countries' economic growth.

Overall, having looked at the goodness of fit of all constructed models with the yield spread as a single factor, it was concluded that the yield spread explains GDP growth better at 8 quarters, 4 quarters and 1 quarter horizons in the U.S., Norway and Russia respectively. In the case of Ukraine 1-quarter growth model seems to make most sense, however, due to the restricted sample so far it doesn't seem possible to get adequate results if using it with predictive aim.



As a result, in combination with the spread significance in different models the goodness of fit determined the choice of one best-fit model for each of 3 countries to be used in further forecasting.

5.3. Out-of-Sample Forecasting

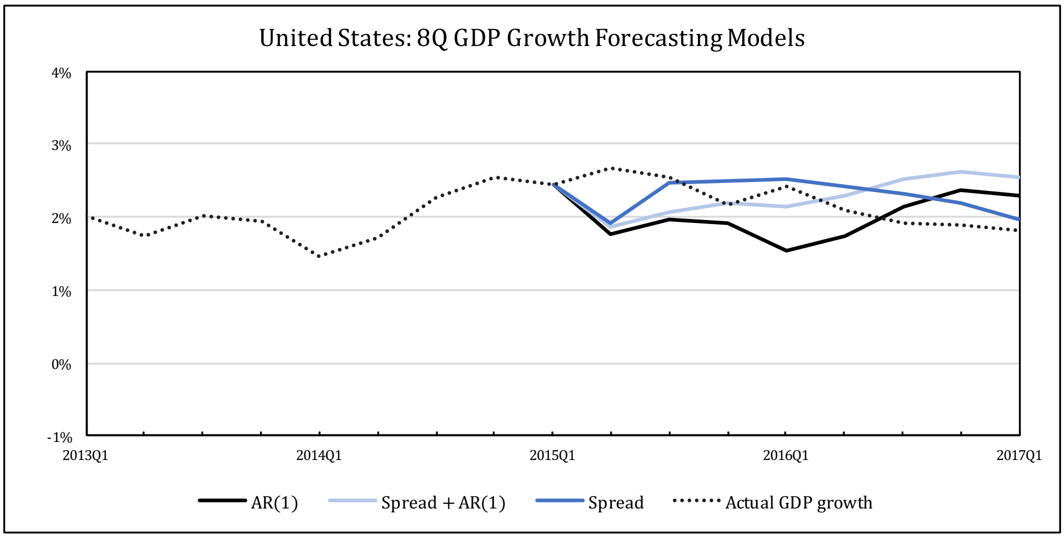
The forecasting sample for all countries was set at 2 last years: 2015:Q2 to 2017:Q1. For this period models with simply spread and both spread and AR(1) factors with identified optimal forecasting horizons are used to produce the growth forecasts for this time frame, which are further compared with the forecasts of the benchmark model AR(1) and actual growth records (using RMSE and D-M stats).

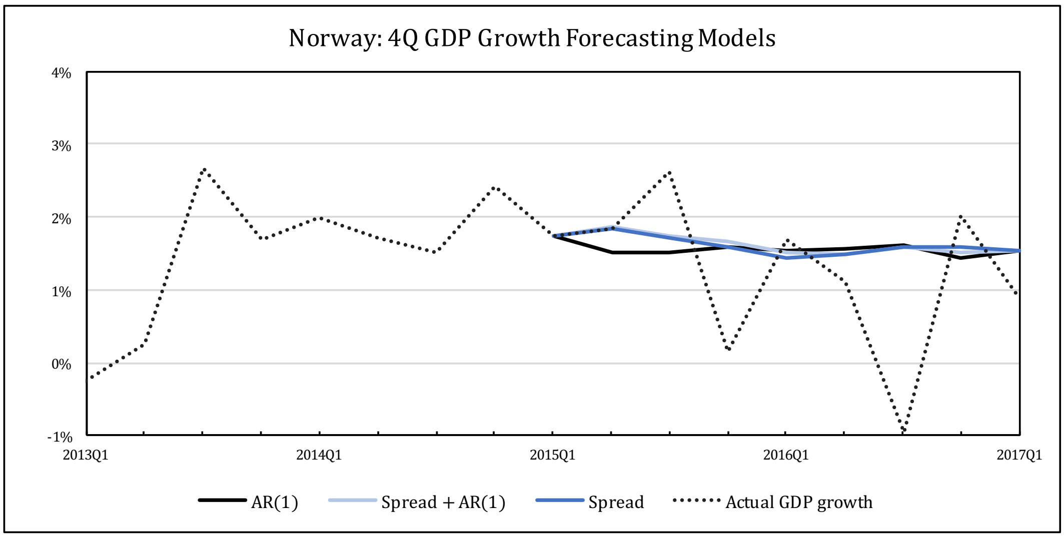
Since we want to evaluate the forecasts accuracy fairly, we use each of the models in a sequence of recursive regressions for an investor who is making forecasts based on the data that is available for him at the moment and reassessing them as the new data is becoming available in the following period. For example, an investor willing to predict economic growth in the USA for the 2nd quarter of 2015, using the 8-

quarter spread model in 2013, would make estimation based on the data up to 2nd quarter of 2013. In the next quarter, with an updated information, the model's coefficients for the next forecasts would be reassessed and forecasts themselves would be corrected. The same approach is taken in this research to adequately evaluate the accuracy of different types of models.

The results of forecasts' evaluation for all models and all countries is summarized in Appendix: Table 7. As can be seen from RMSE calculated for each model, for both the U.S. and Norway the models with spread as a single factor were producing the lowest errors values and consequently were chosen as preferable for the future growth forecasting.

The graphical representation of the performance of different forecasting models of the 8-quarter and 4-quarter GDP growth for the U.S. and Norway respectively is shown below.

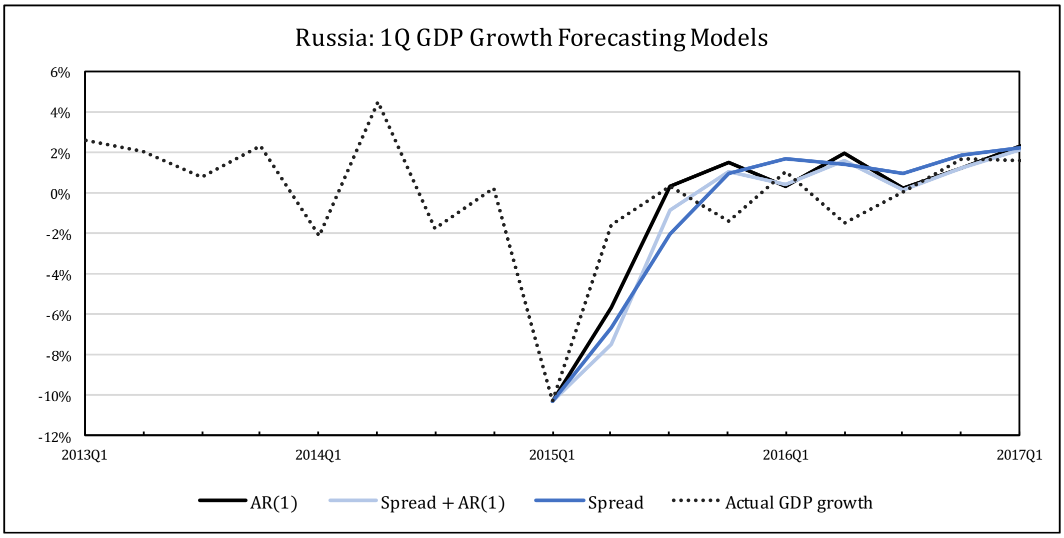




As we can see from the graphs, in the U.S. dominance of the spread model over the others is clearer than in the case of Norway. This is expected, since as was discussed before, the explanatory power of spread models in Norway is quite low, and, apparently, the drops in Norwegian economic growth after the 2nd quarter of 2015 were connected with the situation on global oil market and could be captured neither by the spread model, nor by AR(1) or their combination. However, even taking into account the presence of a few shocks in Norwegian economy, the yield spread seems to provide closer-to-reality forecasts, which is reflected in lowest calculated RMSE measures by the spread model in Table 7 (see Appendix).

Additionally, looking at the Diebold-Mariano (D-M) statistics, we can infer that for both developed countries forecasts provided by the spread factor model are significantly different from those made by the benchmark AR(1) model (at 90% significance level).

On the other hand, turning to the results of Russia, we can see that AR(1) model is preferable in this case as provides lower Root Mean Squared Errors than all the other models, as stated in Table 7 and as is illustrated by the graph below.



We should notice that even though an AR model fails to capture the volatility of growth, it does capture the trend of this growth quite successfully, which appears to give more useful results than the models which are trying to predict future growth looking at the yield curve. There are 2 possible explanations for that: either AR(1) is a good model itself or spread models perform badly, and since the latter is probably not true according to quite high models' R^2, then we can presume that despite high volatility there is a certain pattern in Russian growth that can be captured by AR(1)-term better than by the yield spread factor.

All in all, the forecasting ability of the yield spread has been proved by the cases of developed countries, represented by the U.S. and Norway, and in the case of Russia as a proxy for emerging countries in this research, we can see that in terms of forecasting the yield spread model may underperform simple AR(1) model, which can be connected with high volatility of growth in such economies, high level of uncertainty, still low development level of the financial markets, and simply the choice of the forecasting sample, with fewer number of shocks experienced by the economy.

6. Conclusions

This research has investigated the significance of the yield curve as a predictor of the subsequent economic growth in the countries at different stages of economic development, specifically, ex-communist East-European countries with inverted yield curves (Russia, Ukraine) as opposed to the industrialized (the U.S. and Norway). The main research findings are presented below:

- The yield spread has shown overall significance in relation to the GDP growth across all the countries that were studied, however, demonstrated different forecasting ability in each country over different horizons.

- Overall, models of cumulative GDP growth were found to perform better than those of marginal GDP growth in all countries. The latter ones have little sense, being representative only for the U.S.

- For the U.S, the yield spread for sure is a significant predictor of future growth, and among other researched countries there is no candidate to outperform the U.S spread model, at least within this forecasting approach. This can be explained by high level of financial market capitalization. Apart from that, within the taken sample U.S experienced fewer shocks and hence fewer outliers, which resulted in better model estimation.

- In developed countries, the yield spread can be used for relatively longer-term horizons compared to the short-term forecasting ability of the yield curve in emerging countries, represented by Ukraine and Russia in this research. Specifically, the best models' forecasts for the U.S. and Norway can be obtained over 8-quarter and 4-quarter forecasting horizons respectively, as opposed to the best performance of 1-quarter models for Ukraine and Russia.

- For the U.S. and Norway, it is reasonable to account for the yield curve slope and shape when forecasting future economic growth. The evaluation of conducted forecasts according to RMSE has shown the preference of using the single spread factor model for forecasting growth in aforementioned countries as opposed to Russia.

- We conclude that in Norway it brings some added value when including spread in a forecasting model, however quite a low level of models' fit over all forecasting horizons points out the existence of other very influential factors affecting Norwegian economic growth more significantly than the yield curve (i.e. oil prices etc.).

- On the contrary, in Russia an auto-regression forecasting model performs better than any of the models that include spread component, which means that presumably despite high volatility of Russian growth, there is an overall pattern (positive or negative) in it which can be captured by a simple AR(1) model better than by the yield curve slope.

- Ukrainian data that is available up to now don't let make definite conclusions regarding the predictive ability of the yield curve; nevertheless, near-significance of the yield spread over 1-quarter GDP growth puts a shadow of existing relation between the yield curve and economic activity in Ukraine. Definitely, with more data becoming available, this relation deserves attention and should be reassessed.

- As a result of this research we want to give a suggestion for further investigation of the yield spread in emerging countries overall and Ukraine and Russia specifically, since even based on the short sample of data available right now, we are able to conclude that the relation between the yield curve and economic growth that has been studied in the industrialized world has applications in un-studied before post-soviet emerging countries.

- What is important is that by this research we have shown that it is possible to analyze financial markets of such countries and make inferences from them, and we encourage following studies in this area.

- Specifically, regarding Ukraine, we suggest developing this study as the adequate data will be becoming available, so that fair conclusions could be made about the actual predictive power of the Ukrainian yield curve in forecasting economic cycles, which would provide valuable information for international investors, willing to diversify into Ukrainian economy.

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Appendix

Table 1. Summary of the literature studying the yield curves outside the U.S.

	Paper	Researched countries	Model	Period
1	Andreou, Osborn, Sensier (2000)	Germany, UK	Time Series	1955 – 1998
2	Berk, Van Berggeijk (2000)	Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Japan, Netherlands, Switzerland, UK	Time Series	1970 – 1998
3	Canova, De Nicoló (2000)	Germany, Japan, UK	VAR	1973 – 1995
4	Galbraith, Tkacz (2000)	Canada, France, Germany, Italy, Japan, UK	OLS and Maximum Likelihood	19XX – 1997
5	Ahrens (2002)	Canada, France, Germany, Italy, Japan, Netherlands, UK	Probit	1970 – 1996
6	Atta-Mensah, Tkacz (2001)	Canada	Probit	1957 – 1966
7	Estrella, Rodrigues, Schich (2003)	Germany	GMM	1955 – 1998
8	Kotlán (2002)	Czech Republic	OLS	1994 – 2001
9	Stock, Watson (2003)	Canada, France, Germany, Italy, Japan, UK	Time Series and Granger	19XX – 1999
10	Mehl (2006)	Brazil, Czech Republic, Hong Kong, Hungary, India, Korea, Malaysia, Mexico, the Philippines, Poland, Saudi Arabia, Singapore, South Africa and Taiwan	Time Series	19XX – 2005
11	Brunetti, Torricelli (2009)	Italy	LSTR and Probit	1983-2005
12	Anand (2011)	India	Time Series	2004 – 2008
13	Gogas, Pragidis (2011)	France, Germany, Italy, Norway, Portugal, Spain, UK, Sweden	Probit	199X – 2009
14	Choudhry (2015)	Ireland, Italy, Portugal, Spain, Greece,	GARCH-M	2001 – 2014
15	Shareef, Shijin (2016)	India	VAR	1996 – 2015

Table 2. Data Description

		Descriptive Statistics					Unit Root Tests	
		Mean	*Median*	*St. Dev*	*Skew*	*Kurt*	*ADF*	*KPSS*
U.S.	GDP	3,655,043	3,681,500	310,039	-0.0989	2.1432	0.5743	0.1156
	r_t^s	1.9899	1.0833	2.0678	0.9081	2.4123	0.0172	0.0684
	r_t^l	3.5863	3.6633	1.2469	0.1305	2.0855	0.1138	0.0722
Norway	GDP	725,210	736,696	54,571	-0.2698	1.9936	0.5596	0.1476
	r_t^s	3.4556	2.6000	2.1096	0.7378	2.0152	0.0349	0.0699
	r_t^l	3.7650	3.9333	1.4640	0.0288	2.2740	0.2242	0.0874
Russia	GDP	18,627,566	19,936,513	3,281,444	-0.6199	1.8899	0.8064	0.2370
	r_t^s	9.0790	8.0033	3.6857	1.3778	4.9306	0.0071	0.1356
	r_t^l	11.0466	8.4133	7.3279	3.4486	16.4042	0.0000	0.2434
Ukraine	GDP	267,536	274,243	18,957	-0.3808	1.5176	0.4946	0.1340
	r_t^s	18.0133	17.3870	6.6189	0.4717	2.5035	0.2065	0.1389
	r_t^l	12.3332	13.0061	2.1450	-0.0409	1.5303	0.5309	0.1033

This table reports the descriptive statistics of the data on real GDP, short-term interest rates (r_t^s) and long-term interest rates (r_t^l) for the U.S., Norway, Russia and Ukraine. In the last two columns, the results of the Augmented Dickey-Fuller (ADF) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests for the unit root and stationarity of the data series are presented respectively. The described data covers the period from 2000:Q1 to 2017:Q1 for the U.S., Norway and Russia and the period from 2010:Q1 to 2017:Q1 for Ukraine.

Table 3. Estimation of Cumulative and Marginal GDP Growth Models: the U.S.

Sample: U.S., t = {2002Q1; 2017Q1} *Observations: 61*

Cumulative GDP growth model

	Spread (5)				Spread + AR component (6)				
k	α_0	α_1	*Adj.* R^2	*SER*	γ_0	γ_1	γ_2	*Adj.* R^2	*SER*
1	0.76	0.62**	0.08	2.31	0.33	0.45*	0.40***	0.22	2.13
	(0.53)	(0.25)			(0.50)	(0.23)	(0.12)		
2	0.76	0.62**	0.12	1.92	0.16	0.26**	0.67***	0.53	1.40
	(0.82)	(0.29)			(0.42)	(0.13)	(0.14)		
4	0.59	0.71**	0.25	1.46	0.02	0.20**	0.81***	0.78	0.79
	(0.78)	(0.28)			(0.29)	(0.09)	(0.08)		
6	0.60	0.72***	0.40	1.15	0.04	0.16**	0.84***	0.86	0.54
	(0.61)	(0.23)			(0.26)	(0.08)	(0.06)		
8	0.67	0.70***	0.50	0.93	0.05	0.15**	0.84***	0.90	0.42
	(0.50)	(0.20)			(0.18)	(0.06)	(0.05)		
12	1.03**	0.54**	0.43	0.84	0.07	0.04	0.93***	0.92	0.31
	(0.54)	(0.21)			(0.12)	(0.04)	(0.05)		

Marginal GDP growth model

	Spread (7)				Spread + AR component (8)				
k/j	β_0	β_1	*Adj.* R^2	*SER*	δ_0	δ_1	δ_2	*Adj.* R^2	*SER*
2/1	1.03**	0.54**	0.43	0.84	0.48	0.38°	0.39***	0.20	2.15
	(0.54)	(0.21)			(0.50)	(0.24)	(0.12)		
4/2	0.51	0.77**	0.20	1.84	0.12	0.32*	0.64***	0.54	1.39
	(0.85)	(0.34)			(0.57)	(0.19)	(0.12)		
6/2	0.56	0.77*	0.23	1.79	0.25	0.27	0.63***	0.53	1.40
	(0.89)	(0.39)			(0.54)	(0.19)	(0.12)		
6/4	0.55	0.76**	0.34	1.37	0.10	0.18	0.80***	0.78	0.79
	(0.74)	(0.31)			(0.37)	(0.13)	(0.10)		
8/2	0.76	0.68*	0.19	1.85	0.34	0.20	0.66***	0.52	1.41
	(0.84)	(0.35)			(0.54)	(0.16)	(0.12)		
8/4	0.64	0.73**	0.33	1.38	0.18	0.10	0.82***	0.77	0.81
	(0.74)	(0.32)			(0.35)	(0.10)	(0.07)		
12/4	1.34°	0.33	0.06	1.64	0.35	-0.10°	0.91***	0.77	0.81
	(0.85)	(0.33)			(0.27)	(0.07)	(0.08)		
12/6	1.12°	0.46°	0.17	1.35	0.22	-0.09*	0.97***	0.86	0.56
	(0.74)	(0.29)			(0.25)	(0.06)	(0.07)		

This table reports the estimates of the OLS regressions for cumulative and marginal GDP growth in the U.S. as explained by the yield spread models (5), (7) and alternative extended models with AR(1) component (6), (8) for different forecasting horizons k, where j in models for the marginal GDP growth equals the number of quarters before k as chosen by the authors. The data is sampled quarterly over the period 2002:Q1 to 2017:Q1.
The Newey-West adjusted (HAC-consistent) standard errors are reported in parentheses.
°, *, **, *** indicate significance at the 85%, 90%, 95% and 99% level respectively.

Table 4. Estimation of Cumulative and Marginal GDP Growth Models: Norway

Sample: Norway, t = {2002Q1; 2017Q1} *Observations: 61*

Cumulative GDP growth model

	Spread (5)				Spread + AR component (6)				
k	α_0	α_1	$Adj. R^2$	SER	γ_0	γ_1	γ_2	$Adj. R^2$	SER
1	1.25**	0.53	0.00	4.38	1.68***	0.68°	-0.33**	0.10	4.18
	(0.59)	(0.47)			(0.59)	(0.45)	(0.12)		
2	1.26***	0.59**	0.06	2.51	1.08***	0.53**	0.13***	0.06	2.51
	(0.31)	(0.27)			(0.30)	(0.23)	(0.10)		
4	1.35***	0.46**	0.12	1.49	0.86***	0.29°	0.35***	0.21	1.41
	(0.31)	(0.23)			(0.29)	(0.18)	(0.12)		
6	1.42***	0.33*	0.09	1.25	0.55**	0.11	0.60***	0.40	1.01
	(0.25)	(0.20)			(0.26)	(0.10)	(0.09)		
8	1.45***	0.31*	0.11	1.05	0.35*	0.06	0.75***	0.60	0.70
	(0.20)	(0.16)			(0.18)	(0.06)	(0.09)		
12	1.57***	0.10	0.00	0.95	0.28*	-0.04	0.82***	0.66	0.56
	(0.29)	(0.13)			(0.16)	(0.04)	(0.08)		

Marginal GDP growth model

	Spread (7)				Spread + AR component (8)				
k/j	β_0	β_1	$Adj. R^2$	SER	δ_0	δ_1	δ_2	$Adj. R^2$	SER
2/1	1.20**	0.70°	0.02	4.34	1.64***	0.86*	0.33***	0.12	4.12
	(0.58)	(0.46)			(0.58)	(0.44)	(0.12)		
4/2	1.35***	0.41	0.02	2.56	1.16***	0.33	0.14	0.03	2.56
	(0.36)	(0.32)			(0.31)	(0.33)	(0.11)		
6/2	1.44***	0.15	-0.01	2.61	1.18***	0.12	0.18*	0.01	2.59
	(0.40)	(0.34)			(0.35)	(0.31)	(0.11)		
6/4	1.43***	0.25	0.03	1.57	0.83**	0.11	0.41***	0.17	1.45
	(0.35)	(0.26)			(0.32)	(0.19)	(0.14)		
8/2	1.41***	0.24	0.00	2.60	1.16***	0.20	0.17	0.01	2.58
	(0.39)	(0.30)			(0.34)	(0.28)	(0.12)		
8/4	1.44***	0.20	0.01	1.58	0.82**	0.11	0.42***	0.17	1.45
	(0.36)	(0.25)			(0.33)	(0.17)	(0.14)		
12/4	1.56***	-0.24	0.02	1.57	0.90***	-0.21	0.43***	0.20	1.43
	(0.33)	(0.25)			(0.31)	(0.16)	(0.13)		
12/6	1.55***	-0.09	-0.01	1.32	0.54***	-0.11	0.64***	0.40	1.01
	(0.34)	(0.23)			(0.26)	(0.09)	(0.11)		

This table reports the estimates of the OLS regressions for cumulative and marginal GDP growth in Norway as explained by the yield spread models (5), (7) and alternative extended models with AR(1) component (6), (8) for different forecasting horizons k, where j in models for the marginal GDP growth equals the number of quarters before k as chosen by the authors. The data is sampled quarterly over the period 2002:Q1 to 2017:Q1.
The Newey-West adjusted (HAC-consistent) standard errors are reported in parentheses.
°, *, **, *** indicate significance at the 85%, 90%, 95% and 99% level respectively.

Table 5. Estimation of Cumulative and Marginal GDP Growth Models: Russia

Sample: Russia, t = {2002Q1; 2017Q1} *Observations: 61*

Cumulative GDP growth model

	Spread (5)				Spread + AR component (6)				
k	α_0	α_1	Adj. R^2	SER	γ_0	γ_1	γ_2	Adj. R^2	SER
1	2.87***	1.12***	0.30	5.05	1.49**	0.37	0.51***	0.41	4.63
	(0.65)	(0.22)			(0.71)	(0.29)	(0.14)		
2	2.83***	0.70***	0.15	5.06	0.33	-0.38	0.93***	0.63	3.36
	(0.92)	(0.23)			(0.85)	(0.29)	(0.15)		
4	2.83***	0.45***	0.12	4.30	0.20	-0.14	0.95***	0.80	2.03
	(0.98)	(0.15)			(0.50)	(0.14)	(0.06)		
6	2.85***	0.31**	0.11	3.74	0.10	-0.06	0.97***	0.88	1.35
	(1.02)	(0.12)			(0.33)	(0.08)	(0.03)		
8	2.99***	0.16**	0.07	3.44	0.05	-0.04	0.98***	0.91	1.05
	(0.81)	(0.07)			(0.25)	(0.03)	(0.03)		
12	3.26***	0.06***	0.10	2.87	-0.05	-0.01	0.99***	0.94	0.72
	(0.40)	(0.02)			(0.15)	(0.01)	(0.03)		

Marginal GDP growth model

	Spread (7)				Spread + AR component (8)				
k/j	β_0	β_1	Adj. R^2	SER	δ_0	δ_1	δ_2	Adj. R^2	SER
2/1	2.95***	0.50**	0.05	5.88	1.14*	-0.11	0.67***	0.40	4.65
	(0.76)	(0.24)			(0.68)	(0.21)	(0.11)		
4/2	2.86**	0.31	0.03	5.42	0.63	0.06	0.77***	0.60	3.45
	(1.12)	(0.21)			(0.95)	(0.12)	(0.16)		
6/2	2.77**	0.26*	0.03	5.42	0.58	0.07	0.77***	0.60	3.45
	(1.15)	(0.15)			(0.90)	(0.08)	(0.15)		
6/4	2.84**	0.27**	0.05	4.46	0.25	0.03	0.89***	0.80	2.07
	(1.13)	(0.13)			(0.49)	(0.03)	(0.07)		
8/2	2.87**	0.10	0.00	5.50	0.61	0.02	0.78***	0.60	3.45
	(1.18)	(0.10)			(0.91)	(0.06)	(0.14)		
8/4	2.86**	0.14*	0.03	4.53	0.24	0.02	0.89***	0.79	2.07
	(1.16)	(0.08)			(0.51)	(0.02)	(0.07)		
12/4	2.87**	0.05°	0.02	4.55	0.20	0.02***	0.89***	0.80	2.08
	(1.21)	(0.03)			(0.30)	(0.00)	(0.06)		
12/6	2.97***	0.04*	0.02	3.93	0.08	0.01*	0.94***	0.88	1.37
	(1.07)	(0.03)			(0.34)	(0.01)	(0.06)		

This table reports the estimates of the OLS regressions for cumulative and marginal GDP growth in Russia as explained by the yield spread models (5), (7) and alternative extended models with AR(1) component (6), (8) for different forecasting horizons k, where j in models for the marginal GDP growth equals the number of quarters before k as chosen by the authors. The data is sampled quarterly over the period 2002:Q1 to 2017:Q1.
The Newey-West adjusted (HAC-consistent) standard errors are reported in parentheses.
°, *, **, *** indicate significance at the 85%, 90%, 95% and 99% level respectively.

Table 6. Estimation of Cumulative and Marginal GDP Growth Models: Ukraine

Sample: Ukraine, t = {2010Q1+k; 2017Q1} *Observations: 28–k*

Cumulative GDP growth model

	Spread (5)				Spread + AR component (6)				
k	α_0	α_1	*Adj.* R^2	*SER*	γ_0	γ_1	γ_2	*Adj.* R^2	*SER*
1	1.25	0.40°	0.04	9.19	0.76	0.32	0.28	0.10	9.05
	(2.35)	(0.27)			(2.34)	(0.29)	(0.20)		
2	0.68	0.30	0.03	7.71	-0.38	-0.01	0.71***	0.46	5.85
	(2.52)	(0.24)			(1.85)	(0.19)	(0.20)		
4	-1.36	0.01	-0.04	6.65	-1.11	-0.14	0.87***	0.72	3.41
	(3.09)	(0.20)			(0.96)	(0.12)	(0.12)		
6	-1.22	0.12	-0.02	5.52	-0.21	0.04	0.86***	0.78	2.54
	(2.66)	(0.14)			(0.44)	(0.09)	(0.07)		
8	-1.26	0.19*	0.05	4.34	-0.28*	0.04	0.84***	0.79	1.99
	(1.78)	(0.11)			(0.15)	(0.06)	(0.03)		

Marginal GDP growth model

	Spread (7)				Spread + AR component (8)				
k/j	β_0	β_1	*Adj.* R^2	*SER*	δ_0	δ_1	δ_2	*Adj.* R^2	*SER*
2/1	-0.24	0.17	-0.02	9.63	-0.81	0.00	0.36*	0.05	9.45
	(2.51)	(0.29)			(2.48)	(0.30)	(0.21)		
4/2	-2.88	-0.26	0.01	8.05	-2.01	-0.20*	0.68***	0.49	5.62
	(3.86)	(0.24)			(1.40)	(0.11)	(0.15)		
6/2	-0.23	0.31	0.03	7.81	1.35	0.38**	0.69***	0.55	5.38
	(2.39)	(0.23)			(1.49)	(0.17)	(0.15)		
6/4	-1.74	0.03	-0.05	6.68	-0.05	0.09	0.82***	0.69	3.56
	(2.54)	(0.19)			(0.75)	(0.10)	(0.14)		
8/2	0.21	0.47	0.14	7.47	-0.13	0.18	0.59**	0.42	6.27
	(1.26)	(0.37)			(1.39)	(0.27)	(0.21)		
8/4	-0.36	0.38	0.15	5.84	0.67	0.24	0.75***	0.72	3.37
	(1.06)	(0.27)			(0.98)	(0.16)	(0.12)		

This table reports the estimates of the OLS regressions for cumulative and marginal GDP growth in Ukraine as explained by the yield spread models (5), (7) and alternative extended models with AR(1) component (6), (8) for different forecasting horizons *k*, where *j* in models for the marginal GDP growth equals the number of quarters before *k* as chosen by the authors. The data is sampled quarterly over the period 2010:Q1 to 2017:Q1.
The Newey-West adjusted (HAC-consistent) standard errors are reported in parentheses.
°, *, **, *** indicate significance at the 85%, 90%, 95% and 99% level respectively.

Table 7. Out-of-Sample Forecasts Evaluation

		Forecasting Model		
		AR(1)	Spread	Spread + AR(1)
U.S.	RMSE	0.5712	**0.3656**	0.5505
	D-M		0.0827	0.8492
Norway	RMSE	1.1697	**1.1251**	1.1341
	D-M		0.0899	0.2983
Russia	RMSE	**2.2012**	2.4139	2.5666
	D-M		0.5223	0.4724

This table reports the estimates of the Root Mean Squared Errors (RMSE) and Diebold-Mariano statistics for the AR(1), yield spread factor model and alternative spread model (with an AR(1)-component) of the chosen forecasting horizon k for the U.S. (k = 8), Norway (k = 4) and Russia (k = 1). The Diebold-Mariano (D-M) statistic is HLN-adjusted for the small sample size and is calculated relatively to the benchmark model AR(1). Bold entries indicate the preferred forecasting model with lowest errors measure. The forecast evaluation period is: 2015:Q2 to 2017:Q1.