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Macroeconomic Effects of Oil Prices on US Term Structure and Economic Growth of Oil-Exporting Emerging Economies

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Dedication

This thesis is dedicated to my Heavenly Father, Jesus Christ; and my lovely parents, Mr. Henry Agboola Akinlosotu and Mrs. Deborah Oluyemi Akinlosatu

Declaration

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Abstract

This dissertation is a combination of three key papers that investigate the impact of oil prices on the US term structure and economic growth of emerging oil-exporting economies. The first paper launches an investigation into the US term structure by examining the impact of a global factor (such as oil prices) alongside macroeconomic fundamentals (such as drivers of inflation and economic activity). The novelty of this paper lies in its methodological contribution to the macro-finance literature by developing a six-factor Gaussian Affine model that incorporates a global factor to improve both the in-sample fit and forecast performance of the US term structure of interest rates. The results show that introducing oil price as a global factor into the term structure model helps fit the yield curve better, as the model produces the lowest forecast error compared to competing models. As expected, the macro factor captured in this model plays a significant role in predicting the information of the yield curve in both the short-run and long-run. This chapter motivates future work to look into introducing other global factors, such as economic policy uncertainty, to capture global uncertainty. The second paper focuses on cross-country growth econometrics, based on some competing modelling approaches accounting for regressor endogeneity and individual heterogeneity, as well as period-specific and country-invariant factors associated with cross-country growth regressions. The analysis of this chapter addresses how significant institution quality, alongside the information in the US bond yields and oil prices, are in determining growth in small open oil-exporting emerging economies. Evidence from our preferred model, which is the corrected least square dummy variable (CLSDV II), where we tested the impact of institutional quality, shows that among the variables investigated, oil prices, the US term structure of interest rates, gross capital formation, and institutional quality report a significant impact on the growth rate of these countries. Thus, governments of developing oil-exporting economies will be able to solve the renowned "resource curse paradox" by devoting significant effort into building a strong institutional framework that can efficiently drive other growth determinant variables. The third paper considers the possibility of asymmetries or nonlinear relationships between oil price shocks and GDP growth and fiscal spending. Therefore, the Kilian and Vigfusson (2011*b*) model nests the linear case and computes the Impulse Response Functions (IRFs) correctly in nonlinear models. Evidence emanating from our VAR process reveals some statistically significant evidence of a negative relationship between oil prices and economic growth, which is further affirmed by our IRFs result. In explaining the disparity in growth patterns witnessed in these emerging oil-exporting countries, we examine the transmission mechanism of oil price shocks to the real economy of emerging countries by investigating the fiscal policy habit adopted by these countries on their level of output. Our findings show some statistically significant clear evidence (for Bolivia and Brazil) of fiscal co-movement with oil prices.

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Chapter 1

Introduction

Individual countries possess distinct characteristics, such as natural resources, trade, and income level, among others, that make them stand out among their counterparts and be classified into social, economic, and political rankings. Moreover, in some other cases, researchers have investigated domestic dynamics by categorizing them based on their levels of development, such as developing and developed economies, to determine policies applicable for different categories. It is obvious that economic activities of developing or emerging economies are heavily linked to their developed counterparts, such as the US macro and policy dynamics. Hence, it becomes impossible to discuss the growth of emerging economies without examining the interplay between these economies. However, understanding the transmission mechanisms of how developed economy fundamentals to oil-exporting emerging economies become paramount to this dissertation. In this case, aside from the limitation of data related to the selection of oil-exporting countries, it is important to note that for these countries, oil exports account for the majority of the total share of exports to GDP (about 40% of GDP) and contribute significantly to the government budget.

Among existing transmission mechanisms, such as exchange rate, stock return, yield return, and interest rate, one transmission mechanism that has not been rigorously investigated but has been recognized as the most useful mechanism to predict growth in emerging economies is the slope of the yield curve (specifically, the US term structure of interest rate). However, to the best of my knowledge, there have not been extensive investigations into oil-exporting emerging economies (Mehlum et al. (2006)), as most literature has examined the impact of the yield curve on industrialized economies (see, for example, Arnwine et al. (2004); Estrella (2005); Greenspan (2005), among others). This has come under watch as, in recent times, the inversion of the US yield curve signals a debate for possible implications of a recession. Although scholars have forcefully challenged the idea of future growth of emerging economies being determined by the slope of the yield curve (Greenspan (2005); Bernanke (2006)).

The existing connection between the US yield curve and emerging economies' growth rate is through the possible ability to predict its inflation rate, which plays a key role in the policy development of these countries. Moreover, the spillover from the financial crisis, which originated specifically from the US, has changed the pattern of the international monetary system (Monetary and Committee (2006)). The small market size of emerging economies makes it possible for activities in large economies such as the US to serve as a determining factor in their inflation and growth rate. With this, we can expect further impact on stocks given the high liquidity of the security markets compared to the emerging economies. Finally, exchange rate policies of emerging economies are closely linked with the US dollar, which pronounces the pass-through from US interest rate policies to domestic interest rates of emerging economies.

Before replicating the impact of the term structure of interest on growth in emerging economies, it is critical to understand the forecasting methods employed in the literature. This is important for financial firms, including banks, policymakers, governments, and society at large, to interpret the flow of money and market movements and make decisive decisions. Enormous existing literature exists that has developed several models, ranging from three-factor, four-factor, and five-factor models, to predict the term structure of interest rate dynamics. Nonetheless, these studies have failed to account for the impact of global shocks, except for the recent paper by Abbritti et al. (2018), which incorporated global inflation and growth. Global forces have been indicated in literature to impact the yield curve of cross-country government. For example, the contemporary credit crisis reflect that macro-finance shocks can be transferred to the global market. As a result, the integrated financial system, foreigner holds a large amount of domestic government credit at the international capital markets. Therefore, foreign bonds are usually determined by a domestic country's macro-finance positions, and vice versa. The original paper by Hamilton (1983) emphasized the impact of oil price volatility on the US economy by concluding that the unprecedented rise in oil price contributed to the 1948–1972 US recession. This evidence, coupled with the early 2000 spike and unexpected 2008 fall in oil prices that led to the Lehman crisis, sparked scholars' keen interest in investigating the role of oil price volatility in the macro-economy. Recent work by Hamilton (2009); Yoshino and Taghizadeh-Hesary (2014), among others, further reviews this topic. Despite this established stylized evidence, existing papers on the term structure of interest rate have given little account of the role of international spill-over on the information contained in the yield curves. Although, Aydoğan et al. (2017) documented the existing correlation between oil prices and the stock market, it is dependent on whether the country is an oil-importing or oil-exporting economy. Hence, this dissertation addresses this challenge and investigates the role of global factors such as oil price shocks in predicting the yield curve for an industrialized country such as the US.

To this end, we introduce the role of oil price shocks as a global factor in modeling the yield curve. Our model presents the yield curve determinants (level, slope, and curvature) accompanied by a set of two additional macro factors, similar to the study of Ang et al. (2006). These factors are extracted from the principal components of six predictors of inflation, such as the Consumer Price Index (CPI), Producer Price Index (PPI), Personal Consumption Expenditure (PCE), Core CPI, Core PPI, and Core PCE, and four predictors of economic activity, such as the employment rate, unemployment rate, capacity utilization rate, and industrial production. Generally, most existing literature that has predicted the US term structure has adopted the close-economy framework through the three-to-five-factor model (see, for example, Ang and Piazzesi (2003); Bekaert et al. (2010); Rudebusch and Swanson (2008) Wright (2011); among others). However, our paper steps out from this framework to model the term structure of interest rates from an open-economy perspective. Our approach of no-arbitrage Gaussian process (see, Duffie and Kan (1996); Dai and Singleton (2002)) is linked with the rapidly growing body of literature on recent models for affine term structure. The question of interest here is whether the introduction of oil price shocks into the existing affine term structure model helps fit the yield curve better. Evidence (although limited) has been presented in the literature that independently investigates the impact of oil price shocks on the term structure of interest rates in various industrialized countries and has found a significant role played by oil prices (see, the recent work of Ioannidis and Ka (2018) among others). Moreover, the choice of our global factor portrays a useful economic interpretation as recent oil price shock episodes depict a direct impact on macroeconomic conditions for both oil-importing and exporting countries. Subsequently, understanding the model that performs better based on the comparison of the Root Mean Squared Error (RMSE) computed for the three-factor, four-factor, five-factor, and six-factor models becomes an interesting empirical innovation that our paper seeks to report.

Over time, one of the key drivers of business cycle fluctuations has been oil price volatility. Following the initial shocks of the 1970s, which witnessed a drastic rise in global demand for oil, a considerable number of empirical studies have focused on uncovering the role of oil shocks on macroeconomic activities. However, the debate remains as to the relative impact of these shocks on economies of oil exporters and importers. Policy makers have shown a keen interest in understanding the transmission channels of typical and large shocks, as well as developing the right policy tools for adequate response during these periods. Although, discourse exists regarding the evolution of oil shocks for mostly oil-importing developed economies, the effect of these shocks has not been extensively explored for oil-exporting emerging economies. Few studies exist, leaving the question of the link between business cycle dynamics and oil shocks with inconclusive or limited answers.

In oil-exporting emerging economies, macroeconomic conditions often co-move with oil price evolutions through periods of boom and bust. In most cases, economies that commonly come under pressure during periods when oil prices plunge, as well as benefit from windfalls during periods of oil price increase, are the oil-dependent countries. While the impact of positive oil shocks (an increase in oil price) on the economic growth of resource-rich economies remains a debate, the effect of a consistent fall in price is pronounced through deteriorating macroeconomic performance. The vulnerabilities of these economies tend to silence the possible benefits of these positive oil shocks, evident through their revenue volume in the long run, which have not materialized any significant impact on economic growth. The usual assumption is that when these countries experience an oil price rise in the global market, they are expected to benefit from large capital inflows in the usual dollar currency, which should translate to boosting the domestic exchange rate and, in turn, cause the cost of importation to fall, leading to growth. Could this be prominent evidence of the resource curse paradox, which can be tested through the "Dutch Disease" hypothesis for resource-rich countries? This is one interesting discovery that would emanate later in this dissertation, as scholars have continuously attributed this experience to the persistent weak institutions present in these oil-exporting emerging economies.

Several studies have made efforts to investigate this disappointing growth experienced by resource-rich countries as well as formulate different theories as to why these countries experience slower growth compared to non-resource countries. The two major lines of attraction established in the literature include those that investigated the impact of traditional economic determining factors of growth (see, pioneering works of Basu and McLeod (1991); Sachs and Warner (1995*a*); Mendoza (1997); Rodriguez and Sachs (1999)), and on the other hand, studies that have incorporated the importance of institutional and political factors (see, Mehlum et al. (2006); Isham and Busby (2005); Sala-i Martin and Subramanian (2003*b*) among others) which reflect the "policy choice" of developing oil-exporting countries compared to their developed counterparts. In the search for deep determining factors of growth, the role of institutional factors has been viewed by current literature as significant following dissatisfaction towards the prominent neoclassical growth model that emphasizes investment and capital accumulation as the key instrument to growth. Despite the basic understanding that technological innovation or capital accumulation accounts for significant long-term differences in growth or per capita output, the question as to why some countries succeed and others fail to do well remains unanswered.

Contrary to this theoretical foundation, the emergence Contrary to this theoretical foundation, the emergence of the new institutional economics (NIE) was led by pioneering works such as North and Thomas (1973), North (1981), North et al. (1990), and North (2010). The main objective of the NIE approach was to extend the neoclassical economics approach to growth by introducing institutional factors to explain long-run economic growth. According to the NIE framework, predicting indices for institutional factors include political stability, rule of law, voice and accountability, control of corruption, property rights protection and contract enforcement, and bureaucratic capability. Hence, our aim at this point is to extend the traditional growth model by incorporating the direct impact of institutional factors alongside the US term structure, oil price shocks, and other traditional determinants of economic growth. Among other things, this will help answer the question of "what role do institutions play in the growth of emerging oil-exporting economies?"

Following the series of global oil shocks in the years 1973, 1979, 2000, and 2016, including the recent financial crisis of 2007-2008 (perceived as the most complex and deepest crisis experienced since the Great Depression) that impacted economies worldwide, developing economies witnessed the implementation of counter-cyclical fiscal policies to hedge the negative effects on output, enabling them to maintain social expenditure. However, empirical evidence suggests that during economic downturns, developed economies often adopt counter-cyclical fiscal policies while developing countries pursue pro-cyclical fiscal policies (Aghion et al. (2007); Darby and Melitz (2008)). Among other factors identified in the literature that have provided resilience for developing countries to tackle financial and economic crises and respond better to these problems than their developed counterparts, institutional quality, lower inflation rates, fiscal surpluses, and enhanced reserves have played crucial roles (Didier and Schmukler (2011)). Overall, developing countries have been perceived to recover faster than their developed counterparts since they experienced lesser declines in growth rates and faster recovery rates, with the World Bank reporting higher levels of growth for developing countries in 2011 and 2012. Similarly, developing countries have shown faster recovery in trade, with import demand rising twice both in value and volume compared to their developed counterparts (Frankel (2010*a*)). Therefore, it is vital to investigate this convergence hypothesis by answering the question: will the growth of developing countries catch up with their developed counterparts over time?

Although, a considerable amount of research has established the role of institutional factors as the main cause of economic failure in developing oil-exporting economies (see, for example the works of Mehlum et al. (2006); Béland and Tiagi (2009) among others), some other researchers have linked the deteriorating economic situation in these countries to the resource curse paradox (the negative impact of resource abundance) (see, the initial work of Sachs and Warner (1995*a*)). With continuous volatility of oil prices, the question of how resource-rich emerging economies react to the challenges of the "resource curse," evident through their growth pattern, has regained strong importance and interest in the scope of macroeconomic research. Empirical evidence on the "resource curse" remains inconclusive with mixed findings emanating from literature showing some cases of positive impacts of oil shocks (see, De V. Cavalcanti et al. (2015); Arezki and van der Ploeg (2007); Esfahani et al. (2014) among others) and in some other cases, a negative impact has been recorded (see, Bulte et al. (2005); among others)– presenting a case of growth differences among emerging oil-exporting economies. Countries with more pronounced growth appear to have an operating floating exchange rate regime coupled with a diversified economy (for example, Malaysia) as they tend to recover faster than countries that operate on a fixed exchange rate regime and are heavily dependent on oil proceeds. In addition, Grigoli et al. (2017) maintained that those countries with a more stable inflation rate and have large foreign reserves showed greater prospects and resilience towards oil price shocks.

One obvious stylized fact of oil-exporting emerging economies' growth rates from the shocks of the 1970s till date is that they are characterized by slower growth rates compared to their developed counterparts or non-oil-exporting countries. However, the rate of growth across these countries varies depending on their response to these shocks. This is a consequence of the policy response to counter the shocks through various microeconomic and macroeconomic transmission mechanisms. The differences in growth rates among emerging oil-exporting economies are attributed to a number of reasons, including econometric methods employed for studies that reported a negative impact of oil abundance on growth. One prominent econometric problem spotted in literature is the cross-section approach used to test the resource curse hypothesis, making it difficult to account for time effects of data employed as well as the varying measures of oil price shocks.

It is important to note that the positive relationship between resource abundance and economic performance is not automatic, but rather depends on how the revenue generated from resources is spent. Therefore, our aim is to provide an explanation of the transmission mechanism of oil price shocks to the economies of developing oil-rich countries. One major channel we explore in our research is the fiscal policy response of these countries, with the hope of explaining the growth differences reported in existing studies as well as the common traits attributed to resource-rich countries. In exploring the challenges of fiscal management in these countries and their implications for growth, we document in subsequent paragraphs the common situations faced by these countries during periods of shocks, both in terms of their size and magnitude.

Oil price fluctuations are transmitted to the economy through severe income fluctuations of the government. The uncertainty of future oil income causes government spending to vary following the reassessment of expected income. This results in pro-cyclical fiscal policy being adopted, which leads to a declining growth rate. During periods of positive oil price shocks that are perceived to be consistent, government spending typically increases, specifically on the non-tradable sector by diverting resources away from the tradable sector. The consequence of this is a rise in the unemployment rate and a decline in output productivity. This occurrence is often regarded as the "Dutch disease" since the oil revenue windfall will have a negative impact on long-term growth. In contrast, a negative shock results in a downward adjustment of government spending. In this scenario, reducing current expenditure is usually not considered due to its negative social effects. Similarly, reducing capital expenditure would imply halting the progress of public projects that will, in turn, decrease the productivity of existing investments and increase social costs.

To this end, this dissertation is faced with a number of questions/hypotheses that need to be solved and tested to provide comprehensive insights to policymakers, governments, investors, and society at large. The questions set out in this dissertation are as follows:

- Do global factors, such as oil price shocks, improve the yield curve's predictive power?
- Does the six-factor model outperform existing three-to-five-factor models in forecasting?
- What role do institutional factors play in shaping the growth of emerging oil-exporting economies?
- Is there evidence of growth convergence among emerging economies towards their developed counterparts, or are they falling behind?
- What impact do external conditions have on the growth of emerging oil-exporting economies?
- Is there an asymmetric relationship between oil prices and economic activity in emerging oil-exporting economies?
- How does fiscal policy in emerging oil-exporting economies respond to oil shocks?

The subsequent chapters in this dissertation will attempt to close gaps in the existing body of literature by addressing the above questions through investigating the impact of the US term structure of interest rate, institutions, and oil price on emerging oil-exporting economies. The first paper develops a six-factor Gaussian Affine Model to forecast the term structure of interest rate by investigating the link between the term structure of interest rate and macroeconomic conditions through an integrated "macro-finance perspective". Additionally, the paper examines the volatility of the yield curve explained by macroeconomic indicators by investigating the predictive strength of both latent factors and macroeconomic variables to determine which element contributes more to the yield's volatility. The second paper focuses on integrating our predicted US term structure into the traditional standard growth model to explain the role of institutional quality in the economic growth of selected small open oil-exporting emerging economies. The third paper investigates the role of oil price shocks as a transmission mechanism in resource-rich emerging economies, as well as examining the role fiscal policy plays in explaining the growth differences experienced for the selected countries.

In the first chapter, we examined the term structure of interest rates and macroeconomic fundamentals for the case of the United States. The novelty of this paper is the development of a model capable of predicting the entire 30-year yield curve instead of limiting the prediction to certain interest rates, as continuously repeated in empirical studies. This paper is one of the first sets of empirical research that investigates US bond yields from an open economy perspective while integrating macroeconomic fundamentals, as existing studies have examined the term structure of interest rates for the US from a closed economy perspective. Using monthly data spanning from 01:01:1986 – 01:11:2018, we examined the responsiveness of latent factors that explain the term structure (i.e., level, slope, and curvature) derived from the Gaussian model using the Kalman filter and the adoption of the maximum likelihood test for macroeconomic releases. Based on the six-factor model assumed to follow the Gaussian process developed for forecasting yields of zero-coupon bonds, the study finds that the estimation obtained from the yield forecast shows that the model works well for predicting up to 30-year maturity for the case of the full sample. The root-mean-square-error (RMSE) reported shows that our six-factor forecast process recorded minimal error and outperforms the benchmark model of Ang and Piazzesi (2003) previously reported in existing literature. Overall, the introduction of a global factor variable significantly contributed to better fitting the term structure for the US, with the predictive power of our macro factors more amplified than the latent factors. Additionally, deploying the Diebold-Mariano test to compare our six-factor forecast error with that of the traditional autoregressive (AR) one-month ahead forecast, statistics show that forecast error from the six-factor model is smaller than that reported from the traditional autoregressive (AR) forecast.

The objective of the second paper chapter focuses on introducing our predicted US term structure into a traditional standard growth model while investigating predictors of economic growth in emerging economies. Specifically, we study the impact of institutional quality as a key driver of growth in small open oil exporting emerging economies and any evidence of convergence for emerging economies to their developed counterparts. Modifying the traditional standard growth model, we incorporate the institutional quality index, global oil price, US term structure of interest rate, alongside other growth determinants in investigating growth dynamics of emerging economies using annual data spanning from 1990–2018. The choice of our data span is constrained to the availability of a rich database for our selected countries. Using the Root Mean Square Error (RMSE) for model comparison, we found the Corrected Least Square Dummy Variable (CLSDV II) for dynamic panel data as the best model to explain the growth situation of our selected emerging economies (Brazil, Bolivia, Colombia, Ecuador, Indonesia, Malaysia, Nigeria). It is noticeable that oil price, gross capital formation, institutional quality, and information contained in the US term structure are significantly related to economic growth in emerging economies with institutional quality depicting the highest predictive value of about 15% of the growth recorded in emerging economies. There is evidence of convergence for the emerging economies to their developed counterparts as the initial level of output coefficient depicts a lower negative value. Furthermore, we performed a robust check to compare the performance of our choice of including our predicted US term structure of interest rate into the modified growth model rather than the traditional US short-term Fed rate or the shadow rate. Using the AIC and BIC criteria, our predicted short-term US interest rate depicts the lowest AIC and BIC value, thereby outperforming the traditional Fed rate and Shadow Rate in explaining the growth situation in emerging oil-exporting economies.

In the third chapter, we consider that oil exports make up approximately 40% of the GDP for the selected emerging economies. This leads to some interesting research questions, such as whether the relationship between economic activity and oil prices is asymmetric in oil-exporting emerging economies and how fiscal policy in these economies reacts to oil price changes. We address these questions by examining the asymmetries and macroeconomic impact of oil price transmission in small open oil-exporting emerging economies, using quarterly data spanning from Q1:2000 to Q3:2018. Despite the limited availability of rich databases for our selected countries, our choice of year span captures several recent oil price shocks, including the unprecedented 70% fall in oil price between mid-2014 and 2016, which is among the three significant oil shocks witnessed in recent times (see the later chapter for detailed information). We test and evaluate the premise that the responses from oil price shocks to GDP growth and adjustments of public expenditure are asymmetric using techniques developed by Kilian and Vigfusson (2011*b*) building on censored-regressor nonlinear VARs. Our results provide substantial empirical support for the presence of asymmetries for the sample containing a group of oil-exporting emerging markets. We find that discretionary fiscal policy is a key transmission mechanism for the oil price movements to the real economy of oil-dependent countries.

Chapter 2

Term Structure Dynamics with Unobservable and Observable Factors: A no-arbitrage VAR approach

2.1 Introduction

Understanding the dynamics of the yield curve has become of great interest to both the finance and economics fields. Given future economic conditions, central bankers have closely examined the term structure of interest rates to gauge market participants' expectations. Therefore, investors interested in financial markets are expected to pay close attention to fixed income securities' price movements as they contain substantial information necessary for asset allocation and risk management.

Undoubtedly, macroeconomic indicators affect bond market behavior, but measuring the magnitude and direction of these indicators' effects on the bond market remains a puzzle. Researchers face difficulties in introducing macroeconomic fundamentals and measurements into the term structure of interest rates (see, for example, Ang and Piazzesi (2003); Kim and Park (2013); Dewachter and Lyrio (2006); Diebold et al. (2006)). Now, the question that comes to mind is, "Is it possible to uncover the dynamics between interest rate term structure and macroeconomic factors using a frequency that suits the velocity of information provided on the bond market floor?"

Hence, investigating the collective behavior of the yield curve and macro factors is key for asset pricing, public policy, and investment decision-making. Many existing term structure models used to explain the movements of the term structure mostly use latent factor models, and although these latent factors come with some explanation, they are not given an absolute comparison with macro factors. Some studies have given their latent factors names they are comfortable with, like the study of Litterman and Scheinkman (1991), who named their factors "level", "slope", and "curvature", while Dai and Singleton (2000) labeled theirs "level", "slope", and "butterfly". Irrespective of the names used to label these factors, the most important thing to note is that these factors account for the effect they have on the yield curve rather than interpreting the shocks' economic source.

The factor models depict an advantage of only being able to implement no-arbitrage conditions rather than all conditions that describe the economy's equilibrium. This is in the absence of a general equilibrium model for pricing assets (see, for example, Hansen and Jagannathan (1991)). The majority of existing factor models have been identified as unsatisfactory by Ang and Piazzesi (2003) as they fail to model the direct response of yields to macro factors. On the contrary, previous empirical studies have put in effort to use Vector Autoregressive (VAR) models to directly model the nexus between bond yields and macroeconomic factors. For instance, the studies of Estrella and Mishkin (1997), Evans and Marshall (1998), and Ang and Piazzesi (2003) employed the VAR technique that contains different yield maturities and macro indicators. These studies investigate the relationship between yield movements and macro variables by deducing the variance decomposition and impulse response functions (IRFs). For example, Ang and Piazzesi (2003) linked shocks of inflation and economic activity to level and slope effects across the yield curve horizons, while Evans and Marshall (2001) related shocks of price levels and economic activity to level effects over the yield curve. Asset-pricing studies originally from Sargent (1979) have attempted to model the VAR system of yields in accordance with the null of the Expectations Hypothesis (see also Bekaert and Hodrick (2001)). However, this system lacks the inclusion of macro factors, which is one area of focus for our paper. Hence, the dynamics of the term structure model in our paper follow a Gaussian term structure model that is consistent with deviations from the Expectations Hypothesis (EH). [1]

Our paper makes a novel contribution to the body of literature by not only including macroeconomic variables as observable factors but also introducing a global factor such as oil price as an observable factor into our term structure model by employing a factor representation in our pricing kernel that allows all bonds in the economy to be priced. This makes it more direct to model and trace the effect of macro factors on bond prices. Shocks from both unobservable and observable factors drive the pricing kernel. Given that macro variables are correlated with yields, the inclusion of these variables may produce a better forecast than models that have omitted them. Our paper examines whether macro variables can explain a straight unobservable factors of multiple factor term structure models. Likewise, we investigate the behavior of latent factors with the introduction of macro factors into the term structure models.

Several advantages emerge from our methodology over previous empirical VAR approach studies. First, our model allows for direct comparison of latent yield factors with macro variables. Second, our term structure models include yield maturities for up to 30 years. Third, rather than just understanding the behavior of yields included in the VAR process, our model enables us to identify changes in the entire yield curve response to macro shocks. Fourth, our variance decomposition technique can help estimate the portion of the term structure movement associated with macro shocks as well as latent variables. Lastly, given that our VAR process is subject to nonlinear no-arbitrage restrictions, our model maintains the VAR approach tractability.

Given that our term structure model is Gaussian and thus a VAR model, it is easy to compute the impulse response functions (IRFs) and variance decompositions. Specifically, our model presents a unique version of a discrete-time model originally proposed by Duffie and Kan (1996), which sets out bond prices as exponential affine functions of essential state variables, some of which are observable macro indicators in our model. The affine model can be reduced to a VAR with cross-equation restrictions in the Gaussian process.

[1] See Dai and Singleton (2002), Duffee (2002), and Fisher (1998) for further review.

Therefore, our model allows us to compute variance decompositions that help to spell out the proportion of yield curve movements associated with observable and unobservable factors. Subsequently, we can extract the IRFs graph of shocks to different factors on any yield maturity, as the no-arbitrage model provides bond prices for the entire maturity spectrum.

In our paper, we form our observable macro factors by using principal component analysis to extract two groups of factors that measure price changes and economic growth, which we use as proxies for inflation and real activity as an internal variable effect. For the external variable effect, we use oil prices as a global variable. These observable factors are then accompanied by latent factors. Based on existing term structure studies that propose the adoption of up to three latent variables as satisfactory to account for the most principal attributes of the yield curve, we construct our term structure model using a similar approach, containing three latent factors (labeled level, slope, and curvature), two macro factors (labeled inflation and real activity), alongside one global factor (labeled oil prices).

Our results show that the imposition of no-arbitrage cross-equation restrictions not only improves in-sample forecast performance but also helps to produce better out-of-sample forecast performance from the VAR process. The forecast performance further improves with the introduction of macro variables into the term structure model with the existing latent factors. Evidence in our paper shows that a crucial part of the unobservable factors inferred from the traditional models with only latent variables from yields is associated with macro factors. Specifically, two latent factors out of three, "slope" and "curvature," can be associated with macro variables (particularly inflation and oil), while the "level" factor qualitatively survives largely intact following the inclusion of macro factors into the models.

Our paper finds that macro variables are able to explain a significant amount of bond yield variation. For example, we find that macro variables explain up to 38% of the forecast variance for the short and middle end of the yield curve maturities at long horizons. However, this forecast proportion associated with macro variables declines at longer yield maturities. For instance, we find that at the long end of the yield curve (30-year yield), about 7% of the forecast variance is associated with macro variables at the short-end horizon (3-month forecast horizon), while at the extreme forecast horizons (30-year forecast horizon), about 0.3% of the forecast variance is associated with latent factors.

Further sections of this paper are outlined as follows. Section 2.2 presents an overview of existing term structure VAR approach studies. Section 2.3 outlines the general model motivation, specific parameterization of the model, and estimation technique. Section 2.4 provides a summary of the data and estimation procedures. Section 2.5 discusses the results from our estimation including IRFs, variance decompositions, and forecasting results. We conclude the paper in Section 2.6.

2.2 Literature review

The awareness generated by affine models as an analytical tool for pricing bonds at a stock floor was founded on the basis of three premises: first, the premise of an exponential affine in the pricing kernel related to the economic shocks encountered; second, the premise of a contingent Gaussian with respect to restructuring state variance; and third, examining log yield errors and the premise of cost accrued for risk being affine in state variables [2]. While investigating the pricing of the term structure of interest rates with a linear regression, Tobias et al. (2013) developed an alternative approach to pricing the term structure using a defined three-step OLS from the development of predictable components and factor restructuring given their level of regressed lagged as the pricing factor to evaluate the vulnerability of returns from treasury given the pricing factor's lagged level and existing restructuring pricing factor. This methodological process has advantages over the existing methods used by Hamilton and Wu (2012) and Joslin et al. (2011) as this approach does not restrict the development of any premise concerning the serial correlation errors when pricing bonds. The notable key differences in the approach used are the exclusion of an imposed repetition of bond pricing, thereby allowing for a simple linear regression for estimation of the model parameters, unlike the optimization of model parameter subsets with numerical representation. The absence of a compulsory notion of the critical element of yields is ideally priced.

However, Hamilton and Wu (2012) discovered a distinct multi-dimensional method for affine models estimation by pooling together the strength of both numerical methods and OLS regression, which does not require the normalization of the affine model. In the estimation of Tobias et al. (2013) research model, the zero coupon yield data were incorporated while establishing their specification of a four-factor and five-factor model, which was similar to the data employed in the work of Gürkaynak et al. (2007)[3] established from the Nelson-Siegel-Svensson curves and maturity of yields at $n = 3, \dots 6, \dots, 120$ months to eliminate the cross-section for the period of 01:1987–12:2011. Findings from their work on the properties of time series yields reveal that the pricing yield errors were not more than 0.4, and the standard deviation was less than 1 for all maturities. Results from the decomposition process for yield pricing errors show the existence of strong serial correlation, while no autocorrelation exists for the return pricing error (See Tobias et al. (2013) for a detailed discussion).

The specification of their five-factor model in examining the reaction when pricing interest rate risk given each factor detailed that price risk is associated with a constant negative element (significant) which implies that investors expect positive excess returns if they possess the level portfolio. The general information extracted from the model shows that higher slopes are expected to produce higher excess returns, which is similar to the findings of Campbell and Shiller (1991). In contrast to the evidence reported by Cochrane and Piazzesi (2005) that excess bond returns are largely predicted by a single return forecasting factor, Tobias et al. (2013) reveal that the second, fourth, and fifth critical elements of treasury yields have been able to predict volatility in excess bond returns, having implemented their five-factor specifications. The regression findings depict a fit value (R^2) of 65.5% of bond returns on the five principal components.

A critical examination of the behavioral intersection between macroeconomic indicators and the yield curve has contributed to improving the choice of investment techniques for pricing bonds and implementation of healthy public policy (Ang and Piazzesi (2003)). In various literature, authors have adopted different term structure models that incorporate latent factors to capture the spread of the term structure (although these factors are used differently when interpreting macro variables). For example, Dai and Singleton (2000),

[2] See, Tobias et al. (2013); Kim and Wright (2005); Dai and Singleton (2000); Duffee (2002); Chen and Scott (1993); Collin-Dufresne and Goldstein (2002).

[3] Data obtained from http://www.federalreserve.gov/pubs/feds/2006/200628/feds200628.xls.

rather than using economic measures (activities) to account for shocks that affect the yield curve, they depicted the factors as "level," "slope," and "butterfly"; Pearson and Sun (1994) termed theirs "short rate" and "inflation," used to account for unobserved factors as their estimation refused to employ the inflation rate data. One benefit of using the factor model in the absence of a general model is the ability to allow for a no-arbitrage condition while holding other conditions that entail economic balance constant (see Hansen and Jagannathan (1991)); although it has continually faced criticism over the years as it has not been able to satisfactorily account for the response of yields to macro variables. On the contrary, a direct model (a vector autoregressive model) has been developed to try to investigate the nexus between macroeconomic variables (including shocks from monetary policy) and yield movements (for example, see Evans and Marshall (1998); Gali (1992); Sims and Zha (1996); Estrella and Mishkin (1997)).

According to Ang and Piazzesi (2003), recent literature has used the Macro Vector Autoregressive (VAR) model to investigate the nexus between yield curve movements and macroeconomic shocks. The VAR approach allows for variance decomposition and impulse response functions, which aid in this investigation[4]. In their study, they collected zero-coupon bond yields data spanning from June 1952 to December 2000 of different maturities (spread across 1, 3, 12, 36, and 60 months), retrieved from Fama Centre for Research in Securities Prices (CRSP) files for long maturities (and Treasury bills for short maturities). They grouped macro variables into two categories - inflation (proxied by PPI of final goods, CPI, and commodity market spot price as "PCOM") and real activity (measured with Unemployment rate as "UE", employment growth rate as "EMPLOY", industrial growth rate as "IP", and Newspaper advert for Help Wanted index as "HELP") - and used principal component analysis to categorize them into "inflation" and "real activity" variables for model estimation.

Their study found that macro variables explained yield movements to a great extent (close to 85%) at both short and middle horizons of the yield curve, while about 40% could be explained at the long horizon. Inflationary shocks accounted for the larger portion of the effect at the yield curve's short horizon. Examining the behavior of the latent factors of term structure (Level and Slope among the three traditional factors), the level factor survived the inclusion of macro variables; however, macro variables were able to highly influence both level and slope. Nevertheless, introducing the no-arbitrage assumption of cross-equation restriction aided the out-of-sample prediction.

Interestingly, based on existing empirical evidence, macroeconomic fundamentals have been found to impact the activities of bond markets, although quantifying the magnitude of this effect has proven difficult. Over time, researchers have faced challenges in quantifying and incorporating macroeconomic indicators into term structure modeling to determine the connection between interest rate spreads and macroeconomic fundamentals. Shocks from macroeconomic variables are a day-to-day occurrence, with each indicator representing different facets of an economic outlook for a country, albeit with a high level of misrepresentation. Therefore, it is important to consider evaluating an expanded range of macro factors that are commonly released to account for the true state of the economy. Building on this prior stipulated information, Lu and Wu (2009) developed two systematic economic factors to investigate the link between macroeconomic releases and the term structure of interest rates using the dynamic factor model[5].

[4]See Bekaert and Hodrick (2001) and Sargent (1979) for examples of the VAR approach in asset pricing.

[5]They adopted seventeen macro releases, with seven accounting for inflation measures and ten capturing

The method of model estimation is similar to earlier studies in identifying the co-movement of an economy given numerous macroeconomic fundamentals (see Bernanke and Boivin (2003); Crone and Clayton-Matthews (2005); Engle and Watson (1981); Quah et al. (2008); Bernanke et al. (2005)). Their estimation findings show that the extracted two systematic macro fundamentals explain 77.9% - 82.1% of the variation in swaps and London Interbank Offered Rate (LIBOR) at different maturities (ranging from short-term of one month to long-term of ten years). All inflation measure shocks depict a significant positive effect on interest rates (presenting a uniform impact across maturities). On the contrary, output shocks (including employment indicators) have a more significant effect on the short-term horizon of the yield curve compared to the long horizon, thereby causing the term structure to depict a "slope effect".

The movement of the yield curve experiences a high level of volatility in its direction during shifts in the business cycle. The returns on long-term securities follow an upward climb in yields compared to short-term securities during the downturn of an economy (recession), although investors are not motivated to take on this risk during this period. Long-term securities act countercyclical to economic activity, while short-term securities act procyclical following Fed interest to stabilize the economy by means of cutting yields. Just like the Taylor Rule (1993) proposed "a cut by 1% in nominal yields given a 2% fall in economic GDP growth rate by the Fed". The business cycle remains a part of every economic system, and in the case of a recession being experienced, a period of expansion is set to follow, thereby defining the business cycle as a phase in every economy. The upward slope depicted by the yield curve during the recession phase does not only give a bad current picture of the economy but also predicts that better moments lie ahead. Provided with these stated assumptions, research scholars have been able to forecast an economy's GDP growth given the yield curve term spread while adopting the OLS technique[6].

The forecasted GDP growth rate and term spread of the yield curve were found to move in the same direction, indicating a positive relationship (i.e., as the yield curve slopes upward, the forecasted GDP growth rate also shows an upward movement). Term spread has also proven to be a useful tool for predicting economic downturns using discrete models and has played a significant role in developing business cycle index variables (for further details, see Stock and Watson (1989); Estrella and Hardouvelis (1991); Estrella and Mishkin (1998) for more details). However, some papers have noted drawbacks related to variations in the parameters used in the model, which can slow down the interpretation of predicted yield curve movements (as noted by Stock and Watson (2003)). Nevertheless, the application of term spread has recorded tremendous success over the years.

The model proposed by Ang et al. (2006) investigates what the yield curve says about

output shocks (with different frequencies of release, spanning from 01:1990 – 05:2004). For inflation measures, they used series such as the Core Consumer Price Index (CCPI), Consumer Price Index (CPI), Core Personal Consumption Expenditure (CPCE) deflator, Personal Consumption Expenditure (PCE), Core Producer Price Index (CPPI), Producer Price Index (PPI), and Gross Domestic Product (GDP) deflator. In the case of output shocks, they used series such as Industrial Production (IP, accounting for goods production), Real Gross Domestic Product (RGDP, a reliable measure for output growth), Non-farm payroll (accounting for firm employees' payroll, excluding farms), Consumer spending (accounting for the demand side of the economy), Retail sales (accounting for the demand side of the economy), and others (such as personal income, durable goods orders, business inventories, durable goods orders orders minus transportation, capacity utilization rate).

[6]Further reading can be obtained from papers that have employed US data to investigate the slope of the yield curve using GDP growth (see, for example, Chen and Scott (1993); Dotsey (1998); Harvey (1993); Hamilton and Kim (2002); Laurent et al. (1988))

GDP growth using zero-coupon bond yields with maturities of 1, 4, 8, 12, 16, and 20 quarters spanning from Q2:1952–Q4:2001. The no-arbitrage framework is used to develop the model, which has advantages over previous yield curve models. Unlike early works that incorporate different lags given several instruments in forecasting GDP growth (see Dotsey (1998) and Stock and Watson (2001)), the estimation of the yield-curve model in this study provides information about the maturity that can best predict GDP growth. The findings indicate that the yield curve has successfully helped in selecting the maturity spread that predicts GDP growth, with the maximum maturity spread being the best measure. Moreover, the nominal short rate was found to be dominant in explaining future GDP growth compared to the yield curve slope, as observed for both in and out-of-sample. Additionally, incorporating the inflation factor into the model shows a significant impact on forecasting GDP growth, which is in consensus with the findings of Stock and Watson (2001).

Despite the recorded performance of the model, it is not immune to criticism as some literature has reported difficulty in applying these models to certain cases, such as when the data is nonlinear and leads to a poor likelihood. To address these challenges, Hamilton and Wu (2012) proposed a reduced-form characterization of observable macroeconomic factors and yields for Gaussian affine term structure estimation. This was achieved by presenting the observable data of the Gaussian affine term structure model to be incorporated into the reduced-form parameters used for identification. Additionally, the choice of parameters can be directly imposed into the reduced-form parameters during estimation[7].

The study employs the use of minimum-chi-square estimation (MCSE) to prevent the complications associated with numeric maximum likelihood estimation (MLE) and account for the asymptotic advantage of maximum likelihood estimation in estimating and identifying Gaussian affine term structure models (GATSM). The study concludes that the use of both local and global maximum likelihood indicates that higher inflation leads to an increase in pricing output risk and a decrease in inflation risk price. This is contrary to the findings of Ang and Piazzesi (2003) thatonly used local maximum likelihood. However, the observation that macro models and their lag specification act inconsistently when pricing observed risk of macro factors was found to be similar to that of Ang and Piazzesi (2003). Their findings were generally similar to those of Ang and Piazzesi (2003) with slight differences that can be attributed to the differences in the dataset employed.

To this end, our study establishes its research foundation on the knowledge that the existing term structure macro-VAR studies have failed to report concrete evidence beyond 15 years of yield maturity, as well as adopting models beyond 5-factor models (which mainly consist of three latent factors and two macro factors). Various models have been utilized to model the term structure of interest rates, such as the three-factor, four-factor, and five-factor models (see Table 2.1). However, our study attempts to capture distinct aspects of the term structure by creating a six-factor model of the term structure of interest rates to account for additional sources of variation beyond what has been accounted for in the existing three, four, and five-factor models. The six-factor model incorporates the same factors as the five-factor model as well as taking into account a volatility factor.

[7] Unlike the maximum likelihood approach, switching from reduced-form to structural parameters is easier with the help of simple numerical and analytical computation (although the numerical approach seems much easier to calculate). Other research papers have also sought to offer solutions to the majority of the highlighted problems using various approaches (see, for example, the methods employed by Collin-Dufresne et al. (2008), Christensen et al. (2011), and Joslin et al. (2011)).

The inclusion of a volatility factor in the six-factor model is due to the fact that the volatility of interest rates can significantly impact the term structure. For example, during times of economic uncertainty or market stress, longer-term bond yields may increase to compensate for the added risk of holding those bonds. By incorporating a volatility factor into the model, researchers can more accurately capture this dynamic and potentially enhance the accuracy of their predictions.

Moreover, our study aims to address potential errors or biases in existing models by developing a six-factor model. For instance, the three-factor model may oversimplify the term structure by assuming that all interest rates move in unison, while the four- and five-factor models may not capture all the intricacies of the term structure. By creating a more comprehensive model with additional factors, we can potentially enhance the model's fit to the data and decrease potential inaccuracies in our estimates. Therefore, we develop a six-factor term structure macro VAR model capable of investigating the dynamics of yields with macroeconomic variables from 3-month maturity up to 30-year maturities to fill the existing research gap in empirical literature strands. This allows us to examine the US economy as an open economy, which goes beyond the closed economy often reported in existing studies. Our motivation for introducing a global factor, such as oil prices, emanates from the original work of Hamilton (1983) that emphasized the impact of oil price volatility on the US economy. They concluded that the unprecedented rise in oil prices contributed to the 1948–1972 US recession. Furthermore, the recent work of Aydoğan et al. (2017) documented that the correlation between oil prices and financial securities, including bonds, is dependent on whether the country is an oil-importing or oil-exporting economy. Despite these stylized facts, this perspective is yet to receive adequate recognition from existing studies.

2.3 The Term Structure Model with Macro Variables

Based on the macro dynamics presented in Equation 2.1, and the short rate equation[8], our study develops a discrete-time term structure model that combines both macro factors and latent factors. Section 2.3.1 outlines the general setup of the model, and the estimation procedure for the dynamic factor models (using Maximum Likelihood and Kalman Filter) is derived in Appendix A.1.

$$f_t^o = (f_t^{o,1}, f_t^{o,2}, f_t^{o,3}) \tag{2.1}$$

$$r_t = \delta_0 + \delta_1^{'} X_t \tag{2.2}$$

[8]We assume that the affine function of all latent variables is defined by the one-period short rate r_t. According to Duffie and Kan (1996), the short rate follows the movements in contemporaneous macro factors, such that the short rate r_t is given as $r_t = a_0 + a_1{}' f_t^0$. In the case where the short rate r_t is defined as the affine function of latent factors, it is given as $r_t = b_0 + b_1^{'} X_t^u$, of which VAR is a unique Gaussian case. For the purpose of this study, we specify the unobservable factors X_t^u as orthogonal to the observable factors f_t^0; thus, it can be written as $r_t = \delta_0 + \delta_1^{'} f_t^o + \delta_2^{'} X_t^u$. In order to identify individual unobservable factors separately, we employ the restrictions from no-arbitrage.

Table 2.1: Term Structure Factor-Models

Author(s)	Subject of Research	Factor-model	Methodology	Result
Ang and Piazzesi (2003)	A no-arbitrage vector autoregression of term structure dynamics with macroeconomic and latent variables	Utilized the five-factor term structure model including Inflation, Economic activity (GDP), and Latent variables (level, slope, and curvature)	VAR Technique	Result shows that models with macro factors forecast better than models with only unobservable factors as macro indicators explains about 85% of the variation in the yield curve
Lu and Wu (2009)	Macroeconomic releases and the interest rate term structure	Employed the two-factor term structure model comprising of Inflation (modeled using PCA of 7 inflation predictors) and Economic activity (modeled using PCA of 10 economic activity predictors)	Maximum Likelihood and Kalman filter	The two factors-model (inflation measure and output activities) predict 77.9–82.1% of the daily variation in LIBOR and swap rates from one month to 10 years with inflationary shocks have depicting positive and large impact on all interest rate maturities while output-related shocks depicts a slope effect (greater impact on the short rate rather than long rate)
Tobias et al. (2013)	Pricing the term structure with linear regressions	Five principal components of yields	Three-step OLS Regression Technique	Comparing the forecast performance between four, and five-factor model, statistical evidence shows that their five-factor model specification outperforms Cochrane and Piazzesi (2009) four-factor model.

2.3.1 General Model Setup

State dynamics

Assuming we have K_1 unobservable latent factors f_t^u and K_2 observable macro factors f_t^o, thus, the vector set out as $F_t = (f_t^{o'}, f_t^{u'})$ can follow a Gaussian $VAR(p)$ process defined as:

$$F_t = \beta_0 + \beta_1 f_t^o + \theta u_t \tag{2.3}$$

where $u_t \sim IIDN(0,1)$. Unobservable factors (f_t^u) follows $AR(1)$ processes such that the coefficient of β_1 set out in Eq.2.3 correspond with the latent variables defined as $X_t^u = f_t^u = 0$. Therefore, we set out the K-dimensional vector of the latent variables X_t to define the state of the economy, where $K = K_1 + K_2$. Our study partitions the factors vector X_t into K_1 unobservable factors X_t^u and K_2 observable factors X_t^o. The unobservable vector contains only contemporaneous latent yield factors $X_t^u = f_t^u$, while the macro variables $X_t^o = f_t^o$ at time t is contained in the observable vector. We process for inflation, real activity, and oil by taking the bivariate VAR of the function set out in Eq.2.1.

Hence, using the compact form as a Gaussian VAR first order, we model the dynamics of $X_t = (X_t^{u'} \ X_t^{o'})'$ as:

$$X_t = \mu + \beta X_{t-1} + \sum \varepsilon_t \tag{2.4}$$

where $\varepsilon_t = u_t^{u'}, 0, ..., 0, u_t^{o'})'$, and $u_t^u(u_t^o)$ account for shocks to the unobservable (observable) factors.

Pricing kernel

In formulating our term structure model, we make the assumption of no-arbitrage, as established by Harrison and Kreps (1979), which guarantees the existence of an equivalent risk-neutral measure Q. Under this measure, the pricing of any asset Y_t with zero dividends at time $t+1$ fulfills the function $Y_t = E_t^Q(exp(-r_t)\ Y(t+1))$ such that the exp is accounted for under the measure of Q. The transformation of the risk-neutral measure into data-generating measure using the Radon-Nikodym derivative is given as $\xi_(t+1)$. Hence, we have $E_t^Q(Z_{t+1}) = \frac{E_t(\xi_{t+1})Z_{t+1}}{\xi_t}$ for any time $t+1$ random variable $Z_(t+1)$. We are able to price any asset in the economy (particularly zero-coupon bonds) using the no-arbitrage assumption. Thus, we assume that $\xi_(t+1)$ is set out in a log-normal process:

$$\xi_{t+1} = \xi_t exp\left(-\frac{1}{2}\lambda_t^{'}\lambda_t - \lambda_t^{'}\varepsilon_{t+1}\right) \tag{2.5}$$

where the time-varying of the market price of risk linked with sources of uncertainty ε_t is captured by λ_t. λ_t is parameterized as an affine process set out as:[9]

$$\lambda_t = \lambda_0 + \lambda_1 X_t \tag{2.6}$$

[9] Among others, the study of Duffee (2002) and Dai and Singleton (2002) have commonly used this specification in Eq.2.6 for continuous time modeling.

Such that λ_0 depicts $K-dimensional$ vector and λ_1 depicts the $K \times K$ matrix. Eq.2.5 and Eq.2.6 link the underlying state variables (unobservable and observable factors) shocks with ξ_{t+1}, and thus, determine how yields are affected by these factor shocks. With this, the λ_0 $K - vector$ consist of $K_1 + K_2$ free parameters of which the top row and bottom row contains $K_1 \times 1$ and $K_2 \times 1$ respectively, while matrix λ_1 consist of $(K_1 + K_2)^2$ free parameters consisting of the upper-left and upper-right corner $K_1 \times K_1$ and $K_1 \times K_2$ respectively, and lower-left and lower-right corner $K_2 \times K_1$ and $K_2 \times K_2$ respectively. We therefore set out the pricing kernel m_{t+1} as:

$$m_{t+1} = \frac{exp(-r_t)\xi_{t+1}}{\xi_t} \tag{2.7}$$

Thus, substituting the short rate function $r_t = \delta_0 + \delta_1^{'}\ X_t$ we have the pricing kernel re-written as:

$$m_{t+1} = exp\left(-\frac{1}{2}\right) \lambda_t^{'}\lambda_t - \delta_0 - \delta_1^{'}X_t - \lambda_t^{'}\varepsilon_{t+1} \tag{2.8}$$

Bond Pricing

Taking Eq.2.8 as a nominal pricing kernel that prices all nominal asset in a country, the overall gross return process R_{t+1} of any nominal assets fulfils:

$$E_t(m_{t+1}R_{t+1}) = 1 \tag{2.9}$$

Hence, we assume an n-period zero-coupon bond is represented by P_t^n such that Eq.2.9 allows for the recursive computation of bond prices by:

$$P_t^{n+1} = E_t(m_{t+1}P_{t+1}^n) \tag{2.10}$$

Then, considering Eq.2.1 for the state dynamics of X_t combined with Eq.2.2 for the short rate r_t dynamics and Eq.2.5 for the Radon-Nikodym derivative helps to develop the discrete-time Gaussian K-factor model with K_1 latent factors and K_2 macro factors. This forms the affine term structure model given bond prices being set out as exponential affine function of state variables. Specifically, bond prices process is as follows:

$$P_t^n = exp(\bar{A}_n + \bar{B}_n^{'}X_t) \tag{2.11}$$

where, the values of $\bar{A}_n$ and $\bar{B}_n$ can be defined by the following difference equations:

$$\bar{A}_{n+1} = \bar{A}_n + \bar{B}_n^{'}\left(\mu - \sum \lambda_0\right) + \frac{1}{2}\bar{B}_n^{'} \sum \sum^{'\bar{B}_n} - \delta_0, \bar{B}_n^{'} = \bar{B}_n^{'}\left(\phi - \sum \lambda_1\right) - \delta_1^{'} \tag{2.12}$$

where $\bar{A}_1 = -\delta_0$ and $\bar{B}_n = -\delta_1$. Therefore, we define the continuously compounded yield y_t^n for an n-period zero-coupon bond as:[10]

$$y_t^n = -\left(\frac{\log P_t^n}{n}\right) = A_n + B_n^{'}X_t, \text{where}, A_n = -\frac{\bar{A}_n}{n}, \text{and} B_n = -\frac{\bar{B}_n}{n} \tag{2.13}$$

[10]Note: Yields are affine function of state variables X_t, therefore, we can interpret Eq.2.13 as the state space system observation equation. In addition, the observable variables X_t^o is capable of producing further observation equations

2.4 Econometric methodology and data description

2.4.1 Estimation procedures

The econometric approach of our study progresses as follows: first, we conduct a principal component analysis to uncover the systematic order in our zero coupon bonds and explain the broad nexus between the common factors extracted from the bond yields and the behavior of other macroeconomic fundamentals, categorized into three factors: inflation, economic activity, and global factors. Second, in the model estimation, we transform the system of yields and macro factors (Y_t^u, X_t^o) into a system of unobservable and observable factors, denoted by $Z_t = (Y_t^{u'}, X_t^{o'})$. The yields are systematic functions of the state variables Z_t, allowing our model to infer unobservable factors from the yields. Our VAR estimation of Eq. 2.13 assumes that unobservable components are orthogonal to macro shocks, which guarantees no arbitrage.

We estimate the model by employing the Kalman Filter and Maximum Likelihood procedure (see Appendix A.1). In this process, we develop a two-step estimation procedure. The first step estimates the yield dynamics using the Kalman Filter optimization process, and the second step estimates the macro dynamics using Maximum Likelihood optimization algorithms. Our two-step procedure helps us to overcome the difficulties linked with forecasting models with many factors using Maximum Likelihood. Third, using the Diebold and Mariano (1995) (DM) test, we conduct a basic forecast evaluation that compares the predictive accuracy of our macro model yield dynamics and that of the traditional ARIMA model to ascertain any significant difference in forecast errors. Forecast error is defined as $e_{it} = \hat{y}_{it} - y_t$, where $i = 1, 2$. Fourth, our study uses ordinary least squares (OLS) to estimate the impact of macro dynamics on bond yields, as well as using variance decomposition to explain the contribution of latent and macro factors to forecast variances.

2.4.2 Data description

In this paper, we use US zero coupon bond yield data with maturities ranging from 3 months to 30 years, covering the period from 01:1986–11:2018. The bond yield data for 3 months, 1 year, and 30 years are obtained from Thomas Reuters' DataStream EIKON monthly data files. Table 2.2 provides summary statistics for our sample period, which reveals some stylized facts about our data. The yield data show mild kurtosis with some level of consistency across maturities and positive skewness across all maturities. Likewise, the probability value of the Jarque-Bera test fails to reject the hypothesis of normal distribution. We focus on the yields for 3 months, 1 year, 10 years, 20 years, and 30 years, given the large coverage of yields investigated in our study. However, full results are reported in the appendix. These selected yields show that yields near maturity reflect a high level of correlation, with correlations of 82%, 84%, 98%, and 99% for 3 months, 1 year, 10 years, 20 years, and 30 years, respectively. In our model estimations, we incorporate all yields from 3 months to 30 years with all of them measured with error.

Our study uses US zero coupon bond yield data spanning from 01:1986 to 11:2018, with maturities ranging from 3 months to 30 years. The yield data for maturities of 3 months, 1 year, and 10 years to 30 years are sourced from Thomas Reuter's DataStream EIKON monthly data files. Table 2.2 provides summary statistics for our sample period, which reveals some stylized facts. The yield data exhibit mild kurtosis with some level of consistency across maturities, and positive skewness across all maturities. Additionally, the Jarque-Bera probability value does not reject a normal distribution. For our study, we select yields of 3 months, 1 year, 10 years, 20 years, and 30 years to demonstrate that yields nearing maturity display a high level of correlation. The results indicate that there is a correlation of 82

Our macroeconomic variables consist of 12 monthly economic releases spanning from 01:1986 to 11:2018, which are sorted into three groups: inflation measures, real economic activity measures, and global measures. Among the 12 series, six are inflation measures: the Producer Price Index (PPI), Core Producer Price Index (CPPI), Consumer Price Index (CPI), Core Consumer Price Index (CCPI), Personal Consumption Expenditure (PCE) deflator, and Core Personal Consumption Expenditure (CPCE) deflator. The CPI variable measures the mean change in consumer food basket prices, the PPI measures changes in the selling prices of domestic producers for finished products, and the PCE deflator accounts for the average change in the prices of the purchased food basket by consumers (the core value excludes food and energy prices as they tend to be volatile). The real activity variables include five series: the Unemployment Rate (rate of unemployment, UE), Employment (rate of employment, EM), Industrial Production (goods production, IP), Capital Utilization Rate (usage of available resources in percentage, CUR), and Personal Income (earnings from investment inventories, wages, and other ventures, PI). The global factor variable is the oil price in US dollars. All series are measured using their difference in log growth rate, such that $Y = ((\ln(Y_t)$ - $\ln(Y_{t-1}))\ \times 100)$. These macro series include most of the existing variables used in previous monthly VAR macro studies (see, for example, Ang and Piazzesi (2003); Lu and Wu (2009)).

In order to reduce the dimensionality of our system, we perform a principal component analysis (PCA) on each group of variables and extract the first principal component (PC) of each group, as shown in Table 1. This means that we extract the first principal component factor from the inflation measures predictors, and for the real activity measures predictors, and we use the oil price as a singular variable for the global measure. This leaves our model with three variables, which we call inflation, real activity, and oil price. More specifically, we first ensure that each series has zero mean and unit variance, and then stack the six (five) variables associated with inflation (real activity) into a vector $V_t^1(V_t^2)$. For each individual group i, the vector V_t^i is defined as:

$$V_t^i = Af_t^{o,i} + \varepsilon_t^i \tag{2.14}$$

Where $V_t^1 = (CPI_t, CCPI_t, PPI_t, CPPI_t, PCE_t, CPCE_t)$ for our inflation group measures or $V_t^1 = (UM_t, EM_t, IP_t, CUR_t, PI_t)$ for real activity group measures. The stochastic term ε_t^i satisfies $E(\varepsilon_t^i) = 0$ and $\text{var}(\varepsilon_t^i) = \Gamma$, where Γ is diagonal. The matrices A and Γ are either 6×1 or 5×1 for inflation and real activity group respectively. The deduced macro factor $f_t^{o,i}$ exhibit zero mean from V_t^i $(E(f_t^{o,i}) = 0)$ and have the usual unit variance $(var(f_t^{0,i}) = 1)$.

2.5 Estimation results

This paper has several sections that examine the effects of observable macro factors on term structure models. In Section 2.5.1, we analyze and interpret the parameter estimates of both the Yields-Only and Macro Models. We also investigate the IRFs of each macro

Table 2.2: Principal Component Analysis

Principal Component Analysis: Inflation

	1st	2nd	3rd	4th	5th	6th
CPI	0.34	0.57	-0.16	0.67	0.21	-0.22
CCPI	0.51	-0.29	-0.02	0.33	-0.45	0.59
PPI	0.41	-0.5	0.14	0.02	0.75	-0.03
CPPI	0.16	0.26	0.95	-0.05	-0.08	-0.01
PCE	0.54	-0.14	-0.10	-0.28	-0.39	-0.67
CPCE	0.38	0.51	-0.22	-0.61	0.18	0.39
% variance explained	0.51	0.74	0.9	0.96	0.99	1.00

Principal Component Analysis: Real Activity

	1st	2nd	3rd	4th	5th
UR	-0.42	0.54	0.13	0.72	-0.01
ER	0.37	-0.63	0.09	0.67	0.01
IP	0.58	0.38	-0.07	0.06	-0.71
CUR	0.58	0.40	-0.09	0.06	0.70
PI	0.12	0.05	0.98	-0.14	-0.01
% variance explained	0.47	0.70	0.90	0.99	1.00

Note: We normalize the six (five) macro indicators that represents inflation (real activity) to unit variance and zero mean: where for each group i the normalized data followsV_t^i follows a 1 factor model ($V_t^i = Af_t^{o,i} + \varepsilon_t^i$) where A represent the factor loading, $E(f_t^{o,i}) = 0$, $cov(f_t^{o,i}) = I$, $E(\varepsilon_t^i) = 0$, and $cov(\varepsilon_t^i)$ $= \Gamma(diagonalmatrix)$. The principal component columns represent the number eigenvalue of factor loading such as six(five) factor components derived for macro variable predictors inflation (real activity) from first to smallest eigenvalue. The percentage of variance explained for the nth PC reflects the cumulative proportion of the explained variance from the first to the n^th eigenvalue.

indicator in Section 2.5.2 to understand the impact of macro factors on the term structure models. In Section 2.5.3, we present the variance decomposition that allows us to attribute variance forecasts to shocks in latent and macro factors. Our study shows that imposing cross-equation restrictions from no-arbitrage produces better forecast results compared to unrestricted VARs commonly reported in macro literature. However, our term structure model's incorporation of macro factors enables us to obtain these better forecasts. Furthermore, we compare the latent factors obtained from different models in Section 2.5.1 and find that macro factors account for some of the latent factors in the Yields-Only model.

2.5.1 Parameter Estimates

Yields-only model and Yields with Macro Variables Model

On the one hand, Table 2.3 (Panel A) presents the results of our Yields-Only model estimation with the order of latent factors unspecified. However, based on the estimation results, we present the ordering of the latent factors by decreasing autocorrelation. Consistent with existing literature on multi-factor models, our model has one highly persistent factor, one less persistent factor (but still strongly persistent), and one factor that strongly reverts to its mean.

We closely follow the latent factor labeling in the early work of Litterman and Scheinkman (1991). For this study, we choose the 3-month, 15-year, and 30-year yields to represent the short, medium, and long ends of the yield curve, and assume they are measured without error to form the three unknown factors called the latent factors. In order to show the effect of these latent factors, we define the first latent variable as "Unobs 1," which corresponds to the yield curve "level" transformation as $\frac{(y_t^3+y_t^{15}+y_t^{30})}{3}$. Our analysis reveals a high correlation of 99% between the level of transformation and Unobs 1. However, the second latent factor (Unobs 2), defined as $y_t^{30} - y_t^3$, shows a high correlation of 99% with the spread transformation, while the third latent factor (Unobs 3), defined as $y_t^3 - y_t^{15} + y_t^{30}$, shows a high correlation of 98% with the curvature transformation. Table 2.3 (Panel A) presents our Yields-Only model estimation results without specifying the order of latent factors. However, based on the estimation result, we present the latent factors ordering by decreasing autocorrelation. In consistency with the existing literature on multi-factor estimates, our model has one highly persistent factor, one less persistent but still strongly persistent factor, and one factor with strong mean-reversion. Table 2.3 (Panel B) presents our macro variables model. The results in Panel B reveal no significant difference from the evidence in Panel A (Yields-Only model) in terms of the autocorrelation of latent factors. Therefore, we suppose that our first to third latent factors (Unobs 1-3) should have roughly similar strong persistence effects in the macro variable model.

2.5.2 Impulse responses

Factor weights across yield curve

From our VAR model, the weight of the B_n coefficient attributed to the term structure model of each yield maturity n helps determine the effect each factor poses on the yield curve. The initial response of yields to the macro factors is also obtainable from the weight of B_n. We have scaled the B_n coefficient such that it corresponds to the movement of one

Table 2.3: Yields-Only Model and Macro Model Estimates

Panel A: Yields-Only Model		
Companion form ϕ		
0.996	0.000	0.000
0.004	0.996	-0.004
0.000	0.000	0.988
Short rate parameters		
Unobs 1	**Unobs 2**	**Unobs 3**
0.053	-0.050	0.140
Panel B: Macro Model		
Companion form ϕ		
0.981	0.000	0.000
-0.009	0.888	0.000
0.000	-0.006	0.923
Short rate parameters		
Unobs 1	**Unobs 2**	**Unobs 3**
0.049	-0.036	0.036

standard deviation of factors. Figure 2.1 plots these weights as a function of yield maturity for the Macro model. From Figure 2.1, the most persistent factor, called the level factor (Unobs 1), is expected to affect all the maturities of yields in the same way. The coefficient of the second factor, called the slope factor (Unobs 2), is downward sloping and relatively moves the short end of the yield curve to the long end. The coefficient of the third factor, called the curvature factor (Unobs 3), has a twisting effect as the movement affects all three horizons (short-end, middle-end, and long-end) of the yield curve with varying signs.

Furthermore, examining the corresponding coefficients of B_n for our macro variables (inflation, real activity, and global), the coefficients depict a flat shape across the three macro factors, signifying that the yields across all maturities are affected in the same way. Although the magnitude of our macro factor weights is higher than the level, slope, and curvature factor weights, the effect is slightly weaker across the yield curve. Figure 2.1 only provides insight into the effect of initial shocks as a function of yield maturities. However, our study is also interested in examining how these initial shocks transmit through time. Thus, in order to identify the yield curve's long-term responses from shocks to the macro factors following the yield curve's initial response, we subsequently compute the IRFs.

We examine the IRFs to yield maturities (3-months, 15-years, and 30-years). The term structure of our model enables us to obtain yield curve movements in response to shocks at all horizons (short-end, middle-end, and long-end). Our model estimation ensures that yield movements are arbitrage-free. The IRFs reported in Figure 2.2 plot yields of 3 months, 15 years, and 30 years of the Macro Model. We compute the IRFs using an unrestricted VAR with macro factors, ordering the macro factors first before the yields with increasing maturities. The IRFs are expressed as annualized percentages for shocks of one standard deviation, with the x-axis representing yield months. Based on Figure

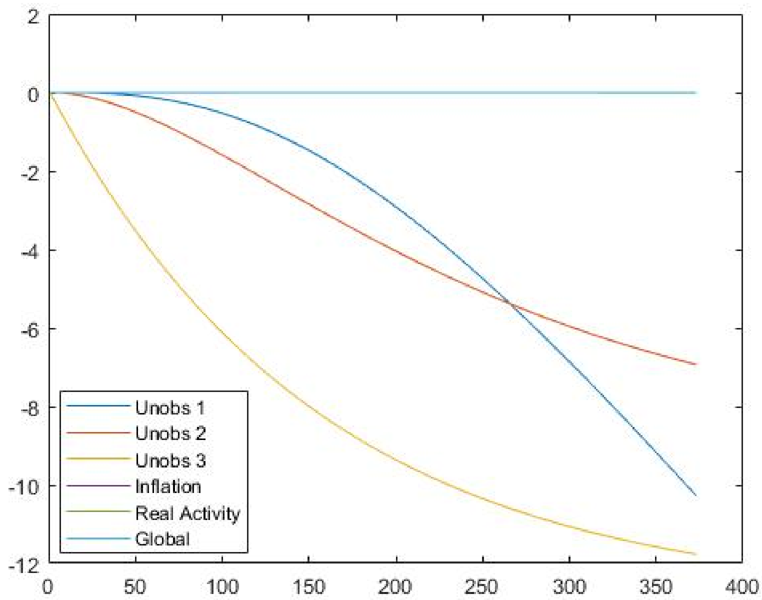

Figure 2.1: B Coefficient from Macro Model

2.2, the IRFs from the Macro Model depict a more pronounced response than the IRFs emanating from the unrestricted VAR model.

Figure 2.2 shows that the response of 3-month yields to a 1-standard deviation inflation shock initially increases by about 2 basis points. The response peaks after 2 years at 3 basis points, then gradually decreases. Longer yields' response to a 1-standard deviation inflation shock shows a similar overall pattern. The immediate response of the 15-year yield (30-year yield) is only 6 basis points (7 basis points). The response peaks at around 7 basis points (9 basis points) after 2 years before leveling off slowly. In the unrestricted VAR model, the response of yields to oil is slightly higher for 3-month yields but slightly lower for longer yields (15-year and 30-year) than the response to inflation. The initial response of 3-month yields to a 1-standard deviation oil shock rises and reaches its peak of around 3 basis points after 3 years before gradually decreasing. The response of longer yields initially increases by around 5 basis points (5 basis points) for 15-year (30-year) yields and reaches its peak after 3 years by around 7 basis points (8 basis points) before leveling off. However, the response of yields to real activity is much larger in the unrestricted VAR model than the response to inflation and oil. The initial response of 3-month yields to a 1-standard deviation shock of real activity shows a hump-shaped pattern, with an initial decrease of about 12 basis points followed by a minimum after 7 years of about 15 basis points before leveling off slowly. For longer yields, the initial response of 15-year (30-year) yields shows a decrease of about 1 basis point (2 basis points) before rising (after 1 month) and reaching its peak by about 2 basis points (1 basis point) after 5 years.

On the other hand, examining the second column of Figure 2.2 that depicts the Macro Model, the shape of the IRFs is similar to the unrestricted VAR IRFs, but the responses are slightly higher in basis points for yields' response to an oil shock. For example, the initial response of 3-month yields, 15-year yields, and 30-year yields to a 1s.d. inflation shock is 2 basis points, 7 basis points, and 7 basis points, respectively, and later peaks after 2.5 years to around 7 basis points and 9 basis points for longer yields, i.e., 15-year and 30-year yields, respectively. The initial response of 3-month yields to a 1s.d. oil shock increases to around 4 basis points, and peaks after 4 years to around 5 basis points (2 basis points higher than the unrestricted VAR) before it dies off slowly. For longer yields, the IRFs show an initial response to a 1s.d. oil shock for 15-year yields (30-year yields) to rise by around 6 basis points (6 basis points), later peaks after 4.5 years to around 7 basis points (7 basis points) before it levels off slowly. However, the response to real activity depicts about the same order of magnitude of effect as the unrestricted VAR[11].

Observing that our 3-month interest rate shows a decline after a real activity shock, it is difficult to pinpoint any one variable reported in our PCA (Table 2.2) as solely responsible for the decline. This is because the real activity factor is composed of multiple variables, and the impact of each variable on the 3-month interest rate may depend on a variety of factors. That being said, we can observe that movements in the unemployment rate (UR) and employment (ER) are more closely related to each other than to movements in industrial production (IP) and capital utilization rate (CUR). If a positive demand shock leads to an increase in employment and a decline in the unemployment rate, this could lead to a rise in the real activity factor and a decline in the 3-month interest rate. However, it is important to note that movements in disposable personal income (PI) can also play a significant role in shaping the real activity factor, as the third component of the PCA is dominated by PI. A positive demand shock could lead to an increase in disposable personal income, which could contribute to a rise in the real activity factor and a decline in the 3-month interest rate.

2.5.3 Variance decomposition

We construct the variance decomposition analysis in order to examine the magnitude of contributions of latent and macro factors to forecast variance. With this, we can examine the proportion of forecast variance attributed to each latent and macro factor, which are closely related to the IRFs explained in the previous section.

We present a comprehensive variance decomposition in Table 2.4 for the 3-month, 15-year, and 30-year yield maturities. The interpretation of the top row with respect to observable (macro) and unobservable (latent) factors is as follows: 0.10%, 2.20%, and 1.03% of the 1-step ahead forecast variance for the 3-month yield is explained by inflation, real activity, and oil, respectively. Similarly, 0.08%, 0.00%, and 0.00% of the 1-step ahead forecast variance is explained by the first, second, and third unobservable factors, respectively[12].

Examining the Macro Model, real activity exhibits greater predictive power for forecast variance than inflation and oil at the 3-month yield maturity for all horizons. Although at short horizons, the forecast variance attributed to real activity is very low at around 2.20%, as the horizon increases, the proportion of variance increases to 22.27% for the 15-year yield and 25.69% for the 30-year yield. In contrast, for longer yield maturities (15-year and

[11] Evidence of the IRFs of the three-macro model (inflation, real activity, and oil) in this section closely correspond to the earlier evidence in the study of Ang and Piazzesi (2003) that examined the IRFs of a two-macro model (inflation and real activity) including three latent factors in a five-factor term structure model.

[12] We employ Cholesky orthogonalization for inflation, real activity, and oil, which are correlated.

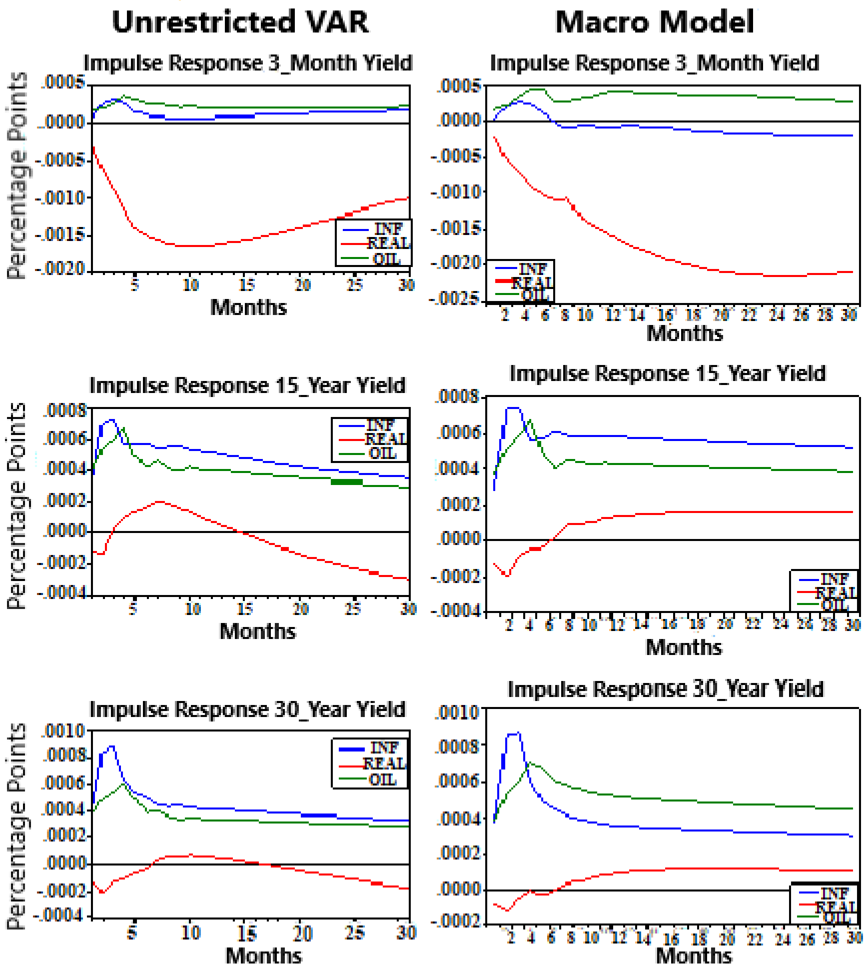

Figure 2.2: Impulse Response Function

30-year), inflation exhibits greater predictive power for forecast variance than real activity and oil across all horizons except for the short-end horizon of the 15-year yield, where oil exhibits greater predictive power. Generally, the magnitude of the effect captured at the long end of the yield curve exhibits a much smaller predictive forecast variance compared to the intermediate end of the yield curve.

Focusing on the forecast variance of the latent factors presented in Table 2.4, the most persistent latent factor that corresponds to the level effect is the Unobs 1. The Unobs 1 variance decomposition remarkably decreases across the yield curve horizon for the 3-month yield but increases across yield horizons for longer yields, with the 15-year yield showing a greater forecast variance decomposition. Comparing the predictive forecast variance of the three unobservable factors, the Unobs 1 has a much larger effect, explaining about 0.12%, 0.94%, and 0.4% across the 3-month, 15-year, and 30-year yields, respectively, of the unconditional variance in the Macro Model. Unobs 2 and Unobs 3 have a negligible impact across all points of the yield curve and for all forecast horizons.

2.5.4 Forecasts

From the variance decomposition outcomes presented and discussed in the previous section, it appears that term structure models that incorporate additional observable factors, such as global variables, can better forecast future yield movements. However, this assumes that a specific model remains the true model after estimation, and this may not be the case in typical settings where more parsimonious data depictions often outperform advanced models. Therefore, we conduct an out-of-sample forecast experiment to determine the validity of this assumption.

Our procedure for estimating out-of-sample forecasts over the 31-observation sample (3-month yield and 1-year to 30-year yield) is as follows. For each given date t, we estimate our model using all available data up to and including time t, and then forecast the subsequent month's yields at time $t+1$ for all 31 yield maturities. To compute our macro factors (inflation and real activity), we use principal component analysis (PCA) to accommodate several predictors of these indicators. Next, we estimate the bivariate VAR and short rate equation of the macro dynamics using all available data up to time t for the Macro Model. Therefore, our model uses all available data at time t to forecast yields at time $t+1$.

We conducted a comparison of models that ranged from out-of-sample models (Yields-Only Model and Macro Model) to in-sample models (Unrestricted Macro Model and cross-equation Macro Model). First, we employed the Root Mean Square Error (RMSE) criteria to investigate forecast errors attributed to each model. Second, we used the DM test to examine the forecast error comparison between our models (in-sample Yield-Only Model and Macro Model) and the traditional Autoregressive forecast Model[13].

[13] The DM test allows us to investigate whether two forecasts, $\hat{y}1t, t = 1, ..., T$ and $\hat{y}2t, t = 1, ..., T$, are equally good. We define the error as $e_{it} = \hat{y}it - y_t, i = 1, 2$, where the loss associated with forecast i being a function of the forecast error eit is denoted with $g(e_{it})$. In this case, $g(e_{it})$ is the squared absolute value of e_{it}, so $g(e_{it}) = |e_{it}|^2$. The loss differential between the two forecast errors can be defined as $d_t = g(e_{1t}) - g(e_{2t})$, which can be said to have equal forecast accuracy only if the loss differential produces a zero value for all t. Therefore, we can test the null hypothesis denoted as $H_0 : E(d_t) = 0$ (indicating that both forecasts have the same accuracy) against the alternative hypothesis denoted as $H_1 : E(d_t) \neq 0$ (indicating that both forecasts have different levels of accuracy). Considering the test of the null hypothesis for a 1-month-ahead forecast, assuming the stability of the covariance and other regularity conditions on

Table 2.4: Variance Decomposition

	h	**Macro Factors**			**Latent Factors**		
		Inflation	**Real Activity**	**Oil**	**Unobs 1**	**Unobs 2**	**Unobs 3**
3-month yield							
Yield-Only	3				0.03	0.00	0.00
	15				0.01	0.00	0.00
	30				0.01	0.00	0.00
Macro	3	0.10	2.2	1.03	0.08	0.00	0.00
	15	0.19	22.27	0.16	0.02	0.00	0.00
	30	0.13	25.69	0.07	0.02	0.00	0.00
15-year yield							
Yield-Only	3				0.32	0.00	0.00
	15				0.59	0.00	0.00
	30				0.65	0.00	0.00
Macro	3	2.26	0.44	3.42	0.14	0.00	0.00
	15	7.49	0.24	4.42	0.37	0.00	0.00
	30	7.53	0.33	4.2	0.43	0.00	0.00
30-year yield							
Yield-Only	3				0.07	0.00	0.00
	15				0.27	0.00	0.00
	30				0.37	0.00	0.00
Macro	3	3.69	0.29	3.39	0.00	0.00	0.00
	15	6.51	0.58	3.95	0.15	0.00	0.00
	30	5.66	1.00	3.58	0.25	0.00	0.00

Note: Our table presents the contribution of factor i to h-step ahead forecast of the 3-month yield. The interpretation of the top row in respect to observable (macro) and unobservable (latent) factors follows that 0.10%, 2.20%, and 1.03% of the 1-step ahead forecast variance is explained by inflation, real activity, and oil respectively. Likewise, 0.08%, 0.00%, and 0.00% of the 1-step ahead forecast variance is explained by the first, second, and third unobservable factors. Similar interpretation is applicable to the remaining rows for forecast horizons across yield maturities.

We present the outcome of our estimation in Table 2.5, with lower RMSE values indicating better forecast estimates. We highlight the best statistics in bold. Our out-of-sample estimation forecasts over the last 155 months of our sample, including the yields from the financial crisis period to the current date of our sample (i.e., from 2008:M1 to 2018:M11), reflecting more interest rate volatility over the full sample. From our estimation results of our forecast performance, we note the following points regarding the models. We establish our forecast comparison based on estimation procedures that compare the results of different models[14].

First, in examining our full-sample models estimation, we compare the forecast performance of the initial estimation procedure (unrestricted VAR estimate). Based on our RMSE criteria, the results show that the Macro Model forecast performs better compared to the Yields-Only Model, except for the longer yield maturity, which is the 30-year maturity where the Yields-Only Model depicts better forecast performance. This implies that introducing macro factors into the term structure helps produce better forecast performance. On the other hand, when considering the comparison of forecast performance that imposes cross-equation restriction models, the result shows that overall, the Macro Model estimation procedure that includes inflation and real activity (where oil is held constant or restricted in the model estimation) depicts a better forecast result across yield maturities, except for the 3-month yield and 2-year yield where the combination of real activity and oil, and inflation and oil depict better forecast performance, respectively. Generally, comparing the forecast performance results of both estimation procedures (unrestricted VAR and cross-equation restriction), evidence shows that the inclusion of macro factors (especially inflation and real activity, where oil is held constant) helps produce a better forecast performance of yield maturities.

Second, focusing on our out-of-sample forecast performance, we compare the forecast performance of the initial estimation procedure (unrestricted VAR estimate). Based on our RMSE criteria, where the lowest value depicts better forecast performance, the results show that the Macro Model outperforms the Yields-Only model only for yield maturities up to 9 years, while the Yields-Only model outperforms the Macro Model for longer yield maturities up to 30 years. On the other hand, considering the comparison of forecast performance that imposes cross-equation restriction models, the results show that, overall, the Macro Model estimation procedure that includes inflation and oil (where real activity is held constant or restricted in the model estimation) depicts better forecast results across yield maturities, except for the 3-month yield and 1-year yield where a combination of real activity and oil depicts better forecast performance. Generally, our out-of-sample estimation shows that comparing forecast performance results of both estimation procedures (unrestricted VAR and cross-equation restriction) for longer yield maturities (from 2008:M1 – 2018:M11), the evidence shows that the inclusion of macro factors (especially inflation and oil, where real activity is held constant) helps to produce better forecast

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d_t, we will have $T^{\frac{1}{2}}(\bar{d} - \mu)$ distribution converge to $N(0, 2\pi f_d(0))$, where $f_d(.)$ represents the spectral density of d_t and $\bar{d}$ captures the loss differential of the sample mean. Therefore, the DM statistic is defined as $DM = \frac{\bar{d}}{\sqrt{\frac{2\pi \hat{f}_d(0)}{T}}}$, where $\hat{f}_d(0)$ represents the consistent estimate of $f_d(0)$.

[14] For example, our forecast comparison will compare the general forecast performance of our model's estimation procedure (i.e., comparing unrestricted VAR forecast performance to cross-equation restriction estimation procedure). Likewise, we conduct model comparison within the estimation procedure (i.e., comparing forecast performance of Yields-Only model and Macro Model with the unrestricted VAR estimation procedure).

performance for yield maturities.

Therefore, we conclude that incorporating term-structure restriction helps to produce a better forecast both in-sample and out-of-sample compared to the unrestricted VAR. Additionally, incorporating macro variables can improve the forecast result, although the out-of-sample forecast generally performs better. This may be due to forecasting only a fraction of the total sample. Moreover, introducing an additional macro factor to proxy for global effects (using the oil price variable) to establish a six-factor model as an extension of Ang and Piazzesi (2003)'s five-factor model further improves the forecast performance, specifically for the out-of-sample forecast. However, it is important to note that this improved performance is based on introducing an additional macro factor to the existing given number of unobservable factors[15]. Interestingly, based on the RMSE values, our forecast estimate outperforms the results produced in the existing study of Ang and Piazzesi (2003).

2.5.5 Factors comparison

Finally, in Table 2.6, we address the issues associated with introducing macro factors that result in changes in the initial latent factors of the Yields-Only model. Our regression model regresses the latent factors extracted from the Yields-Only model on both macro and latent factors from the Macro Model. In this context, using the normalized form of our variables, we produce two sets of regressions: the first set of regressions regresses latent factors from the Yields-Only model on only macro variables (as set out in Panel A), and the second set of regressions regresses latent factors from the Yields-Only model on both macro variables and latent factors derived from the Macro model (as set out in Panel B).

Focusing on Panel A, the latent factors are poorly accounted for by macro factors, as characterized by the low fitted value across the three latent factors (level, slope, and curvature), although these factors load significantly on macro factors. For example, the level factor loads significantly on macro variables (inflation, real activity, and oil) despite the low R^2 of 1%; specifically, the loading of inflation and oil is positive and relatively large (compared to real activity), with values of 0.10 for both variables. This implies that the traditional level factor accounts for a relatively strong inflation and oil effect. On the other hand, regressing the second traditional slope factor on macro variables, the estimation produced a relatively higher R^2 of 4% with significant loading values, particularly the negative loading on oil (-0.40). Thus, a greater proportion of the traditional slope factor is likewise related to oil dynamics. Lastly, macro factors poorly account for our third traditional curvature factor, with a relatively low R^2 of 1%, but the curvature factor loads significantly on macro factors, especially the negative loading that is specific to the oil variable (-2.34).

Examining Panel B, we present the regression of latent factors from the Yields-Only model on latent and macro factors from the Macro model. In this panel, the level factor from the Macro model depicts a qualitative dissimilarity with the magnitude of the coefficient differing from 1 (at the 0.01% level), thus signaling a statistical difference between

[15]See Appendix A.2 (Figure A.1) for a forecast comparison (Yields-Only model and Macro model) of actual and predicted yield maturities for an unrestricted VAR model. Panel A represents the Yield-Only model's comparison of actual and predicted yields maturities, while Panel B represents the Macro model's comparison. The first row contains the actual yield maturities and the second row contains the predicted yields.

Table 2.5: Forecast Comparisons

Yield (Mnt, Yr)	Unconstrained VARs				VAR with Cross-Equation Restriction		
RMSE Criteria	Y-O M	Macro M	Ang Y-O M	Ang Macro M	INF	Real Activity	Oil
Full- Sample							
3	0.0133	**0.0109**	0.2495	0.2540	**0.0106**	0.0111	0.0114
1	0.0118	**0.0097**	0.2776	0.2722	**0.0101**	**0.0101**	0.0104
2	0.0102	**0.0082**			0.0087	**0.0086**	**0.0086**
3	0.0090	**0.0073**	0.3730	0.3644	0.0077	0.0076	**0.0074**
4	0.0081	**0.0068**			0.0071	0.0070	**0.0067**
5	0.0075	**0.0065**	0.3793	0.3725	0.0068	0.0066	**0.0062**
6	0.0072	**0.0063**			0.0066	0.0064	**0.0059**
7	0.0069	**0.0062**			0.0065	0.0063	**0.0058**
8	0.0068	**0.0062**			0.0064	0.0063	**0.0058**
9	0.0067	**0.0062**			0.0064	0.0063	**0.0058**
10	0.0067	**0.0062**			0.0064	0.0063	**0.0058**
11	0.0066	**0.0061**			0.0064	0.0063	**0.0058**
12	0.0066	**0.0061**			0.0064	0.0063	**0.0058**
13	0.0066	**0.0061**			0.0064	0.0063	**0.0058**
14	0.0066	**0.0061**			0.0064	0.0063	**0.0059**
15	0.0066	**0.0061**			0.0064	0.0063	**0.0059**
16	0.0066	**0.0061**			0.0064	0.0063	**0.0059**
17	0.0065	**0.0061**			0.0064	0.0063	**0.0059**
18	0.0065	**0.0061**			0.0064	0.0063	**0.0059**
19	0.0065	**0.0061**			0.0064	0.0063	**0.0060**
20	0.0065	**0.0061**			0.0064	0.0063	**0.0060**
21	0.0065	**0.0060**			0.0064	0.0063	**0.0060**
22	0.0064	**0.0060**			0.0064	0.0063	**0.0060**
23	0.0064	**0.0060**			0.0064	0.0063	**0.0060**
24	0.0064	**0.0060**			0.0064	0.0063	**0.0060**
25	0.0064	**0.0060**			0.0064	0.0063	**0.0060**
26	0.0063	**0.0060**			0.0064	0.0063	**0.0060**
27	0.0063	**0.0060**			0.0064	0.0063	**0.0060**
28	0.0063	**0.0061**			0.0064	0.0063	**0.0060**
29	0.0063	**0.0061**			0.0064	0.0063	**0.0060**
30	**0.0056**	0.0061			0.0064	0.0063	**0.0060**
Out-of-Sample							
3	0.0146	**0.0134**			**0.0123**	0.0132	0.0130
1	0.0128	**0.0112**			**0.0110**	0.0111	0.0112
2	0.0106	**0.0088**			0.0088	**0.0086**	0.0089
3	0.0089	**0.0071**			0.0072	**0.0069**	0.0072
4	0.0077	**0.0062**			0.0061	**0.0059**	0.0061
5	0.0068	**0.0057**			0.0054	**0.0052**	0.0055
6	0.0062	**0.0054**			0.0051	**0.0049**	0.0051
7	0.0058	**0.0053**			0.0049	**0.0047**	0.0049
8	0.0056	**0.0053**			0.0048	**0.0046**	0.0048
9	0.0054	**0.0053**			0.0048	**0.0046**	0.0048
10	**0.0053**	0.0054			0.0048	**0.0046**	0.0047
11	**0.0053**	0.0054			0.0048	**0.0046**	0.0047
12	**0.0052**	0.0054			0.0048	**0.0046**	0.0047
13	**0.0052**	0.0054			0.0048	**0.0046**	0.0047
14	**0.0051**	0.0054			0.0048	**0.0046**	0.0047
15	**0.0051**	0.0054			0.0048	**0.0046**	0.0047
16	**0.0051**	0.0054			0.0048	**0.0046**	0.0047
17	**0.0050**	0.0054			0.0048	**0.0046**	0.0047
18	**0.0050**	0.0053			0.0047	**0.0046**	0.0047
19	**0.0049**	0.0053			0.0047	**0.0046**	0.0047
20	**0.0049**	0.0053			0.0047	**0.0046**	0.0047
21	**0.0048**	0.0052			0.0047	**0.0045**	0.0046
22	**0.0048**	0.0052			0.0046	**0.0045**	0.0046
23	**0.0047**	0.0051			0.0046	**0.0045**	0.0046
24	**0.0047**	0.0051			0.0046	**0.0045**	0.0045
25	**0.0046**	0.0050			0.0045	**0.0044**	0.0045
26	**0.0045**	0.0050			0.0045	**0.0044**	0.0045
27	**0.0045**	0.0049			0.0044	**0.0043**	0.0044
28	**0.0044**	0.0048			0.0044	**0.0043**	0.0044
29	**0.0044**	0.0048			0.0044	**0.0043**	0.0044
30	**0.0040**	0.0047			0.0043	**0.0042**	0.0043

Note: Our out-of-sample model forecast over the last 155 months of our full sample size and presents the RMSE of the forecast for comparison across models. The best statistics value depicted by the lowest RMSE in model comparison denotes a better forecast performance, which we depicted in bold highlights in Table 6. First, we estimate our models for in-sample observation, and then update our estimation for each observation in our out-of-sample models. Our unrestricted VAR estimates presents our Yields-Only model (consisting of only three latent factors without the macro factors) with 31 yields observation (consisting of 3-month yield, and 1–30-year yields), and our Macro Model (consist of the three latent factors alongside the three macro factors such as inflation, real activity, and oil) represents a VAR estimate with fitted macro factors alongside all 31 yields observation. Thus, the first two models are formed from an unconstrained estimation, while the last three models impose a cross-equation restriction (where one macro factor is held constant) as derived from the non-existence of arbitrage. Each Macro factor represented denotes that the factor's restriction in the model estimation (for example, RMSE values presented under INF depicts the forecast performance results for inflation being restricted in the model estimation and vice-versal).

the two latent factors. Therefore, we reject the hypothesis that the coefficient is equal to 1 at the 1% level. Furthermore, loadings on macro factors, as reflected by the coefficient of the fitted value (R^2), remain significant, thereby suggesting that macro factors capture some of the level factor. One reason for the survival of the level factor following the introduction of macro factors is simply related to the fact that level factors are proxies for the 1st principal component of the yield curve. Thus, given that the unobservable factors are linear combinations of yields, the 1st principal component (also the level of the short rate) is the best linear combination that explains the term structure movements. Therefore, adding macro factors still does not make these factors resemble the level factor of the yield curve, making this factor still relevant to interpreting term structure movements.

Our regression of the Yields-Only slope factor (Unobs 2) on factors from the Macro model also yields a loading value much smaller than 1 (0.01), similar to the level factor. Although the R^2 value indicates a significant impact, the coefficient on macro factors shows a smaller negative loading compared to Panel A. This implies that from the Macro model, movements of macro factors explain a smaller part of the traditional slope factor. When macro variables increase, the slope narrowly converges due to the increase of the short rate relative to the long rate. Finally, evaluating the regression result of the Yields-Only traditional curvature factor (Unobs 3), evidence still supports a significant negative coefficient on macro variables, with the curvature coefficient statistically different from 1 at the 1% significance level. It is worth noting that the correlation across latent factors jumps to 0.99 in Panel B of the regression analysis because the independent variables in this panel are the factors derived from the macro model. These factors are constructed to explain the variation in the yield curve that cannot be accounted for by the observed macroeconomic variables in Panel A. Essentially, the high correlation across the latent factors indicates that they are closely related and capture similar variation in the yield curve.

Furthermore, in Panel A of the table, the coefficient estimates for the three unobserved factors show that they have a positive effect on the slope of the yield curve, with Unobs 1 having the most substantial impact. This implies that investors demand a higher return for holding longer-term bonds due to the increased risk of interest rate changes and inflation. Moreover, the same factors have a negative impact on the curvature of the yield curve, with Unobs 3 having the most significant effect. This suggests that changes in the slope of the yield curve are often accompanied by changes in its curvature, and investors demand a higher return for holding intermediate-term bonds due to the increased risk of changes in the slope and curvature of the yield curve. In Panel B, the regression results show that Unobs 1 and Unobs 2 have a positive impact on the level and spread of the yield curve, respectively. This implies that investors demand a higher return for holding longer-term bonds due to the increased risk of interest rate changes and inflation, and investors demand a higher return for holding bonds with longer maturities due to the increased risk of changes in the slope of the yield curve. In contrast, Unobs 3 has a negative impact on both the level and spread of the yield curve. This suggests that investors demand a higher return for holding intermediate-term bonds due to the increased risk of changes in the slope and curvature of the yield curve. The estimated coefficients show that the level and spread factors have positive effects on both the slope and curvature risk premia, while the curvature factor has a negative effect on the curvature risk premia.

The slope risk premium compensates investors for holding longer-term bonds instead of shorter-term bonds, while the curvature risk premium compensates them for taking on the risk of changes in the shape of the yield curve. These risk premia are related to other risk premia in the term structure, such as the term premium, which compensates investors for holding bonds with longer maturities. The level factor in Panel B captures the term premium, which explains why it has a positive effect on the slope and curvature risk premia. The spread factor captures the difference between long-term and short-term bond yields, which is also related to the term premium, explaining its positive effect on the risk premia. The curvature factor captures the curvature risk premium directly, which explains its negative effect on the curvature risk premia.

In summary, the regression analysis results in Table 2.6 demonstrate that unobserved factors related to inflation, real activity, and oil have a significant impact on the slope, curvature, and term premium of the yield curve. The results indicate that changes in the slope and curvature of the yield curve are often accompanied by changes in the term premium, which is the additional return that investors demand for holding longer-term and intermediate-term bonds. This implies that investors are willing to pay a premium to compensate for the increased risk of interest rate changes and inflation, as well as changes in the slope and curvature of the yield curve.

Table 2.6: Yields-Only and Macro Factors Comparison

Dependent variable	**Independent Variables**						
	Inflation	**Real activity**	**Oil**	**Unobs 1**	**Unobs 2**	**Unobs 3**	**Adj R2**
Panel A: Regressions on macro variables							
Unobs 1	0.097	0.022	0.104				0.01
"level"	(0.078)	(0.024)	(0.843)				
Unobs 2	0.198	0.023	-0.395				0.04
"spread"	(0.189)	(0.058)	(2.039)				
Unobs 3	0.292	-0.005	-2.342				0.01
"curvature"	(0.310)	(0.094)	(3.341)				
Panel B: Regression on factors from macro model							
Unobs 1	0.001	0.001	0.003	0.005	-0.001	0.000	0.99
"level"	(0.001)	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)	
Unobs 2	-0.002	-0.001	-0.003	0.004	0.007	-0.000	0.99
"spread"	(0.001)	(0.000)	(0.005)	(0.000)	(0.000)	(0.000)	
Unobs 3	-0.095	-0.015	-0.198	0.001	0.004	0.010	0.99
"curvature"	(0.000)	(0.000)	(0.003)	(0.000)	(0.000)	(0.000)	

Note:Our regression table models latent factors from Yields-Only model (as dependent variables) on macro factors as well as latent factors from Macro model (as independent variables). We normalized all variables and present the standard errors in the parentheses. In Panel A, we present coefficients obtained from the regression of Yields-Only latent factors on macro factors. In Panel B, we present coefficients obtained from the regression of Yields-Only model on macro factors as well as latent factors derived from the Macro model.

2.6 Conclusion

The main aim of this paper is to present a term structure model of the yield curve that includes unobservable yield variables (latent factors) and observable macroeconomic variables (macro factors), using a Gaussian framework. Our model focuses on uncovering the joint dynamics of zero-coupon bond prices and macro variables in a factor model of the term structure. This approach builds upon previous studies of yields and macro variables that use VAR models, by incorporating no-arbitrage assumptions through the introduction of a global factor into the term structure equation. This enables us to investigate the US economy from an open-economy perspective, rather than the closed-economy perspective commonly used in existing studies.

Our paper finds that macro factors and oil prices explain approximately 68.87% and 13.3%, respectively, of yield curve movements at short- and intermediate-term horizons, but only about 17.73% and 10.92%, respectively, of yield curve movements at long-term horizons. The results show that the effect of real activity shocks is more pronounced at the short end of the yield curve, while the effect of inflation shocks is more pronounced at the middle and long ends of the yield curve. When comparing the unobservable factors from the traditional model of three latent factors of the term structure, the Unobs 1 (level) factor mostly survives following the inclusion of macro variables, but a greater portion of the level and slope factors is associated with the macro variables, especially inflation and oil. Furthermore, our cross-equation restriction from no-arbitrage helps boost our out-of-sample forecast, and introducing macro factors into our term structure model further improves forecast performance.

Based on a comparison of forecast errors, our paper establishes that our six-factor term structure model outperforms the five-factor model for the sample size of yields with maturities of 3 months, 1 year, 3 years, and 5 years, investigated by Ang et al. (2006), for both the yields-only and macro model. Furthermore, by deploying the Diebold and Mariano (1995) test for forecast predictive accuracy between our model and the traditional ARIMA forecast procedure for one-month ahead forecast, our model demonstrates a higher predictive accuracy when comparing the forecast errors of both models. Despite the various methodological procedures employed in this paper, we acknowledge that we have not extensively considered other global variables to further establish the significance of global factors in the term structure model. Moreover, this paper acknowledges the work of Kim et al. (2021)[16] and Kumar et al. (2021)[17] that has captured the impact of uncertainty on financial securities in developed and emerging economies, which can be incorporated into our six-factor model using the PCA technique to develop a global factor variable that captures uncertainty in our term structure model for US bonds; however, this is beyond the scope of the current paper. Hence, we strongly recommend that future research should build a term structure model that includes uncertainty variable in the development of a global factor index in order to account for uncertainty indicators such as economic policy uncertainty and the volatility index (VIX), among others, to investigate the forecast performance of the six-factor model. Our model can also be tested for other developed countries, such as the Eurozone bonds, as well as for the prediction of other forms of financial securities. Furthermore, in line with the study of Ang et al. (2006), our paper points out that assuming orthogonality between latent and macro factors implies the inability of the term structure movements to predict changes to macro variables. Hence, we recommend that future work explore this limitation.

[16] Examines the relationship between financial uncertainty and interest rate movements in Asian bond markets. The authors use a sample of seven Asian economies and employ a GARCH model to estimate the impact of financial uncertainty on interest rate volatility. The study finds that financial uncertainty has a positive and significant effect on interest rate volatility in all the economies studied. However, the effect of financial uncertainty on interest rate volatility is found to be more significant in the more developed economies than in the less developed economies.

[17] Examines the differences in the effects of uncertainty on economic activity in advanced and emerging economies. The authors use a panel of 20 advanced and emerging economies over the period of 1990-2014 and estimate the impact of uncertainty on economic activity using a dynamic panel data model. The study finds that the impact of uncertainty on economic activity is more significant in advanced economies than in emerging economies. However, the impact of uncertainty is more persistent in advanced economies compared to emerging economies.

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Chapter 3

Institutional Quality as Transmission Mechanism for Growth in Oil Exporting Emerging Economies

3.1 Introduction

Since the emergence of the studies by Sachs and Warner (1995*b*, 1999, 2001*a*) that revealed the negative impact of resource abundance on economic growth, researchers have investigated plausible mechanisms for such a negative relationship, referred to as the "resource curse". Earlier studies such as Corden and Neary (1982) and Corden (1984), among others, affirmed the existence of Dutch disease where resource abundance leads to real exchange rate appreciation, resulting in decreased export and hence, reduced growth. Rent-seeking behavior by economic agents due to resource abundance has been argued by Kolstad (2009), and Al-Kasim et al. (2013) to facilitate non-productive activities and enhance government corrupt behavior. This rent-seeking behavior plays a role in the negative relationship between resource abundance and growth. Furthermore, de Medeiros Costa and dos Santos (2013) and Sala-i Martin and Subramanian (2013) recognize that the failure of governments to practice efficient bureaucratic systems, implement growth-oriented policies, and ensure the right institutional quality contributes to the resource curse in resource-rich economies. Resource abundance diverts both resources and attention from human capital development, hindering growth (Gylfason, 2001).

One prominent and key question that analysts and policymakers are constantly confronted with in developing and emerging economies is the quest to sustain economic growth. Until recently, past economic literature provided little information on this issue. In fact, since the 1990s, studies centered around cross-country growth estimations have tried to investigate the long-term differences between, for instance, growth rates and stagnation in Africa and South America, and the miracle episodes in Asia. However, a fundamental element of growth has been ignored over time for developing countries, particularly its lack of persistence. If the output track for developing countries reflects a mountain, cliff, and plain rather than a steady "hill" (as is the case for industrialized economies), seeking justification for average cross-country differences in growth patterns can present misleading results (Pritchett (2000)). Moreover, from a developing country perspective, following such an approach cannot help solve the critical question of why some economic downturns might be relatively prolonged, or why we see some growth episodes end much earlier and faster. [1].

However, a more suitable approach might be to explore information on turning points for specific countries' growth performance (Berg et al. (2012)). Therefore, if a country's economy shows a falling-off-the-cliff trend over a period of time and later experiences a turnaround by climbing a mountain (steady progression), it is appropriate to investigate this transition as well as the time of the growth episode to unravel any useful patterns and activities. Similarly, if a country's economy reflects steady progression over a number of years and suddenly depicts the opposite, it will be helpful to understand what path out of growth represents. Perhaps other countries can follow a different path for better results. Among others, studies that attempted to unravel information on growth transitions, as pioneered by Ben-David and Papell (1998) and Pritchett (2000), include Aguiar and Gopinath (2007), Jones and Olken (2008), and Reddy and Minoiu (2009).

Evidence from these studies has been mixed, with some supporting the institutional elements perceived to be crucial from a cross-country perspective. Nonetheless, most studies opine that growth transition remains a mystery, and that the "usual assumption" only explains a tiny fraction of activities that take place during a country's transition. More specifically, according to Hausmann et al. (2005), political regime changes as well as currency depreciation show a correlation with growth acceleration, while a fall in investment plays an important role in economic downturns.[2] On the other hand, macroeconomic instability, export collapses, and conflicts are associated with growth deceleration Rodríguez et al. (2006). In other words, a provisional conclusion reached in these studies is that the factors needed to get growth going (initiating the growth process) might differ from the factors needed to keep it going (sustaining the growth process).

Our paper contributes to the existing body of knowledge in the literature by paying strict attention to predictors of growth for emerging economies while modifying the standard growth model to include some external conditions that impact small open oil-exporting emerging economies. A long period of fastened growth in emerging economies is needed to close the per capita income gap with developed or rich economies. Hence, spikes in growth levels have become a common scenario for developing and emerging economies, including regions with a poor growth record in the past, such as Sub-Saharan African countries (for example, Nigeria). What differentiates poor-performing regional economies from their developed counterparts is the rapid end of their growth spell sooner than later. Thus, an important question to unravel is what countries' institutions mean for growth transitioning, especially for emerging economies that have recently witnessed strong growth. Do institutional factors contribute to a country's resource use for better economic growth? Most resource-rich emerging economies have witnessed a situation where their resource abundance results in economic stagnation, known as the "resource curse." However, Stevens (2003) pointed out that this scenario can arise from a number

[1] Panel regression can be able to explain this issue but might not be able to account for growth turning points and can be misspecified if it does not capture growth dynamics in a steady linear model with some set of indicators

[2] Whether investment booms relate with up-breaks is not clear (Jones and Olken (2008)). However, unlike previous studies that focused on domestic investment as the major driver of sustainable growth (see, for example, Murphy et al. (1989); Nurkse et al. (1966); Rosenstein-Rodan (1943) among others), Sachs (1989) proposed a massive scale-up of aid inflows to facilitate capital deepening in emerging economies.

of conditions, including a rise in short-term inflation, an increased level of corruption, and a fall in domestic consumption capacity as a result of rising commodity prices (see Bacon and Tordo (2006)).[3]

Our study attempts to provide a comprehensive understanding of the various transmission channels through which fiscal policy may connect with institutional and governance incentives in impacting growth performance for resource-rich economies. Specifically, we present new empirical evidence on the direct and indirect impact of institutional quality on economic growth performance following the fiscal management transmission channel. Our study argues that the windfall management of "institutional quality" is crucial to the growth of resource-abundant economies compared to the strength of their fiscal performance (represented by government size). Thus, the magnitude of the effect on resource-abundant economies is dependent on the country-specific strength and quality of institutional infrastructure in place. To this end, our paper attempts to empirically disentangle the direct impact of country-specific institutional quality on the growth of resource-rich economies through the indirect impact of their fiscal performance using annual panel data of 7 resource-rich countries from 1996-2018. To achieve this key research goal, we make a novel empirical contribution by conducting a methodological exercise of comparing various econometric techniques and establishing the best model that best describes the growth situation in oil-exporting emerging economies.

Based on our theoretical argument, we estimate that earnings from natural resources, particularly oil exports, hinder growth in small open emerging economies with weak institutions compared to countries with better institutions. This is in line with the assumption made by Bhattacharyya and Hodler (2014) that oil-rich countries such as Nigeria might witness less corruption and a better growth rate following its first free and fair election that took place in April 2011. Unfortunately, this has not been the case ten years down the line as growth seems to have deteriorated over time (Bhattacharyya and Hodler (2014)).

The remainder of the paper is set out as follows. Section 3.2 presents stylized facts on institutional quality, natural resource efficiency, and economic growth. Section 3.3 describes the theoretical motivation of our study, while Sections 3.3.1-3.3.3 outline the concept of growth and convergence, growth determinants, and the model of the study, respectively. Section 3.4 describes our dynamic panel data estimation. Section 3.4.1-3.4.3 explain the First Difference GMM, System GMM, and Corrected Least Square Dummy Variable estimation setups. Section 3.5 presents the data, variable properties, and methodology. Section 3.6 presents our empirical results and discussions. Section 3.7 presents results from our empirical model comparison. Finally, Section 3.8 concludes and provides the policy implications of the study.

3.2 Stylized Facts: institution quality, natural resource efficiency and economic growth

Undoubtedly, some resource-rich economies benefit from their resource wealth, while others experience a deteriorating economic state. We discuss some well-known facts reported in

[3]Other factors include poor control of government spending, heavy economic and political dependence on revenue from production and export of natural resources, and rising real exchange rates in reaction to revenue from resource exports that in turn depress other sectors (such as industry and agriculture) of the economy (termed the "Dutch Disease").

existing studies that investigate oil-dependent oil-exporting economies in line with their poor macroeconomic performance, as well as contrasting this with those economies that have benefited from their natural resource rent. We also discuss the cross-country stylized facts on the impact of natural resources on economic outcomes. The main objective of our stylized facts is to outline the numerous diverse experiences of resource-rich oil-exporting countries and unravel the underlying puzzle they exhibit. Evidence of the resource curse exists for many countries, including small open oil-exporting emerging economies (see, for example, the cases indicated in the study by Auty (2001) among others). However, the most exciting example is possibly Nigeria (see cases presented by Sala-i Martin and Subramanian (2013))[4].

Evidently, for Nigeria, the huge oil exports have not benefited the economy in a way that positively translates to the standard of living of its citizens. Despite a positive spike in physical capital growth set at 6.7% annually since 1960, there has been a deep blow to its Total Factor Productivity (TFP) that has witnessed an approximate annual decline of 1.2%. The manufacturing sector capacity utilization rallies around one-third of the total economy, with two-thirds of this capacity often managed by the government, leading to increased wastage. The oil wealth intended for the country has been carted away by several military dictatorship successions, and this oil wealth has basically reformed the governance and politics of Nigeria. It is, therefore, difficult to maintain that the non-oil-export sector worsening competitiveness, given the existence of the Dutch disease, can absolutely explain the poor economic performance. Rather, fiscal imperatives and price movements that appear to drive the exchange rate policy are likely the determining factors of the resource boom (Sala-i Martin and Subramanian (2013)). Other small open oil-exporting emerging economies (Bolivia, Indonesia, Colombia) have witnessed negative or delayed economic growth in the last few decades. Likewise, members of the OPEC also witnessed a fall in GDP per capita during the same period (Stokke (2008)). For example, the interference of the "air bridge" since 1994 that resulted in the shift of the production of cocoa paste from Bolivia to Colombia (resulting in the boom of Colombia's agricultural sector) has been able to boost employment, including self-employment, both in urban and rural areas (Stokke (2008)). However, the emerging financial opportunities, as well as the increasingly economic spill-over effects from this sector, have exacerbated civil unrest and violence, especially in rural areas (Angrist and Kugler (2008)).

Examining the effects of the Dutch disease, according to Sala-i Martin and Subramanian (2013), early empirical evidence for the declining manufacturing sector in response to oil shocks has been mixed. However, evidence from Harding et al. (2009), which investigated 135 countries from 1975-2007, shows that economies respond to resource windfalls by reducing exports of non-resource by 35%-70%, while imports of non-resource rise by 0.1%-35%, rescuing approximately 30% of the manufacturing sector. These pieces of evidence pertain mainly to cross-sectional analysis of countries (averaging up to four decades) through pooled panels, dynamics, and country fixed effects techniques. In another study that employed a more comprehensive disaggregated sectoral data, a corresponding evidence reports that a 10% oil windfall accounts for about a 3.4% decline in value added to the economy, and this is even lesser for countries with high capital inflow restrictions (Ismail (2010)).

[4]From 1965 to 2000, Nigeria's oil wealth generated per capita increased from US $33 to US$325, however, since independence, income per capita has maintained a constant value of approximately US $1,000 in PPP - setting Nigeria among the fifteen poorest countries in the world.

Furthermore, using quasi-experimental analysis, Caselli and Michaels (2013) provides evidence for within-country effects of the Dutch disease for Brazil by utilizing the municipal oil dependence dataset to reflect the level of concentration from a geographical perspective. It reveals that oil wealth fails to have an extensive impact on the non-oil sector of the economy. Although, in line with the Dutch disease hypothesis, the manufacturing sector shrinks and the service sector expands, which in turn boosts household income (through a higher government wages policy) by 10%. This Brazilian evidence aligns with the Dutch disease hypothesis but also leads to corruption and waste at the local level (Caselli and Michaels (2013)).

More recent evidence has emerged from investigating the nexus between institutional variables (focusing on political institutional quality) and the resource curse (see, for example, Cabrales and Hauk (2011)) as well as the interconnection between institution and resource abundance (see, for example, Wick and Bulte (2006)). These studies have focused exclusively on one major issue: the effect of the resource curse on institutional quality and less on the role of institutional factors (as a transmission mechanism) in evading the curse through growth as some institutional indicators can push against the assumption of Sachs and Warner (1995*a*), the reality that resource abundance can result in resource inefficiency. In this case, depending on a country's institutions to ensure resource efficiency and mitigate the resource curse can boost economic growth as more incentives are better aligned for resource efficiency given the market cost; thus, encouraging resource conservation, which moves the industry to better production frontier. However, until recently, very little effort has been put forward in investigating institution factors and resource use efficiency except for the work of Hartwell and Coursey (2015) that found an existing correlation between broad economic freedom, better public health, and environmental factors for the period 1960-1992.

In order to address the plausible relationship between institution (accounting for resource use efficiency) as a transmission mechanism for growth of small open oil-exporting emerging economies, we need to investigate countries' institutions that greatly utilize resources that translate to growth. From a theoretical perspective, which institutional factors can mitigate the "curse" from resource efficiency for resource-rich countries? Following Hartwell (2013) taxonomy of institutions, which is similar to the early study of Kolstad (2009) that investigates which institutions matter for the resource curse, we focus on utilizing the institutional quality index developed by the World Bank which will be explained in detail in Section 4.3. While the debate on the role of institutions as a transmission mechanism for growth continues to linger, some existing studies have questioned whether resource abundance is a curse. Evidence to this regard has been mixed, as some researchers like Bulte et al. (2005) and Mehrara (2009) argue for the presence of a resource curse, while on the contrary, Cavalcanti et al. (2011) and Van der Ploeg and Poelhekke (2010) oppose the results of the presence of a resource curse.

3.3 Theoretical Motivation

With reference to previous studies, the growth engine proposed by Solow (1956) reflects the assumption of exogenous technical change. This implies that growth models aim to be compatible with growth realities, but the possibilities of clarifying them have not been fully documented. Two distinct weaknesses are associated with this model. First, the difficulty of adopting the exogenous growth model in explaining long-run cross-country growth differences. Second, economic decisions are actually triggered by changes in productivity, which is assumed to be exogenous in the Solow model. Given this scenario, it is necessary to investigate both the channels through which factors determine long-run cross-country growth differences and the changes in productivity to gain a comprehensive understanding of this growth phenomenon.

It is not surprising that issues related to modeling growth have continually resurfaced over time for a number of reasons. Two basic reasons that this study documents are: first, the development of new and more reliable datasets for gross examination of cross-country per capita income level comparisons that have continually captured the attention of researchers; and second, the fact that new theoretical tools provide researchers with better knowledge of growth paths given intertemporal and dynamic optimization, which has continually attracted the interest of researchers. In this context, we develop our theoretical motivation by criticizing the drawbacks associated with the traditional model, which fails to provide a basic explanation for some real-world phenomena. We aim to provide a more comprehensive examination of growth determinants. A summarized version of the traditional model assumes that the growth rate is dependent on the original position of the economy and that the law of diminishing returns will see poorer economies depict a faster growth pace compared to their richer counterparts (the conditional convergence hypothesis). Additionally, the model foresees that a large gap in capital stock that generates return differentials would result in a substantial flow of capital stock from richer economies to poorer economies. However, both implications have since been rejected by empirical evidence.

The shortcomings of the traditional model motivate researchers to explore alternatives to growth explanation. For example, the study of Romer (1986) proposes a model that perceives long-run economic growth not to be determined by exogenous technological progress, but rather through capital accumulation that is able to generate externalities to compensate for diminishing returns. Similarly, in the study of another pioneer of a revised growth model, Lucas Jr (1988) launches a growth model that highlights the fundamental role played by human capital in restraining the diminishing returns to the accumulation of physical capital as well as facilitating growth. One key attribute of Romer's and Lucas's growth model is its ability to incorporate various aspects of economic theories and their consequences. A specific illustration of this scenario is the successful interaction inspired by economic growth, between macroeconomics (initially controlled by the business cycle theories) and economic development (previously focused on the analysis of economic and institutional planning).

From this brief overview of stylized facts, our aim is to present a comprehensive growth model that aligns with the vast empirical literature on endogenous growth models. These models aim to link a country's growth rate to political, economic, and social factors by using large sample sizes of countries and time.

Generally, our theoretical motivation, established from the existing study of Loayza et al. (2002), is centered around two elementary themes for the development of a comprehensive econometric growth analysis, as set out in Eq. 3.17. The first is addressing the uncertainty surrounding the disparities in aggregate economies transitory over a satisfactory long period, by analyzing the convergence hypothesis. This aligns with the idea that a country's growth is determined by its initial economic position, thus maintaining that the law of decreasing returns to scale assumes poorer countries should depict a faster growth than their rich counterparts. Therefore, we include the initial level of real GDP among our explanatory variables to control for the initial economic position. The second theme is to highlight key determinants of growth supported by existing theories, by identifying variables that can explain perceived disparities in growth processes. Although we set up our growth estimation to account for long-run trends, we also capture short-run periods that feature some cyclical effects, which are significant in mirroring the business cycle. Our estimation introduces the output gap as a growth determinant at the beginning of each period to investigate cyclical reversion. The output gap not only improves the regression fit but also eliminates possible chances of overestimating the transitional convergence speed captured in the initial output coefficient. We use the difference between potential and actual GDP at the start of each period to obtain our output gap.

3.3.1 Growth and the convergence concept

Following the recent questioning of the role of technological innovation as a major player in the long-run growth process by the contemporary endogenous growth model that incorporates increasing and constant returns to capital, the studies of Aghion and Howitt (1992) and Grossman and Helpman (1991a) initially maintained that the incorporation of variables such as innovation, human capital progress, externalities, and knowledge development to capital can enhance self-sustained growth for a country. Their argument was based on the diminishing returns experienced from private investment, while social investment postulates constant or increasing returns resulting in spillover of knowledge that can promote growth. Romer (1986) proposed that the absence of diminishing returns to capital makes GDP per capita growth rate dependent on the previous per capita income level. Hence, from the endogenous growth model, the existence of knowledge spillover and increasing returns will somewhat eliminate the occurrence of convergence, and there would be a situation of divergence. This situation emanates from the postulation that developed countries' growth rate at steady-state is determined by the pace at which innovative ideas are created and incorporated into the production process. Thus, a scenario of divergence would imply a situation where higher-income economies maintain an increased rate of economic growth when compared to lower-income economies, resulting in an increased level of inequality over time (Artelaris et al. (2011)).

The analysis of the convergence concept can be divided into two major categories: δ-convergence and β-convergence. On the one hand, as noted by De la Fuente (2000), when examining the development of per capita income distribution, the first question that arises is whether this variable's dispersion exhibits a declining trend over time. The δ-convergence, as explained by Barro and Sala-i Martin (1992), is related to this question and investigates the distribution of income at a given point in time. A decline in the distribution of real per capita income indicates the existence of convergence. This helps to determine whether the distribution of income across economies is becoming more equal over time, which is consistent with the concept of convergence theory.

On the other hand, another plausible question to consider is whether each country's relative position within the income distribution stabilizes over time, or whether poor economies are able to catch up with rich economies. These questions relate to the concept of conditional and absolute β-convergence proposed by Barro and Sala-i Martin (1992). Absolute β-convergence captures the possibility of a selected region or country to converge to a similar level of per capita income. This assumes that countries are homogeneous in their operations but differ in their per capita income level, and they all have similar steady-states. Originally, it is expected that poor countries will grow at a faster pace than rich countries, so that in the long run, per capita income will converge to the same level. However, this does not imply the complete disappearance of inequalities from the economy as countries may experience different shocks addressed differently, as well as differences in structural formation. Although these shocks are expected to have a transitory effect, in the long run, things are expected to reshape and take their relative positions for different countries.

On the contrary, conditional β-convergence acknowledges that countries possess different economic conditions that make their activities differ from each other. For example, countries can converge towards discrete steady-states as a result of differences in savings attitudes, technology, fiscal policy, tax rates, etc. Therefore, given a conditional β-convergence, individual regions or countries can converge to their steady-states unique from others, making income disparities linger for a very long period. One clear empirical distinction between conditional and absolute β-convergence is that, following the estimated equation, it is normal for other variables apart from the initial income to propose differences in steady-states across regions and countries. This implies that convergence is conditional, depending on several factors.

As a result of changes in these conditioning variables over time and their convergence across regions and countries, there is a possibility of absolute convergence in income in the long run, reflecting a moderate equalization of the underlying elements. Under this scenario, the estimation of both absolute and conditional β-convergence may exhibit slight differences in estimation results of convergence rate. However, this does not imply conflicting results between the two, once it is acknowledged that they measure different concepts De la Fuente (2000). The estimation of conditional convergence accounts for the speed at which an economy arrives at a "pseudo-steady-state" with its location dependent on the prevailing value of the conditional variable. The estimation of absolute convergence measures the overall magnitude of income convergence resulting from gradual changes in various structural activities over time.

Notably, according to Haider et al. (2010), the convergence concepts might reflect some interrelation but are not equivalent. Looking from a peripheral perspective, it is possible to link absolute β-convergence with declining dispersion, but this might be the reverse given that the global economy is more stochastic than deterministic. Barro and Sala-i Martin (1992) highlights that although β-convergence is a necessary condition for δ-convergence, it is not sufficient as countries' activities tend to reshuffle over time, indicating the possibility of experiencing random shocks. In this case, we can see β-convergence to be consistent with δ-divergence, thereby indicating that rich economies grow faster than poor economies. In the absence of further examination, it is difficult to conclude that β-convergence is equivalent to δ-convergence.

3.3.2 The Model

This section of the paper will focus on developing a simple model that captures the main factors of growth theory discussed in the previous section. There are possibilities for the model to produce contrasting results regarding cross-country income distribution based on the predicting values of certain variables that account for the proposed assumption of determining factors of the rate of technical progress and the features of production technology. From the initial development of De la Fuente et al. (1995), our model emphasizes the cross-country relative productivity resulting from two key players: technological advancement and capital accumulation, which are determined by the amount of investment in both human and physical capital as well as the rate of technology diffusion.

Contemporary economic growth models have adopted the neoclassical model proposed by Solow (1956), which is based on the assumptions of exogenously determined factors such as diminishing returns of capital, technological innovation, constant returns to scale, and capital and labor substitutability. These models identify variables such as investment, technological advancement, savings, and population growth as the driving force of growth in various economies. This model provides the fundamental framework for discussing the existing controversy surrounding economic growth and convergence. The growth dynamics can be divided into two dimensions of growth processes: cutting-edge and catching-up growth. Countries at the catching-up stage tend to grow faster than countries that have already reached their cutting-edge.

On this note, to examine the cross-country growth specification, we set up a simple foundational framework to explain the growth dynamics for a standard growth econometric model. Considering a country i at time t, we assume that the Harrod-neutral technological progress, which implies labor-augmenting technological progress, forms the technological innovation in the production function. Thus, $A_{i,t}$ represents knowledge as the labor-augmenting technological progress, and labor input is captured with AL to reflect the efficiency unit. $A_{i,t}$ is constant with exogenous representation: g_i. Assume output is represented by $Y_{i,t}$, $A_{i,t} = A_{i,0}e^{g_i t}$, and $L_{i,t} = L_{i,0}e^{n_i t}$. The notions for for standard per capita of outpur per worker efficiency are represented by $\hat{y}_{i,t} = \frac{Y_{i,t}}{A_{i,t}L_{i,t}} \equiv \frac{y_{i,t}}{A_{i,t}}$ and the output per worker by $y_{i,t} = \frac{Y_{i,t}}{L_{i,t}}$.

Similar to the Mankiw et al. (1992) one-sector growth model, the prediction of the model is that we consider the first-order Taylor approximation of $\ln \hat{y}_{it}$ around the steady state $\hat{y}_i^*$ such that:

$$(\ln \hat{y}_{i,t} - \ln \hat{y}_i^*) \simeq e^{-\lambda_i t}(\ln \hat{y}_{i,0} - \ln \hat{y}_i^*) \tag{3.1}$$

$$\text{so that } \ln \hat{y}_{i,t} \simeq e^{-\lambda_i t} \ln \hat{y}_{i,0} + (1 - e^{-\lambda_i t}) \ln \hat{y}_i^* \tag{3.2}$$

where the speed of convergence is captured by $\lim_{t\to\infty} \hat{y}_{i,t} = \hat{y}_i^*$ which accounts for how fast $\hat{y}$ converges to $\hat{y}^*$ when $\hat{y} < \hat{y}^*$. Suppose we have a Cobb-Douglas production, in Eq. (3.2) $\lambda_i = (1 - \alpha_i)(n_i + g_i + \delta)$, the average weighted of the initial and steady state values are captured by $\ln \hat{y}_{i,t}$ with λ_i representing the exponential decline of the weight on $\ln \hat{y}_{i,0}$ for any $t \geq 0$. For the long-run consideration, the initial condition can be neglected.

However, to set out the dynamics as observable $y_{i,t}$ given that $\hat{y}_{i,t}$ is unobservable, we recall:

$$\ln \hat{y}_{i,t} = \ln y_{i,t} - g_i t - \ln A_{i,0} \tag{3.3}$$

$$\ln \hat{y}_{i,0} = \ln y_{i,0} - \ln A_{i,0} \tag{3.4}$$

and re-write Eq. (3.2) as

$$\ln y_{i,t} = g_i t + (1 - e^{-\lambda_i t}) \ln \hat{y}_i^* + (1 - e^{-\lambda_i t}) \ln A_{i,0} + e^{-\lambda_i t} \ln y_{i,0} \tag{3.5}$$

We make output per worker growth between 0 and t be captured with g_i' such that:

$$g_i' = \frac{\ln y_{i,t} - \ln y_{i,0}}{t} \tag{3.6}$$

Subtracting $\ln y_{i,0}$ and dividing by t from (3.5) we obtain

$$g_i' = g_i + \gamma_i(\ln \hat{y}_i^* + \ln A_{i,0} - \ln y_{i,0}) \tag{3.7}$$

$$g_i' = g_i + \gamma_i(\ln \hat{y}_i^* - \ln \hat{y}_{i,0}); \text{ where } \gamma_i = \frac{1 - e^{-\lambda_i t}}{t} \text{ is crucial in empirical growth.} \tag{3.8}$$

In (3.8), g_i, the technological progress, and $\gamma_i(\ln \hat{y}_i^* - \ln \hat{y}_{i,0})$, the 'catch-up effect' – the gap between initial conditions and $\ln \hat{y}_i^*$ – which diminishes to zero as $t \to \infty$ defines the output per worker growth rate between 0 and t in country i.

A further simplified assumptions for $g_i = g$ (technical progress) and $\lambda_i = \lambda$ (convergence speed) $\forall i$ defines (3.8) as:

$$g_i' = g + \gamma(\ln \hat{y}_i^* - \ln \hat{y}_{i,0}) \tag{3.9}$$

This means that for cross-section, given that g and λ are constant across countries, a negative correlation exists between g_i' and the initial condition ($\ln \hat{y}_{i,0}$) for the average growth rate at any given time. Although, there is an expectation that countries might converge towards their own balanced growth path (BGP) [5].

3.3.3 Growth Determinants

To ensure that we avoid errors of omission in identifying factors that predict economic growth, we consider a wide variety of both social and economic factors. We group these factors into three major macroeconomic dimensions: structural policies (including education/human capital, financial depth, international trade openness, and public infrastructure), stabilization policies (including macroeconomic stabilization policies and the risk of balance-of-payment crisis and external imbalances), and external conditions (including terms-of-trade shocks and period-specific shifts).

On the one hand, in examining the variables related to structural policies, it is clear that governments play a vital role in influencing the long-term growth of their country, even though disparities may arise in identifying which public policy variables are able to adequately explain long-term growth. While most theoretical studies have focused on either one or a combination of few policies, the majority of empirical studies have conducted comprehensive investigations into factors that contribute to growth performance. Therefore, we will focus on various policy variables that help structure economic activities. Although we acknowledge that differentiating between structural and stabilization policies can be subjective, it is useful to capture trends and the direct impact of different policy pathways on long-run growth as well as cyclical fluctuations.

Our first area of focus under the structural policies is education/human capital. It is interesting to note that the intensity of diminishing returns in other production factors such as physical capital can be restrained by human capital in delivering long-run eco-

[5] See, Barro (2004) and other Barro's books/papers on growth determinants and convergence for cross-country studies

nomic growth. Thus, aside from education/human capital's direct impact as one of the factors of production, it can determine technological innovation rates and promote technological engagement for countries that produce technology and those that simulate them, respectively. Similarly, it can also complement other factors such as natural resources and physical capital[6]. Our second policy area focuses on a country's financial depth, as a well-performing financial system is capable of aiding long-run economic growth following its direct impact on economic efficiency and indirect impact through various growth channels. There are greater tendencies of risk diversification through the financial market by trading, pooling, and hedging of financial instruments as they can help signal profitable investment operations and facilitate crowdfunding for them. Moreover, financial instruments can deploy corporate controls and supervise manager activities, hence reducing principal-agent issues associated with inefficient investments[7]. The third policy area explored in this study is the country's international trade openness. Existing literature has documented five channels through which trade can impact economic growth[8]. The majority of empirical evidence depicts a positive relationship between international openness and economic growth, which indicates a virtuous cycle of increased openness leading to improved economic growth that, in turn, facilitates higher trade[9]. The last structural policy area we consider in this study relates to government infrastructure and services. Among others, the studies of Barro (1991) and Barro and Sala-i Martin (1992) examine the channels through which government infrastructure and services can impact growth and have emphasized the role of public service in facilitating long-run economic growth. Irrespective of how government infrastructure and services are treated (i.e., either as classic or unconventional public goods), they can act as direct inputs in the production process, helping to boost TFP and encourage private investment through property right protection; this, in turn, impacts positively on economic growth[10].

On the other hand, the inclusion of stabilization policy variables as determining factors of economic growth is crucial given their predicting power and the improvement in regression fit over relevant horizons of economic policy. Apart from their significant effect on cyclical fluctuations, stabilization policies can also impact long-run growth as cyclical and trend growth are argued to reflect an interrelated process. Over the short and long term, both crisis-related and macroeconomic stabilization variables have an impact on economic performance. Among others, monetary, fiscal, and financial policies can help curb balance-

[6] We proxy for education/human capital policies by adopting gross secondary school enrollment.

[7] Studies around cross-country, industry, and firm-level investigations provide evidence of financial development's role leading to better economic performance (see, for example, the study of Levine (1997) for summary evidence on the theoretical background as to the financial development role with macroeconomic activities). We measure financial depth as the ratio of financial institutions' domestic private credit supplied to GDP.

[8] First, trade can facilitate higher specialization, resulting in profitable use of total factor productivity (TFP). Second, trade can develop potential markets, allowing domestic firms to benefit from economies of scale by increasing their TFP. Third, through secure interaction between international firms and the market, trade can disseminate enhanced managerial practices as well as technological innovations. Fourth, flexible trade can reduce domestic firms' anticompetitive practices. Lastly, trade liberalization curtails firms' incentives to engage in unproductive rent-seeking activities.

[9] We measure our international trade openness with trade volume (export + import) divided by GDP.

[10] The theoretical importance of Barro's studies has been well-established in the conclusion of recent empirical works (see, for example, Calderon and Servén (2011)). Several alternatives exist to measure government infrastructure and services, among these variables is the gross capital formation which we use as our measure of government infrastructure and services.

of-payment and financial crises and contribute to macroeconomic environment stabilization for long-term growth. By using stabilization policies to minimize uncertainty, firms can increase investment, enable economic agents to focus on productive activities (instead of posing for high-risk engagements), and decrease societal conflict associated with ex-post rent distribution (for example, disputes between employees and business owners during inflation shock).

The first area of focus under the stabilization policies relates to macroeconomic stabilization policies. Interestingly, this is a broad subject and we will focus mainly on two channels: the interrelated impact of monetary and fiscal policy. We begin by examining the absence of price stability, captured by the average inflation rate that corresponds to the country and time period.[11] Subsequently, we examine GDP cyclical volatility, which depicts instability in productivity. We measure this indicator by observing the standard deviation of the output gap for the respective country and time period. Second, we reflect on the danger of balance-of-payment crisis and external imbalances, which is captured by the overvaluation of the real exchange rate index, following the initial proposition in Dollar (1992) methodology. The overvaluation of the real exchange rate highlights the role of exchange rate policies and the monetary impact that misreports resource allocation between the domestic and exporting sectors. Countries can become vulnerable to the risk of external imbalances arising from resource misallocation, which in most cases is accompanied by a balance-of-payment crisis that can lead to the country heading towards recession.

Finally, it is important to consider external conditions that can influence a country's growth experience. Empirical evidence highlights the transmission cycles through external financial inflows, international trade, and investors' insights towards anticipated profits of the global market (Boileau, 1996). Moreover, the volatility of long run trends can spread across countries, aided by technological progress dissemination and the demonstrated effect of economic reforms (Keller, 2002). In this study, we consider two basic variables that account for individual country terms-of-trade shocks as well as countries period-specific shift. Analyzing the terms-of-trade shocks helps to investigate the volatility of production costs and consumption inputs, as well as a country's export international demand, which have been highlighted in earlier studies as factors that influence growth (Easterly and Rebelo, 1993; Easterly et al., 1997; Fischer, 1993). Country-specific time shift outlines the general global conditions for a given time period, depicting global booms and recessions, technological innovations, and volatility in the allocation and cost of foreign capital flows.

Our study extends the existing growth model in two ways. First, we introduce institutional factors and US Term Structure as determinants of growth for emerging oil exporting economies. Second, we explore methodological techniques that best explain the growth situation of emerging economies. The contribution of institutional quality in facilitating economic growth in emerging economies has recently received a wide and renewed interest from scholars, as contemporary evidence affirms its significance in driving long-term growth (Acemoglu et al. (2012); Tebaldi and Elmslie (2008)). Considerable amount of literature (see, for example, Gradstein (2004); Tebaldi and Elmslie (2008)) have independently investigated the level to which institutional quality impacts long-term economic growth, exploring various types of institutions including private or public, economic, so-

[11] This serves as a good quality measure of monetary and fiscal policies and is positively related to other variables of weak macroeconomic policies, such as the foreign exchange black market premium and fiscal deficit.

cial, or political. Cross-country empirical examinations have been of great importance in revealing the scarcity and deficiency of both institutional and macroeconomic data for most emerging countries, which can prevent robust policy understanding for country-to-country comparisons (Srinivasan (1995)). In essence, the clear evidence that weak institutional quality hampers economic growth in emerging economies means that researchers need to propose methodological measures to further strengthen this case (Aron (2000)). Although adopting institutional measures to explain growth outcomes has been a complicated procedure over time due to setbacks in effectively arriving at the best proxy for the variable.

Second, studies on growth exhibit a range of issues including methodology, data, and identification which have been ignored or underestimated by scholars over time (see the study of Temple (1999) for a comprehensive survey). Based on Heston and Summers (1996), there has been an increasing expansion of growth research using Penn World Tables data, but scholars have failed to frequently use several model specifications, measure errors, and data outliers to test the sensitivity and robustness of their results. This signals the possibility of estimation bias and the existence of variable omission. Therefore, we intend to solve this problem by exploring methodological techniques that interpret the growth situation of emerging economies and conducting a robust test to further affirm our methodological technique and variable selection.

3.4 Dynamic Panel Data Estimation

The Generalized Method of Moments (GMM) estimator is constructed by exploiting the counterpart moments of samples of the data-generating model. Among others, the main benefits of the GMM estimator include: (1) The easy characterization of its large sample properties, which encourages comparison and provides a neutral method of testing both estimation and sampling error. (2) The ability to construct a GMM estimator without the full data-generating process being specified, which makes it easy for researchers Hansen (2010).

Generally, estimating panel data implies the need to deal with the heterogeneity problem by either observing the first difference (given that the panel's dimension is normally time series) or introducing the within transformation (one-way fixed effects models). However, a key difficulty of applying the one-way fixed effect model to dynamic panel data (DPD) having small T and large N is the possibility of autocorrelation between the regressor and error term, caused by the demeaning procedure that deducts the value of y individual's mean from each X (i.e., the regressor created from the demeaning process is not independently distributed from the error term) (Nickell (1981)). The common solution to this issue at hand is to take the difference of both sides (set out in Eq 3.11) to remove the constant term and individual effect of the initial model (set out in Eq 3.10).

$$y_{it} = \alpha_1 + \rho y_{i,t-1} + \beta_2 X_{it} + U_i + \varepsilon_{it} \tag{3.10}$$

$$\Delta y_{it} = \rho \Delta y_{i,t-1} + \beta_2 \Delta X_{it} + \Delta\varepsilon_{it} \tag{3.11}$$

The elimination of the individual effect immediately makes instrumental variables available for estimation. Therefore, we can construct our instrumental variables by taking the difference or lagged level from the third and fourth lags of y, given that the series is large enough. In estimating dynamic panel data, Arellano and Bond (1991) argues that the proposed instrumental variable approach fails to utilize all the information present in the sample. Hence, conducting a GMM estimation is a more efficient estimation for dynamic panel data models. The problem of estimating DPD models using too many instruments has been established in earlier simulation studies (see Bun and Kiviet (2006) for extensive reading); therefore, it is necessary to omit some instruments with high-order lags to reduce the degree of over-identification. Arellano and Bond (1991) key strategy is to emphasize the work of Anderson and Hsiao (1982) that considers necessary instruments to be internal, which are the lagged values of the regressors, as well as allowing for the introduction of external instruments (see Eq 3.12).

$$y_{it} = X_{it}\beta_1 + X^*_{it}\beta_2 + \varepsilon_{it} \text{ such that } \mu_i + \nu_{it} = \varepsilon_{it} \tag{3.12}$$

Where X_{it} strictly accounts for exogenous regressors and X^*_{it} accounts for the predetermined regressors. These classes of regressors can correlated with μ_i (the individual unobserved effect). There are two main alternative ways of constructing the GMM estimators which include the first-difference GMM setup (the original estimator) and system GMM setup (expanded estimator).

3.4.1 First-differenced GMM setup

Originally established by Holtz-Eakin et al. (1988) and Arellano and Bond (1991) to estimate DPD, the fundamental idea of this strategy is to present the initial regression equation as a DPD model, observe the first-difference to eliminate country-specific unobserved period-invariant effect, and then introduce the lagged two periods or more of the right-hand-side variables as an instrument (in the first-differenced transformed equation) given the assumption that there is no autocorrelation originally identified in the level equation's time-varying error term.

On the one hand, this approach has proved advantageous in estimating DPD growth models in existing studies for the following reasons: (1) For conditional convergence regression, the biasness of omitted variables constant over time is eliminated. (2) For models with endogenous right-hand-side variables, introducing instrumental variables allows for consistent estimation of parameters in the models. (3) Despite the presence of measurement error, instruments make estimations consistent (see, Bond et al. (2001) for further reading). On the other hand, the critical drawback to this approach (first-differenced GMM) behaving poorly is attributed to the presence of weak instruments in the face of small time-series observations, as the lagged level of variables appears as weak instruments in the differenced model. Hence, the first-differenced GMM approach might be problematic for the growth model context (Blundell and Bond (1998), Bond et al. (2001)). To this end, we propose that a plausible result is achievable by employing a "system" GMM estimator as initially introduced by Arellano and Bover (1995) and Blundell and Bond (1998).

Thus, we setup our first-differenced GMM estimator as a transformed model (Eq 3.14) from the original model in Eq 3.13:

$$y_{it} = \alpha y_{i,t-1} + X^{'}_{i,t}\beta + \varepsilon_{it}, \text{ such that } \mu_i + \nu_{it} = \varepsilon_{it} E[\mu_i] = E[\nu_{it}] = E[\mu_i \nu_{it}] = 0 \tag{3.13}$$

where the observation unit and time indexes is captured with i and t respectively. x account for vector of controls (potentially containing lagged values of y) while the two orthogonal components of the disturbance term are μ_i (fixed effects) and ν_{it} (idiosyncratic shocks). Obtaining the transformed model in first-differenced imply differencing the right-hand and left-hand side of Eq 3.13 such that μ_i is removed from the original equation and its related bias omitted-variable:

$$\Delta y_{it} = \alpha \Delta y_{i,t-1} + (\Delta X_{i,t})' \beta + \Delta \varepsilon_{it} \tag{3.14}$$

Although, to improve the first-differenced GMM estimator, other than relying on the lagged dependent variable, the introduction of explanatory variables as well as lagged values of the DPD model's regressors as instruments can be a way forward. Otherwise, it would be appropriate to explore an alternative estimator (the "system" GMM) that can potentially produce improved finite sample properties in the phase of persistent series.

3.4.2 System GMM setup

Following the drawbacks of the first-differenced GMM estimator, we turn to the system GMM, which was originally developed by Arellano and Bover (1995) and Blundell and Bond (1998), and may have better finite sample properties and has been shown to be well-behaved in simulations. In performing the system GMM estimator, we include the lagged differenced values in the level equation as instrumental variables. The rationale for introducing the new set of instruments in the level equation is the potential absence of autocorrelation in the past changes in our y variable with the current disturbance, including fixed effects.

The work of Blundell and Bond (1998) established additional assumptions (see Eq. 3.15) to build a linear GMM with improved sample properties for autoregressive models with persistent series. This condition holds where the mean value of y_{it} (while differing across individuals) remains constant over time $(1, 2, ..., T)$. With this condition in place, we can include the lagged first-differenced series into the level equation as an instrument (Arellano and Bover (1995)).

$$E(\eta_i \Delta y_{it}) = 0, \text{for i = 1, ..., N} \tag{3.15}$$

3.4.3 Corrected Least Squares Dummy Variable (CLSDV) setup

During the last 20 years, it is important to note that the fixed-effects method of dynamic panel data estimation has remained a challenge in econometrics. This has resulted in the proposition and comparison of several GMM estimators (see, for example, Anderson and Hsiao (1982); Arellano and Bond (1991); Kiviet (1995); Blundell and Bond (1998)). Following the inconsistency of the traditional least squares dummy variable (LSDV) estimator for fixed T, the formulation and comparison of these latest estimators becomes inevitable. In spite of the various innovative developments of the GMM estimators, they face two major criticisms. Firstly, the complexity of this method remains a barrier to applied researchers as these estimators might require the researcher to make further decisions (e.g., deciding on which and how many instruments to employ in the estimation procedure). Secondly, the estimators also possess their personalized drawbacks. For instance, the general error term variance and the ratio of variance of the individual-specific effects are critical in performing the GMM estimators (see Bun et al. (2002)).

To this end, we introduce a new estimator for our dynamic panel data model that is simple and has the advantage of not depending on the general error term variance or the ratio of variance of the individual-specific effects. Instead, it is estimated as a bias correction of the LSDV estimator and is closely related to the developments of Kiviet (1995) and Hansen (2001). Evidence from Kiviet (1995) suggests that the bias-corrected LSDV estimator may outperform GMM estimators for limited numbers of time periods (T) and large numbers of N. In Eq. 3.16, we illustrate the first-order bias-corrected LSDV estimation for the dynamic panel data model by representing only one time-varying regressor for ease of exposition.

$$y_{it} = \gamma y_{i,t-1} + \beta X_{it} + \eta_i + \varepsilon_{it} \text{for i = 1,.......,N:t = 1,....T.} \tag{3.16}$$

Where $y_{i,t-1}$ is the one-period lagged value of the dependent variable, X_{it} is the represented regressor, η_i is the unobserved individual-specific effect, and ε_{it} is the stochastic error term. Although we expect a possible correlation between X_{it} and η_i but we assume X_{it} is strictly exogenous to ε_{it}.

3.5 Data and Methodology

In order to examine the impact of institutional quality as a transmission mechanism for growth in small open oil-exporting emerging economies, this study adopts an annual dataset and follows the approach employed in the studies of Apergis and Payne (2014) which investigated the resource curse, institutional quality, and growth for MENA (Middle East and North Africa) countries. The effect of institutional quality is proxied using the Institutional Quality Index (IQI), which is an average index of five institution variables, including voice and accountability, government effectiveness, regulatory quality, rule of law, and corruption. To account for the growth effect of macroeconomic indicators, we employ observable macro variables grouped into three main categories: stability factor (inflation rate, interest rate, and exchange rate), structural factors (secondary school enrollment, trade openness, and public infrastructure), and external conditions (US term structure and oil price shocks) for Bolivia, Brazil, Colombia, Ecuador, Indonesia, Malaysia, and Nigeria.[12]

3.5.1 Variable description

This section of the paper provides a brief description of the variables employed in our estimation analysis, as well as the source of data collection in Table B.1.

- Gross Domestic Product (GDP): GDP reflects the aggregate of gross value added by a country's domestic producers plus any product taxes and subtraction of any subsides not factored into the product's value. Data are in domestic currency.
- Output Gap: it measures the difference between a country's actual GDP and its potential GDP.
- Interest rate: represents the bank's lending rate for short-and medium-term loans to private sectors.

[12] It is worth noting that the real variables are seasonally adjusted using ARIMA X-12.

- Inflation rate: is measured by Consumer Price Index (CPI) as the annual percentage change in the cost of average consumer to acquire a commodity basket of goods and services.

- Real exchange rate: is the nominal effective exchange rate value of a country's national currency against the weighted average of international currencies (specifically US Dollar) divided by price deflator.

- Government Expenditure: measure the aggregate of government current expenditures on goods and services including compensation payments to employees, and spending on national defense and security. Data are measured as a share of GDP.

- Gross Capital Formation (GCF): formerly called gross domestic investment which includes the sum of a country's fixed assets (such as machinery, plants, and equipment; land improvements; construction of railways, roads, schools, hospitals, commercial and industrial buildings) plus inventories (stocks of goods used to meet both temporary and unexpected changes in production process or sales operation by firms) net changes. Data are measured as a share of GDP.

- Secondary School Enrollment: is the ratio of total enrollment (irrespective of age) to the population of age group that is proportional to the level of education exhibited. Secondary school education accomplishes the provision of basic education that kicked-off from the primary level education.

- Trade Openness: is the measure of a country's aggregated value of exports and imports of goods and services as a share of GDP.

- Institutional Quality Index: is measured as an average index of six dimensions of governance as reported by the World Bank following a similar approach of variable selection employed in the work of Aman et al. (2022). Voice and Accountability (represents the extent to which citizens of a country can freely participate in selecting process of their leader to the seat of power, including freedom of association and expression); Political Stability and Absence of Violence/Terrorism (reflects the probability of political instability and/or politically-motivated violence); Government Effectiveness (represents the quality of public and civil services without any form of political pressures, and the credible commitment of government towards quality of policy formulation and implementation); Regulatory Quality (represents government's ability to formulate and implement effective policies and regulations that allows and facilitates the growth of private sector); Rule of Law(represents agents' confidence level and adherence to the rules of society, and specifically, the quality of contract implementation, and property rights); and Control of Corruption (represent the magnitude at which public power is exercised for personal interests).

- Oil price: is the global market benchmark prices (measured in nominal US dollar period averages) which is determined by the largest exporter of oil.

- US term structure: is the short-term 3 months yields return on zero-coupon US bonds.

- Inst._Oil: is the interaction between institutional quality and oil price shocks to examine the fragility of the estimated effect of institutional quality in affecting growth. This helps to account for how well windfall revenues from oil price increases are managed by government of oil exporting emerging economies.

The sample size of our data runs from 1996 - 2018. In the absence of rich data record, for most developing oil-exporting countries, our paper examine 7 small open oil-exporting emerging economies as outlined in 3.5.

Table 3.1: Variable Description

Variable	Definition	Measurement	Source
y_{t-1}	GDP	Million National Currency	IFS
$IntO_{t-1}$	Brent crude oil price	USD per barrel	FRED
$NomO_{t-1}$	Nominal Brent crude oil price	Domestic Currency	Authors' compilation
IQI_{t-1}	Institution Quality Elementary Index	Based on Simple Average Index	World Bank
g_{t-1}	Government expenditure	percentage of GDP	World Bank
gcf_{t-1}	Gross Capital Formation expenditure	percentage of GDP	World Bank
e_t	Real exchange rate	National currency per USD	IFS
TOp_{t-1}	Trade Openness	Percentage of GDP	World Bank
CPI_t	Consumer price index	All items (2010=100)	IFS
$SchEnr_{t-1}$	Secondary School Enrollment	Percentage of gross enrollment	World Bank
$IntIR_t$	US term structure	Short-term (3_m) yields	Authors' compilation
$DosIR_t$	National Interest rate	Lending Rate	IFS
$roilp_t$	real oil price	Deflated by CPI_t	Authors' compilation
$InstQ.OilP_t$	InstitutionQuality.OilPrice	InstitutionQuality$\times$OilPrice	Authors' compilation

3.5.2 Econometric method selection criteria

Having developed the standard growth model, we consider the possibility of endogeneity problems associated with the growth model as specified in existing literature (Peres et al. (2018)). Thus, estimation from the fixed effect (FE) and two-stage least square (2SLS) model can result in biased and inconsistent conclusions and interpretations. Therefore, we address this endogeneity problem by employing the instrumental variable model (GMM) as proposed by Arellano and Bond (1991) (AB) (the first difference GMM) and Blundell and Bond (1998) (BB) (the system GMM).

The system GMM estimation is preferred over the first difference GMM for the standard growth econometric model as the latter is often faced with the problem of weak instruments, as lagged level instruments are not usually highly correlated with their differenced counterparts. The system GMM improves on the difference-GMM by allowing for correction of measurement errors through the combination of level and difference dynamic equations in the estimation procedure. The preconditions for the system-GMM model as the best estimator include significant first-order AR(1) autocorrelation (with a significant p-value) and insignificant second-order AR(2) autocorrelation (with an insignificant p-value). Additionally, the Sargan test of instruments overidentification should be insignificant to ensure the validity of instrumental variables.

However, in cases where a study like ours faces a small N and large T sample size, Bun and Kiviet (2006) proposed the Corrected Least Squares Dummy Variable (CLSDV) estimator, which outperforms the consistent IV-GMM estimators of AH, AB, and BB, based on the bias approximation formula (Judson and Owen (1999)). The justification for this assertion is based on the Root Mean Square Error (RMSE) comparison of the models. The CLSDV has the lowest RMSE values compared to the AH, AB, and BB estimators (see Section 3.2), making it the best econometric model to adopt for this study.

Our lag selection is based on existing empirical evidence that has investigated the length of time it takes for a shock in these regressors to impact the economy. Thus, we review the studies of Ramey (2016) (for lag selection of inflation, domestic and international interest rate), Kraay (2014) (for government spending), Chávez (2020) (for trade openness), Delgado et al. (2014) (for secondary school enrollment), De Vita and Kyaw (2011) (for exchange rate), and Abere and Akinbobola (2020) (for institutional quality index and oil price) to determine our lag selection.

Therefore, our simple general econometric growth model setup aligns with the model specification outlined in the study of Douch et al. (2022), which investigates the role of institutional variables and other determinants of growth in explaining the growth patterns of oil-exporting emerging economies. The model specification is defined as:

$$y_{it} = \alpha y_{it-1} + \alpha_c (y_{it-1} - y_{it-1}^T) + \beta_1 INST_{it} + \beta_2 INSTQ.OilP_{it} + \prod Z_{it} + \mu_t + \eta_i + \varepsilon_{it} \quad (3.17)$$

Where $i = 1, ..., n$ for each country in the panel and $t = 1, ..., T$ is the time period, y represents the log of real GDP output, y^T is the real GDP output trend, the component $(y_{it-1} - y_{it-1}^T)$ captures the output gap for the starting period, $INST$ represents the institutional variable setup, $INSTQ.OilP$ accounts for the interaction between institutional quality and oil price, Z accounts for the set of indicators highlighted as growth determinants set as control variables, μ_t represents the time-specific effect, η_i is the country-specific unobserved factors, ε_{it} accounts for the regression error, and subscripts i and t represent country and time period (normalized to 1 for simplicity), respectively. We express the real GDP for a given period on the left-hand side while the lagged real GDP for the start of the period (accounting for convergence evidence) as well as the explanatory indicators estimated for the same period are expressed on the right-hand side of the regression equation (Eq.3.17). In order to control for movements in cyclical output as well as differentiate between cyclical reversion and transitional convergence, we include the output gap among our explanatory variables. Controlling for the output gap at the start of each period not only helps improve the regression fit but also helps eliminate the possible chance of overestimating the speed of transitional convergence. We use the difference between potential and actual GDP surrounding the start date to measure our output gap, which is included in the regression. Similarly, we introduce the time-specific effect μ_t to control for cross-country conditions that vary over time and can impact on growth performance for countries under investigation. We also introduce η_i to capture country-specific unobserved factors that can potentially be correlated with the selected explanatory variables and facilitate growth. Given the setup in Eq. 3.17, we can estimate the dynamic model growth rate of per capita GDP by employing cross-country, time-series panel data.

3.5.3 Descriptive analysis

This section explores the characteristics of the various variables employed for the estimation process. Table 3.3 reports the number of observations, mean, standard deviation, minimum, maximum, and skewness value in columns 2 to 6, respectively. The mean value represents the average value of each variable, while the standard deviation measures the

Table 3.2: Models RMSE comparison

CLSDV	**AB**	**AH**	**BB**
0.0348	0.0348	0.0530	0.2027
0.0360	0.0421	0.0546	0.2329
0.0518	0.0493	0.0795	0.2916
0.0548	0.0680	0.0845	0.2922
0.0815	0.0747	0.1163	0.0551
0.1097	0.1361	0.1264	0.0601
0.0861	0.0792	0.1198	0.0558
0.1153	0.1438	0.1307	0.0593
0.0308	0.0316	0.0506	0.2157
0.0312	0.0319	0.0481	0.1345
0.0424	0.0415	0.0759	0.2881
0.0429	0.0445	0.0726	0.2075
0.0531	0.0508	0.1047	0.0549
0.0619	0.0663	0.1043	0.0426
0.0557	0.0536	0.1087	0.0543
0.0650	0.0705	0.1076	0.0420

amount of variation from the mean. The minimum and maximum values represent the range of observations in terms of the lowest and highest value, respectively. The skewness value represents the degree of asymmetry in the distribution of the variable, which can be positive or negative.

3.6 Empirical results and discussion

The empirical results in this section address the effect of macroeconomic management on the growth of emerging economies. This enables us to uncover credible measures of how the governments of emerging economies handle and maintain a stable macroeconomic environment, established by the relationship between macroeconomic variables and economic growth. The prior discussion in section 4.3, indicating the various determinants of economic growth, including institutional factors, stability factors, structural factors, and external conditions, will serve as the roadmap for our empirical discussion. Tables 3.4 and 3.5 present our short-run and long-run coefficients of our dynamic panel estimation regression of Eq. 3.17, and our model interpretation follows the conditions set out in section 3.5.2, choosing the $CLSDV$ (long-run coefficients) as the most preferred model for our standard growth model, considering our small N and large T sample size. Using the most commonly used criteria for model selection (the AIC-Akaike Information Criterion and the BIC-Bayesian Information Criterion Fabozzi et al. (2014)) to investigate the role of institutional quality in defining the growth pattern of oil-exporting emerging economies through our chosen preferred model ($CLSDV$), we find the $CLSDVII$ model (having reported a lower AIC and BIC value compared to the $CLSDVI$ model) as the best model to interpret the transmission mechanism of institutional quality to emerging economies' economic growth.

Table 3.3: Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max	Skewness
lngdp	161	8.721	3.978	2.908	16.513	0.367
gdpgap	161	0.000	0.065	-0.344	0.199	0.065
lnroilp	161	3.353	3.495	-1.108	9.639	0.440
intlinterestrate	161	1.707	2.079	-1.793	5.347	0.064
dosinterestrate	161	20.264	16.739	4.53	86.36	1.872
lnsecenr	161	4.267	0.377	2.711	4.7	1.741
lngcf	161	3.098	.256	2.4	3.761	0.171
lngovexp	161	2.401	.604	-0.093	3.098	-2.301
rexchr	154	-1.032	15.309	-137.256	38.705	4.902
lntrdop	161	3.944	0.605	2.75	5.395	0.801
inflation	161	8.376	10.77	-0.224	96.094	4.784
iqi	161	-0.332	0.444	-1.18	0.53	0.008

3.6.1 Macro fundamentals and economic growth

Commencing with the examination of the effect of stability measures on economic growth, we investigate the impact of some selected variables including inflation, domestic interest rate, and government spending. Evidence emerging from our analysis shows that these variables report their expected relationship sign with economic growth; however, none appears to be significant with growth. In macroeconomic management, Fischer (1993) argues that higher inflation rate, interest rate, and exchange rate can impede a country's economic growth, which in the case of our study is not strongly significantly established. The evidence shows that a 1% increase in the inflation rate will result in a significant decrease in economic growth by 0.01% in the short-run but is insignificant in the long-run. Although this outcome might be insignificant, it does not cancel the fact that a higher inflation rate can hamper resource allocation and weaken investment rates that, in return, slow down growth (Fischer (1993)). In the course of maintaining a stable and low inflation rate, some countries choose to peg their currency to a major economy's currency, but this is likely to result in balance of payment or fiscal problems.

Debates have long existed regarding the significance and sign of the relationship between exchange rate regimes and economic growth in developing economies, following the array of indirect transmission mechanisms of exchange rates to the economy. For example, a country's openness to capital flow as well as the level of financial development can serve as indirect transmission channels of exchange rates passing through the economy. Considering the developing countries under investigation in this paper operate a flexible exchange rate system that is prone to shocks, with the existence of a very weak financial system, this can exacerbate business cycles that are capable of impeding the economy's growth (Bailliu et al. (2003)). Existing papers have drawn a connection between flexible exchange rate regimes and increasing price levels that do not yield any benefit to economic growth (see, Broda (2004)). This corresponds to the negative relationship our paper reports from exchange rate to economic growth in the long run; a 1% increase in exchange rate yields a negligible decline in economic growth by 0.00% and 0.01% in the short and

Table 3.4: Dynamic panel regression short-run coefficients

Independent Variable	(1) FE	(2) 2SLS	(3) FDGMM	(4) SYSGMM	(5) CLSDV I	(6) CLSDV II
GDP_{t-1}	0.840***	0.808***	0.810***	-0.022***	0.845***	0.883***
	(0.25)	(0.10)	(0.21)	(0.00)	(0.26)	(0.25)
$Outputgap_{t-1}$	-0.684**	-0.678***	-0.403***	-0.280***	-0.725***	-0.741***
	(0.27)	(0.14)	(0.10)	(0.06)	(0.28)	(0.27)
Macro variables:						
$Dos.Interestrate_{t-1}$	0.001	0.001	0.000	0.002***	0.001	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)
$Inflation_{t-1}$	-0.001	-0.002**	0.000	0.004***	-0.001	-0.001*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$ExchangeRate_{t-1}$	0.000	0.000	-0.000	-0.001	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$GovernmentExpenditure_{t-1}$	0.008	0.015	0.029***	0.006	0.010	0.006
	(0.02)	(0.02)	(0.01)	(0.01)	(0.02)	(0.02)
Structural variables:						
$GrossCapitalformation_{t-1}$	0.051	0.053*	0.024	0.064***	0.056*	0.055*
	(0.04)	(0.03)	(0.03)	(0.01)	(0.04)	(0.04)
$Sec.Sch.Enrollment_{t-1}$	0.087	0.058	0.084	-0.004	0.087	0.067
	(0.07)	(0.05)	(0.11)	(0.04)	(0.07)	(0.07)
$Sec.Sch.Enrollment_{t-2}$	0.057	0.071	0.014	-0.042	0.036	0.073
	(0.07)	(0.05)	(0.04)	(0.04)	(0.07)	(0.07)
$Sec.Sch.Enrollment_{t-3}$	0.041	-0.042	0.022	-0.040	0.056	0.030
	(0.07)	(0.05)	(0.04)	(0.04)	(0.07)	(0.07)
$Sec.Sch.Enrollment_{t-4}$	0.042	-0.052	0.060	-0.001	0.044	0.032
	(0.07)	(0.05)	(0.08)	(0.05)	(0.07)	(0.07)
$Sec.Sch.Enrollment_{t-5}$	0.063	0.038	0.076	0.002	0.072	0.062
	(0.71)	(0.05)	(0.10)	(0.04)	(0.07)	(0.07)
$TradeOpenness_{t-1}$	0.020	-0.007	0.057**	0.002	0.035	0.021
	(0.04)	(0.03)	(0.03)	(0.01)	(0.04)	(0.04)
Institutional variable:						
$Inst.QualityIndex_{t-1}$	0.144***	0.109***	0.097**	0.031***		0.126***
	(0.05)	(0.04)	(0.05)	(0.01)		(0.05)
$IntsQ.OilP_{t-1}$						0.014***
						(0.01)
External variables:						
$OilPrice_{t-1}$	0.079*	0.064**	0.087**	0.027***	0.067*	0.058*
	(0.04)	(0.03)	(0.05)	(0.00)	(0.04)	(0.03)
$Int.Interestrate_{t-1}$	0.027***	-0.050**	-0.018	-0.006	0.010**	0.010**
	(0.01)	(0.02)	(0.04)	(0.01)	(0.01)	(0.03)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
LM Statistics (pvalue)		0.00				
Residual Test (pvalue)	0.07	0.01	0.00	0.08		
Sargan Test (pvalue)		0.76	0.08	0.32		
AB test AR(1) (pvalue)			0.16	0.08		
AB test AR(2) (pvalue)			0.43	0.36		
AIC					27.266	27.171
BIC					44.299	44.203

Note: Estimation results in column (1) to (6) represent the Fixed Effect (FE), Two-Stage Least Square (2SLS), First Difference (FD) GMM, System (SYS) GMM, and the corrected Least Square Dummy Variable (CLSDV) estimation respectively for the long-run growth model coefficient. Our specifications take account of time effect to control for common cross-country shocks. *** p<.01, ** p<.05, * p<.1 values in bracket ( ) is the coefficient standard error.

Table 3.5: Dynamic panel regression long-run coefficients

Independent Variable	(1) FE	(2) 2SLS	(3) FDGMM	(4) SYSGMM	(5) CLSDV I	(6) CLSDV II
GDP_{t-1}	5.237	4.208*	4.272	-0.022***	19.923	-5.916***
	(9.75)	(2.63)	(5.77)	(0.00)	(6.21)	(-1.38)
$Outputgap_{t-1}$	-0.406**	-0.404***	-0.287***	-0.219***	-0.435***	-0.531***
	(0.09)	(0.05)	(0.05)	(0.03)	(0.17)	(0.15)
Macro variables:						
$Dos.Interestrate_{t-1}$	0.001	0.000	0.000	0.002***	0.001	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
$Inflation_{t-1}$	-0.001	0.002**	0.00	0.004***	-0.001	-0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$ExchangeRate_{t-1}$	0.000	0.000	-0.000	-0.000	-0.000	-0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$GovernmentExpenditure_{t-1}$	0.008	0.015	0.030***	0.006	0.014	0.010
	(0.02)	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)
Structural variables:						
$GrossCapitalformation_{t-1}$	0.054	0.056*	0.024	0.068***	0.055*	0.058*
	(0.04)	(0.03)	(0.03)	(0.02)	(0.04)	(0.04)
$Sec.Sch.Enrollment_{t-1}$	0.062*	0.015	0.054	-0.017***	0.064	0.055
	(0.07)	(0.02)	(0.06)	(0.00)	(0.07)	(0.06)
$TradeOpenness_{t-1}$	0.021	-0.007	0.061*	0.002	0.045	0.021
	(0.05)	(0.03)	(0.03)	(0.01)	(0.05)	(0.04)
Institutional variable:						
$Inst.QualityIndex_{t-1}$	0.168***	0.123***	0.108**	0.032***		0.145***
	(0.07)	(0.05)	(0.06)	(0.02)		(0.06)
$IntsQ.OilP_{t-1}$						0.020***
						(0.08)
External variables:						
$OilPrice_{t-1}$	0.086*	0.068*	0.096*	0.027***	0.064*	0.062*
	(0.05)	(0.04)	(0.05)	(0.00)	(0.03)	(0.04)
$Int.Interestrate_{t-1}$	0.028***	-0.047**	-0.017	-0.006	0.012**	0.010**
	(0.00)	(0.02)	(0.04)	(0.01)	(0.01)	(0.00)
Year Dummy	Yes	Yes	Yes	Yes	Yes	Yes
LM Statistics (pvalue)		0.00				
Residual Test (pvalue)	0.07	0.01	0.00	0.08	0.15	0.10
Sargan Test (pvalue)		0.76	0.08	0.32		
AB test AR(1) (pvalue)			0.16	0.08		
AB test AR(2) (pvalue)			0.43	0.36		
AIC					27.266	27.171
BIC					44.299	44.203

Note: Estimation results in column (1) to (6) represent the Fixed Effect (FE), Two-Stage Least Square (2SLS), First Difference (FD) GMM, System (SYS) GMM, and the corrected Least Square Dummy Variable (LSDV) estimation respectively for the long-run growth model coefficient. Our specifications take account of time effect to control for common cross-country shocks. *** p<.01, ** p<.05, * p<.1 values in bracket ( ) is the coefficient standard error.

long run, respectively. A possible explanation for this could be the weak competition in the goods market (as the country is increasingly dependent on imported capital goods) coupled with the weak performance of the monetary policy adopted by developing economies. The study of Acemoglu (2009) reports similar no significant evidence of exchange rate volatility hampering economic growth.

On the other hand, unlike monetary policy shocks, the impact of fiscal policy shocks on macroeconomic factors is more straightforward. The use of government expenditure in the context of this paper typically includes transfer payments and government purchases (including military purchases). The proceeds made from oil exports in these countries can be their key source of financing the government budget aimed at improving the overall economy (Hamdi and Sbia (2013)). Moreover, the impact of domestic interest rates on economic growth remains a widespread debate for developing economies relating to interest rate liberalization arguments proposed by Keynesians (who argue in favor of prior investment) and Neoclassicals (who argue in favor of prior savings) theories. For example, the theory of McKinnon (1973) claims that rather than demand, the supply of loanable funds hinders investment growth in developing nations. The theory further claims that because the demand for loanable funds exceeds supply and financial sectors are restrained, a rise in interest rates in the short-run leads to an increase in deposits of loanable funds that deepens investments, resulting in raising economic growth in the long run. Evidence from our estimation shows that an increase in domestic interest rates will impact economic growth positively by approximately 0.01% in the short-run and long-run, although not significant for our CLSDV estimators, but found to be significant in the system-gmm estimator where the short-run and long-run coefficient shows a 0.02% increase in growth. This concurs with the early study of Orr et al. (1995) that affirms that if the rate of return on investment is much greater than the increase in the interest rate in developing economies, there are possibilities that demand for loanable funds will rise despite an increase in interest rates, which will, in turn, positively impact economic growth.

3.6.2 Structural measures and economic growth

We examine the impact of structural factors in advancing economic activities in emerging economies. To establish this relationship, we investigate the link between several structural variables such as public infrastructure (proxied by gross capital formation), trade openness, and secondary school enrollment. Although all the structural variables investigated report their expected relationship sign with GDP, only gross capital formation significantly impacts growth.

In the course of testing the theoretical exposition of the impact of fixed capital formation on economic growth, scholars have reported mixed evidence ranging from fixed capital formation being crucial for economic growth (see Bond et al. (2010)) to fixed capital formation having a minimal effect on economic growth (see Easterly and Levine (2001)). There is an expectation that a positive policy shock should greatly impact investment as well as resource allocation, which will, in turn, impact growth in the long run; thus, magnifying the influence of institutions on the role fixed capital formation can play in any economy. This is further established in the institution-augmented Solow growth framework that implies weak institutions can hinder the mobilization of capital to adequate infrastructure that can threaten growth. To this end, Romer (1986) and Solow (1956) affirm that investment in capital formation, rather than current consumption, can increase productivity, which is fundamental for a country's growth and development in the long run. Evidence emerging from our estimation shows that a positive policy shock that boosts capital formation can lead to significant economic expansion in developing countries by approximately 6% in the short run and long run, respectively. This further affirms recent studies that report a significant positive impact of capital formation on economic growth (see recent evidence from Rahman and Velayutham (2020)).

Considering that gross capital formation covers investment in schooling, does education matter for the growth of emerging economies? Does the time lag of education influence the growth of emerging economies? Observing our short-run coefficient, our evidence indicates that the effect of a positive shock from secondary school enrollment will lead to an initial insignificant growth of 7% in the first two years, which subsequently declines to approximately 3% in the third and fourth year, respectively, and later rises to 6% in the fifth year. In the long run, we also witness a positive but insignificant impact of secondary school enrollment on economic growth, as a 1% increase in secondary school enrollment results in approximately a 6% rise in economic growth (see Delgado et al. (2014) for similar evidence). The level of insignificance is not far-fetched from existing evidence that claims that a higher level of education is associated with a higher level of general productivity, such that higher education can increase the innovative capacity of a country that can help promote growth (Lucas Jr (1988)) (See, similar positive externality declared in the study of Perotti (1993), which is in line with the endogenous growth theory). This can also imply that as countries continue to develop, improved skills of human capital are required for improved productivity. In addition, a World Bank working paper by Hanushek and Wößmann (2007) concludes that, rather than the typical school attainment or enrollment, the cognitive skills of the labor force have a more significant impact in facilitating economic growth. In the case of developing countries, these skills are largely deficient.

Trade openness has the potential to increase specialization, leading to more efficient use of total factor productivity (TFP) and the development of new markets, allowing domestic firms to benefit from economies of scale and increased TFP. Additionally, international firms can disseminate managerial practices and technological innovations through their interaction with the domestic market. Moreover, flexible trade can reduce anticompetitive practices by domestic firms, curbing their incentives to engage in unproductive rent-seeking activities. Based on this theoretical review, we expect that trade openness has a positive relationship with economic growth in the long run. However, although our estimation shows that a 1% increase in a country's openness to international trade can result in an approximately 2% increase in economic growth both in the short run and long run, this result is not statistically significant. This lack of significance in our trade openness variable may be attributed to the fact that participation in international demand (import) for domestic consumption can potentially harm domestic firms and impede the long-term growth of the country.

On the contrary, assuming that countries engage in foreign demand for domestic exportable goods, this can act as a catalyst for economic growth, leading to a rise in the employment rate as well as income in the exportable sector (Awokuse (2008)). A potential export growth can allow domestic firms to maximize economies of scale, which provides foreign exchange capable of facilitating imports of intermediate goods that can increase capital accumulation and, in turn, boost economic growth (Esfahani (1991)). However, weak institutions in developing countries may expose them to external shocks, leading to uncertainties and domestic conflicts among firms as the country opens up to international trade, which can impede growth in these countries. This will be addressed in the next section.

3.6.3 Institutional measures and economic growth

The quality of institutions in any country is significant in the framework upon which macroeconomic indicators perform. This implies that countries with better institutions (improved systems regarding voice and accountability, government effectiveness, regulatory quality, rule of law, and corruption) have a higher propensity for efficiency in their economic activities, which is capable of propelling economic growth (Iyoboyi and Latifah (2014)). On this note, our results establish that a 1% boost in the institutional quality index of developing countries is capable of significantly boosting economic growth by about 13% and 15% in the short run and long run, respectively. This evidence of a positive impact of the institutional quality index on economic growth is in consensus with recent existing studies by Arezki and Van der Ploeg (2010) and Cavalcanti et al. (2011). Our study observes an interesting finding related to the interaction between institutional quality and oil price shocks to establish the role institutional quality of emerging economies plays following episodes of oil price shocks. Evidence reveals that countries with improved and better institutional quality, coupled with a positive oil price shock, will experience a significant increase in growth of approximately 2% in the short and long run, respectively.

3.6.4 External conditions and economic growth

Given the vulnerability of emerging economies to external shocks due to their reliance on foreign markets and resources, we chose to examine the magnitude and direction of the relationship between key external shock variables and economic growth. In our study, external shock refers to an unexpected change in an exogenous variable that influences some endogenous variables. The external shock variables considered include oil prices and international interest rates (proxied by the US term structure). Both variables are expected to have a positive relationship with economic growth and are found to significantly impact it.

ollowing the impact of the costly financial crisis of 2008 on the global economy, there is a great probability that global financial regulations will witness significant changes. Thus, a way to understand how possible reforms in international financial policy impact economic activities of developing countries is to investigate the transmission channel of international interest rate changes. Therefore, examining the significance, magnitude, and timing of the impact of changes in the US term structure of interest rate on developing economies is a growing policy interest to researchers, especially for developing economies that operate a flexible exchange rate regime tied to the US dollar (playing a close role in their exchange rate policy). Such economies might often have the US yield curve predict their economic activities. There can also be a possible pass-through of the US interest rate policy on securities to domestic interest rates of developing economies, which, in turn, determines the economic performance of the country. The small economy size of these countries makes it possible for the US interest rate to impact their domestic growth performance.

In the case of our paper, we find the typical significant positive impact of a rise in US bond yields on economic growth in developing economies. Evidence shows that a 1% rise in US bond yields will boost the economic activities of developing economies by approximately 0.1% both in the short-run and long-run. This corresponds with the findings obtainable from the recent European Central Bank working paper by Mehl (2009), which shows that information contained in the slope of the US yield curve is significant for future prediction of emerging economies growth in the short-run and long-run (i.e., the yield curve steepening is linked with higher predicted growth). This implies that economic growth in emerging economies reacts in tandem with US interest rates such that investors in US bonds during positive shocks will benefit from an exchange rate boost, making imports cheaper and increasing business productivity, hence, a growing economy. Although most empirical evidence of the impact of short-term US yields on economic growth is common for industrialized countries (see, for example, Estrella et al. (2003) among others) with very few papers on emerging economies (see Mehl (2009)), this evidence coincides with the positive significant impact reported for 14 emerging economies in the study of Mehl (2009).

Moreover, small open oil exporting economies are also perceived to be highly dependent on proceeds accruing from the export of their oil products. However, the implication of a positive oil price shock being beneficial to the economy is dependent on the policies enacted in the economy. Our estimation depicts that a positive oil price shock is able to boost the country's economic growth by approximately 6% both in the short-run and long run. This positive impact on GDP corresponds to the early evidence of Hamilton (1983). The direct effect of this positive oil price shock can directly transmit to the economy from both the demand and supply side (see Kilian and Vigfusson (2013)). On the demand side, an increase in oil price can boost aggregate demand, caused by a rise in purchasing power in the economy, while on the supply side, it can lower production costs, leading to increased productivity.

3.6.5 Evidence of growth convergence

The estimation of growth convergence accounts for the speed at which an economy arrives at a "pseudo-steady-state," with its location dependent on the prevailing value of the conditional variable. It is expected that the initial value of GDP (lagged value of GDP) will result in an increased growth rate. Originally, it was expected that poor countries would grow at a much faster pace to catch up with the growth level of their rich counterparts. Therefore, in the long run, we expect countries' income to converge to the same level. The possibility of poor countries converging to rich countries' level of growth would mean accepting the null hypothesis of the existence of conditional β-convergence. This hypothesis suggests that the slope of the coefficient should be negatively close to zero and significant. This condition is valid for our long-run coefficient of the $CLSDVII$ estimation following the relative decline in output variation, which is statistically significant at the 1% level. This simply means that the small open oil-exporting emerging economies under our investigation show a convergence speed of 591.6% to their developed counterparts' steady-state income level in the long run, which corresponds with the proposition made in the early study of Barro and Sala-i Martin (1992).

3.7 Robustness check

Having established in the previous section using the RMSE approach to highlight the best econometric model (CLSDV) that best interprets our standard growth model, we aim to further confirm whether substituting the author's computed international interest rate for the Fed rate and Shadow rate will help improve our growth model using the CLSDV estimation procedure. To assess the performance of the various econometric models to be estimated, we adopt the most commonly used criteria for model selection - the AIC (Akaike Information Criterion) and the BIC (Bayesian Information Criterion) Fabozzi et al. (2014). The AIC is often referred to as the first model selection criterion following the development of a relationship between the maximum likelihood estimation method and Kullback and Leibler (1951)'s measure of information loss minimization. On the other hand, the BIC, as proposed by Schwarz (1978), is based on information theory but defined within the Bayesian context. Although the study of Burnham et al. (2011) argues in support of the AIC, which coincides with the early study of Yang (2005) that opined AIC to be a better technique for model selection compared to the BIC, we shall be presenting information on both the AIC and BIC for our various model estimations. The greater penalty set for the number of parameters by the latter than the former differentiates the AIC and the BIC. The interpretation of the "best" model comes with the smallest value of AIC and BIC[13].

Following the evidence presented in Section 3.6, we estimated the standard growth model defined in Eq.3.17 by substituting our originally computed US term structure variable (as a proxy for the international interest rate) for the initial Fed. rate and shadow rate variables. We aimed to ascertain which model better explains the growth situation for the selected emerging economies. From the evidence presented in Table 3.6, column 1 represents the estimation of our growth model excluding the international interest rate, column 2 represents the estimation of our growth model with the international interest rate, and columns 3 and 4 represent the substitution of the international interest rate variable for the Fed. rate and shadow rate, respectively. The evidence from the various growth model estimations set out in columns 1–4 shows no significant difference in the estimated coefficients of the other growth determinant variables when compared with the coefficients reported in Table 3.4. The estimated coefficients remain closely similar, with Fed. rate showing a significant positive relationship of 2%, while shadow rate depicts a non-significant negative relationship of -0.02% in emerging countries. However, in determining which model best explains the standard growth model designed for the selected emerging economies, we used the AIC and BIC decision rule. We conclude that the model estimation in column 2 outperforms other models, as it reports the lowest AIC and BIC values.

3.8 Conclusion and policy implication

Are institutional factors, among other growth determinants, instrumental to the economic growth of emerging market oil-exporting economies? Is there any sign of growth convergence in emerging economies to their developed economy counterparts? This paper seeks to address these questions by developing a standard endogenous growth model and esti-

[13] The computation of the AIC (see 3.18) and BIC (see 3.19) is as follows:

$$AIC = -2\ln L(\phi) + 2k \tag{3.18}$$

$$BIC = -2\ln L(\phi) + kln(N) \tag{3.19}$$

where ϕ is the set (vector) of the model parameters, $L(\phi)$ is the likelihood of a given model's data evaluated at the maximum likelihood of ϕ, k is the number of parameters present in the given model, and N is the number of observations.

Table 3.6: Variable Robustness Check

Independent Variable	**(1)**	**(2)**	**(3)**	**(4)**
GDP_{t-1}	0.889***	0.889***	0.889***	0.889***
	(0.273)	(0.273)	(0.273)	(0.273)
$Outputgap_{t-1}$	-0.753***	-0.753***	-0.753***	-0.753***
	(0.273)	(0.273)	(0.273)	(0.273)
$OilPrice_{t-1}$	0.058*	0.058*	0.058*	0.058*
	(0.035)	(0.035)	(0.035)	(0.035)
$Int.Interestrate_{t-1}$		0.010**		
		(0.01)		
$Fed.rate_{t-1}$			0.021**	
			(0.004)	
$Shadowrate_{t-1}$				-0.002
				(0.01)
$Dos.Interestrate_{t-1}$	0.001	0.001	0.001	0.001
	(0.000)	(0.000)	(0.000)	(0.000)
$Sec.Sch.Enrollment_{t-1}$	0.094	0.094	0.094	0.094
	(0.071)	(0.071)	(0.071)	(0.071)
$Sec.Sch.Enrollment_{t-2}$	0.069	0.069	0.069	0.069
	(0.072)	(0.072)	(0.072)	(0.072)
$Sec.Sch.Enrollment_{t-3}$	0.028	0.028	0.028	0.028
	(0.070)	(0.070)	(0.070)	(0.070)
$Sec.Sch.Enrollment_{t-4}$	0.049	0.049	0.049	0.049
	(0.068)	(0.068)	(0.068)	(0.068)
$Sec.Sch.Enrollment_{t-5}$	0.073	0.073	0.073	0.073
	(0.071)	(0.071)	(0.071)	(0.071)
$ExchangeRate_{t-1}$	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
$TradeOpenness_{t-1}$	0.032	0.032	0.032	0.032
	(0.041)	(0.041)	(0.041)	(0.041)
$Inflation_{t-1}$	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
$GrossCapitalformation_{t-1}$	0.045	0.045	0.045	0.045
	(0.036)	(0.036)	(0.036)	(0.036)
$GovernmentExpenditure_{t-1}$	0.008	0.008	0.008	0.008
	(0.020)	(0.020)	(0.020)	(0.020)
$InstitutionalQualityIndex_{t-1}$	0.145***	0.145***	0.145***	0.145***
	(0.052)	(0.052)	(0.052)	(0.052)
Year Dummy	Yes	Yes	Yes	Yes
Residual Test (pvalue)	0.01	0.1	0.13	0.17
AIC	29.679	27.171	27.857	29.051
BIC	45.576	44.203	44.889	46.083

Note: Estimation results in column (1) to (4) represent the Corrected Least Square Dummy Variable (CLSDV) estimation without the international interest rate, with the international interest rate, with the Fed. Rate and Shadow rate respectively for model robust check of the short-run coefficient of the growth model. Our specifications take account of time effect to control for common cross-country shocks. AIC and BIC represent the Akaike Information Criterion and Bayesian Information Criterion respectively for model selection.

mating several dynamic panel regression models for a set of selected oil-exporting countries. Among the estimated dynamic panel models, we found the CLSDV II estimator to be the best model to interpret growth dynamics for our emerging oil-exporting economies. Based on this model, we found that among the growth determinant variables, which were classified into stability, structural, institutional, and external condition measures of growth, institutional factors (proxied by an average index of five institution variables including voice and accountability, government effectiveness, regulatory quality, rule of law, and corruption) and external conditions (proxied by oil price and the US term structure) are significant variables that drive growth in emerging economies. On the other hand, while stability factors and structural factors depict the expected relationship sign with growth, variables (except gross capital formation) captured under these factors do not significantly impact the economic growth of emerging economies.

Our second contribution focuses on investigating the evidence of convergence of our emerging economies to their developed counterparts in the long run. Although other dynamic panel estimators such as FE, 2SLS, and differenced-GMM, including our $CLSDVI$ estimator, did not show any sign of growth convergence for our emerging economies in the long run, our main empirical model ($CLSDVII$ estimator) and system-GMM model that controls for both country heterogeneity and endogeneity problems in growth regression depict a significant value of approximately 592% and a convergence speed of 2% respectively (captured by the negative convergence coefficient) for our emerging economies to catch up with their developed counterparts in the long run.

Our results imply that while some variables captured under stability and structural factors may not be statistically significant, it does not automatically mean that they do not matter for growth. Governments of emerging economies need to prioritize macroeconomic management of institutional and external conditions factors, including gross capital formation, as they are fundamental to driving economic growth. Therefore, considering gross capital formation as a significant determinant in our standard growth model, any effort by the government to raise infrastructure investment will stimulate economic growth and further increase physical capital stock by raising capital investment. Moreover, given the dominant contribution of external conditions such as oil price and US term structure interest rate to growth, governments can use proceeds from oil exports and yields from investment in US stocks to diversify the economy, thereby averting problems related to a mono-economy. Above all, governments of emerging economies should build a conducive environment by maintaining sustainable institutional quality as it is the driving engine for both endogenous and exogenous variables, allowing them to individually generate and adopt best practices for economic progress. Furthermore, emerging economies with strong institutions are more likely to approach convergence of economic prosperity faster.

However, one question we have not adequately addressed in this paper is how oil prices serve as a transmission mechanism for growth in small open oil-exporting emerging economies, given that oil exports make up about 40% of their export share to GDP. Could we perceive oil as a curse or a blessing to these small open oil-exporting emerging economies? This leaves the question of a possible case of the "Dutch Disease" theory applicable to these emerging economies unanswered.

When analyzing data from a panel sample, it is important to consider the possibility of structural breaks, which refer to sudden and significant changes in the underlying relationship between the variables over time. Structural breaks can occur due to factors such as changes in policy, economic shocks, or external events. Rather than assuming homogeneous coefficients in the panel analysis, which may not hold in reality given that different countries may have different structural characteristics, policy regimes, or institutional factors that affect the relationship between the variables, this study decides in the next chapter to estimate country-specific models. Estimating country-specific models can provide more accurate and nuanced insights into the relationship between the variables for each country.

Chapter 4

Asymmetries and Macroeconomic Impact of Oil Price Transmission in Oil-Exporting Emerging Economies

4.1 Introduction

Economic activities in many oil-exporting developing countries are determined by the large swings in oil prices due to their heavy dependence on revenues accruing from oil exports. While some countries have been successful in using the oil proceeds for economic development, others have not. Empirical evidence from Sachs and Warner (2001*b*), Sala-i Martin and Subramanian (2003*a*) and Smith (2004) illustrates that economic growth in resource-rich developing countries tends to be lower compared to their resource-poor counterparts. What happens to these resource-dependant macroeconomies after an unexpected oil price shock? Can positive oil price shocks (unanticipated rise in prices) even be contractionary to small open developing oil exporters because of the increasing uncertainty about future prices or policy responses?

Recently, economists have focused on the asymmetric nature of oil price shocks, leading to new methodological and theoretical contributions. However, most of these studies have focused on developed countries. For example, the study by Pal and Mitra (2015) established the asymmetric effects of oil price changes but in the context of oil product pricing in the United States. This study documented that crude price increases have a significant positive impact on oil product pricing, but the impact of crude price decreases is not significant. Furthermore, few studies that examine the asymmetric nature of oil price shocks on output in developing countries are methodologically sound. Given the stagnant growth of many developing oil-exporting countries in the face of volatile oil prices, there is a further impetus to examine the asymmetric effects of oil prices on output using unbiased methodologies. This is particularly relevant in emerging market countries, as these economies face unique vulnerabilities that make them very different from advanced economies.

Existing theory states that oil price changes can affect economic activities via direct and indirect supply and demand side mechanisms (see Kilian, 2014). Among these the direct channels tend to produce symmetric responses in output whereas the indirect ones can contribute towards asymmetry and amplification in the responses. The direct demand side effect illustrates the changes in aggregate demand caused by changes in purchasing power subsequent to oil price innovations (Baumeister and Kilian, 2017; Baumeister et al., 2017). Additionally, the direct supply side effect refers to the symmetrical changes in aggregate supply due to production cost changes, upon oil price innovations (Rotemberg and Woodford, 1996; Karaki, 2017).

On the other hand, the indirect demand side effect on output following an unexpected oil price shock can firstly arise due to the increased precautionary savings owing to heightened uncertainty (Bernanke, 1983; Edelstein and Kilian, 2009; Pindyck, 1991). Secondly, monetary policy responses to oil price changes can also generate asymmetric effects on output, as most central banks do not tend to react during oil price downturns but overreact when oil prices rise (Bernanke et al., 1997). Finally, unexpected oil price shocks, which are in essence relative price shocks, create allocative disturbances initiating sectoral shifts in consumption causing aggregate demand to change (see, e.g., Hamilton, 1988). In addition, the indirect supply side channel refers to the changes in unemployment/output due to costly reallocation of factors of production from the most affected to the least affected sector creating a mismatch in the factor market (Davis, 1987; Hamilton, 1988). The magnitude of this channel depends on the sectoral contribution from the oil-producing sector, labour market frictions, and on regional heterogeneities (Karaki, 2017).

On the empirical front, in order to illustrate the impact of oil price changes on aggregate output, researchers have primarily relied on time series estimators, mainly vector autoregression (VAR) models. The first strand of literature employs the linear VAR/VECM framework to identify the oil price shocks and is only able to establish weak impacts of unexpected oil price changes on aggregate output (e.g. Hooker, 1996; Hamilton, 1996). More recently, the work of Çatık and Önder (2013) deployed the threshold autoregressive model to investigate the asymmetric relationship between oil price shocks and output in Turkey - evidence shows that oil price increases have a significant negative impact on output, but the impact of oil price decreases is not significant. One major shortcoming of this strand of work is that it lacks an ability to capture the asymmetric and nonlinear nature of oil price shocks (Kilian and Vigfusson, 2009). In order to address these inadequacies, subsequent studies by Mork (1989) and Hamilton (2003, 2009) employ different forms of censored oil prices in VARs. Results from this second strand of literature suggest strong asymmetric effects of oil prices on output.

However, the seminal work by Kilian and Vigfusson (2009) demonstrates that the censored oil price VAR models are fundamentally misspecified, irrespective of whether the data generating process (henceforth DGP) being symmetric or asymmetric. Furthermore, based on the earlier work by Koop et al. (1996), they demonstrate that the structural impulses generated from the models are invalid as they do not take account of the history and size/magnitude of the shocks. Finally, they demonstrate that the previous results obtained from standard slope-based tests for asymmetry based on single-equation models are neither necessary nor sufficient for judging the degree of asymmetry in the structural response functions. Koop et al. (1996) resolve this problem by proposing a direct test which requires the model to be appropriately specified and the nonlinear responses to be correctly simulated. Results employing this methodology, however, tend to find no significant asymmetry of unexpected oil price changes on output (see Kilian and Vigfusson, 2009 and Herrera et al., 2011).[1]

Macroeconomic policy in oil-producing developing countries faces significant challenges arising from the characteristics of oil prices. The implications of oil price volatility require frequent adjustments of budgetary expenditure which are again costly due to factor reallocation and their impact on GDP depends on how the expenditure is financed to smooth out the fluctuations of revenue. The use of oil proceeds that attempts to provide stabilization reserves in periods of high revenue for future period of reduction in oil prices can have large effects on macroeconomic stability via the foreign exchange inflow channel. In addition, the sources from which an oil price shock originates when oil prices are measured in domestic currency are important especially in a small open economy. Oil price movements can be due to changes in international prices or due to movements in the exchange rate. Whether a positive (or negative) oil price shock is beneficial (or detrimental) to the real economy depends on the origins of the shock and also on the policy responses of the economy. The implications of the latter on GDP may become complicated depending whether the country is a primary goods exporter or a manufacturing goods exporter. These features may substantially amplify the effects of large external disturbances to the domestic economy.

Our main motivation is then to examine a plausible hypothesis that tracks the mechanism through which oil price shocks impact on long-term growth for oil-exporting developing countries. In particular, we focus on a possible candidate through which oil price shocks can indirectly affect the real economy: the role of fiscal spending that is designed to keep domestic demand stable in the face of fluctuating oil revenues. Can fiscal spending adjustments contribute to the response of output to oil price shocks (at least in the short-term), while monetary policy responses may be constrained because of the inflexibility of the exchange rate system and the need for reining in inflation? As noted, a common understanding is that institutional and political factors can also contribute to exacerbating the shock's procyclicality. The literature argues that, in the face of high uncertainty about oil prices, policy responses to oil price shocks have contributed more to the positive consequences than the shock itself. To this end, early studies, such as Bernanke et al. (1997), Hamilton (1996), Hamilton (2009) and Ferderer (1996) among others, have examined the policy transmission mechanism of oil sector shocks to the economy and the causes for nonlinearities.

Several recent theoretical and empirical studies have examined the effects of oil price increases in the context of oil-rich open economies focusing on the nature of monetary policy responses and differences in modelling strategy. For example, the analysis of Algozhina (2016), Allegret and Benkhodja (2015), Bergholt and Larsen (2016) and Ferrero and Seneca (2019) prescribes that monetary policy reacts in a varied manner in terms of how it should respond to episodes of changing oil prices. Differences in how the prevailing exchange rate regime interacts with monetary policy and the extent of countries' dependence on oil have been offered as explanations for the mixed results reporting varied monetary policy responses to a positive oil price shock. Given the mixed time series patterns of oil price and monetary policy indicators, a number of interesting questions can be posed: how is fiscal expenditure associated with major oil price movements? What are the real effects of the oil price instabilities and their implied fiscal volatility?

Is the relationship between economic activity and oil prices asymmetric in small open

[1] See Table 4.1 that provides a detailed summary of the most recent and related studies investigating the macroeconomic effects of oil price shocks using similar methodologies and obtaining contradictory results.

oil-exporting emerging economies? How does the fiscal policy stance in these economies react to oil price increases and decreases? In this paper, we tackle these questions by testing and evaluating the premise on which the responses from unexpected changes in oil prices to GDP growth and adjustments of public expenditure are asymmetric using state-of-the-art techniques developed by Kilian and Vigfusson (2011*a*) building on censored-regressor nonlinear VAR models. Our test for asymmetries is a crucial first step not only in understanding the transmission channel of oil price shocks in major oil exporters, but in constructing theoretical models of the propagation of oil sector shocks for typical resource-rich emerging open economies. This is particularly important in countries where there are urgent needs for public investment in infrastructure, fiscal incentives to develop the industrial sector, and the adoption of generous welfare system. Thus, understanding the relationship between government spending and oil prices is important to evaluate how to address fiscal imbalances. Several hypotheses have resulted from the causal link of this relationship (see, for example, Fasano and Wang, 2002).

While there is a substantial body of literature devoted to understanding the nonlinear macroeconomic effects of oil prices using US data and data from developed economies, research focusing on a group of oil-producing emerging economies is, to our knowledge, non-existent.[2] In addition, developing countries are usually small open economies, which requires careful modelling of a mechanism that allows for the transmission of oil price shocks. Thus, building on these papers, this study aims at understanding how oil price changes affect macroeconomic volatility and fiscal spending asymmetrically, while gauging the empirical relevance of such asymmetry and the impact of shocks. By bringing our models to the data, we should be able to throw some light on the mechanisms by which the aggregate economy interacts with oil price shocks hitting the economy and provide an empirical assessment of the implications of the different types of oil price shocks considered here, for which there is scant empirical evidence in the literature for oil-exporting emerging economies.

In particular, this paper aims to provide an assessment on how the macroeconomic implications of oil price shocks may differ depending on the sign and size of the shock through the fiscal transmission factor. Indeed, to capture any abrupt changes in government fiscal stance in response to major oil fluctuations, this suggests a nonlinear application to describe the co-movements between oil prices and fiscal spending. Fiscal spending may fluctuate at a higher level and exhibit more persistence during an increase in oil prices, but stay at a relatively lower level, less persistent and more moderate during the period when the oil price falls sharply.[3] To this end, in addition to the Kilian and Vigfusson (2011*a*) approach, we estimate a univariate unobserved components model to obtain the

[2] A series of papers have separately addressed some of these issues, see, among others, Hamilton (1996), Hamilton (2003), Hamilton and Herrera (2004), Hamilton (2011), Herrera et al. (2011), **?**, Kilian and Vigfusson (2011*b*) and Herrera et al. (2015). Table 4.1 provides a summary. Such analysis however is yet to be carried out for emerging oil-producing economies and as a cross-country comparative study (except that Herrera et al. (2015) offers perhaps the closest analysis to our paper but in that the paper focuses on the OECD countries and does not address fiscal policy).

[3] Although there is always an incentive (at least for politicians) to follow a procyclical fiscal stance in developing countries, especially when there is a surge in the international oil price, because of the lack of central bank independence combined with weak governance, data in more recent years suggest that many oil producers use the reserved proceeds to sustain government increased spending even during the periods of oil price falls, in order to sustain growth in the real non-oil sectors for the period of economic downturn. For example, Nigeria experienced a widening of fiscal deficit and an increase in debt-to-GDP ratio during the recent episodes of oil price reversal but saw mixed movements in GDP and inflation.

slope parameter of our time series. Our analysis employs a battery of econometric tests and is closely related to Hamilton (2003), Kilian and Vigfusson (2011*a*) and Holm-Hadulla and Hubrich (2017) in that we make contributions by explicitly accounting for (1) specifications of nonlinearities in large oil-exporting economies; (2) time variation in the effect of shocks in cases where there are significant nonlinear dynamic patterns; (3) an assessment for the government fiscal stance in propagating the real effect of the shock.

In our empirical analysis, we find substantial evidence suggesting the asymmetric nature of oil price shocks in several countries, irrespective of the magnitude of the shocks. In addition, we explain how the output and fiscal responses to large oil price shocks are significantly different depending on country-specific characteristics and stabilization incentives. Our applications are able to uncover and describe the distinct co-movements between oil prices and fiscal spending which enable us to evaluate the implications for theoretical models of the transmission of oil price shocks and for policy responses to exogenous energy price fluctuations. By carefully examining a sample of emerging economies consisting of African, Asian and South American countries, our results and analysis can be used to motivate further investigation into the roles of oil price fluctuations and public expenditure cyclicality in understanding the growth process specific to developing oil-exporting countries.

The rest of the paper is organized as follows. Section 4.2 presents the theoretical discussion surrounding the asymmetric response of selected oil-exporting emerging economies to oil price shocks. Section 4.3 describes the data and estimation methodology. Section 4.3.2 presents the linear and nonlinear VAR models used for our statistical tests. Section 4.4 sets out the test results, model comparison and empirical properties. Section 4.5 focuses on the oil price shock and fiscal policy interactions. Section 4.6 concludes. Details of the algorithm designed to implement the test for asymmetry are set out in Appendix B.2. Our robustness checks are also appended to the paper.

Table 4.1: Summary of Relevant Literature

Author(s)	Subject of Research	Country	Sample	Variable	Methodology	Result
Hamilton (1996)	Relationship between oil prices and the macroeconomy	US	1948Q1 – 1994Q2	Real GDP, T-bill rate, CPI, import price, oil price	SVAR/VECM, Chow stability and Granger causality tests	In contrary to the evidence reported in Hooker (1996), this early study finds a significant relationship between GDP and net oil price changes. However, it concludes that an increase in prices by 10% subsequent to a 20% decrease would have little effect on aggregate output
Hamilton (2003)	Estimating nonlinear speci1cations between oil prices and GDP	US	1949Q2 – 2001Q3	Real GDP, nominal crude oil price (PPI)	Bayesian methods	The nonlinear regression model strongly rejects the null of linearity. If oil price increases or decreases after 3 quarters, the forecasting regression shows a slightly slower pace of GDP growth than if it had remained stable; although, oil price increases signify a detrimental effect than decreases
Hamilton (2011)	Testing for nonlinearity between GDP growth and oil prices	US	1949Q2 – 2007Q4	Real crude oil price, nominal oil price (RAC), real GDP	OLS slope-based tests	Based on a forecasting regression, an extended sample, different lags, measures of oil prices and adjustment, the study reconfirms the nonlinear relationship between oil prices and GDP growth
Herrera et al. (2011)	Testing for nonlinearity between oil prices and industrial production	US	1947M1 – 2009M9	Real oil price, industrial production index, nominal oil price (RAC)	OLS slope-based test, IRF-based test based on censored-variable VARs	In consensus with the evidence reported by Hamilton (2011) and ?, the study finds a nonlinear reduced-form relationship between oil prices and economic activity, rejecting the null of symmetric IRFs to oil price innovations

Herrera et al. (2015)	Testing for nonlinearity between oil prices and industrial production	OECD countries	1974M1 – 2010M7	Same as above	Same as above	Mixed evidence of asymmetry or nonlinearity, especially for countries with large volumes of oil imports and exports, and when considering large oil price shocks
Karaki (2017)	Testing for nonlinear responses of real GDP to oil price shocks	US	1972Q2 – 2016Q3	Real oil prices (imported crude oil by RAC; crude oil price by PPI), real GDP	OLS slope-based test, IRF-based test based on censored-variable VARs	Consistent with Kilian and Vigfusson (2013), using the 3-year net increase censored prices, there is no evidence against the null of symmetry for a large shock. The results are mixed across different nonlinear specifications for the censored regressor. Asymmetry tends to vanish following the adoption of data-mining robust critical value
Kilian (2009)	Identification of the demand and supply shocks in the crude oil market	US	1968M1 – 2007M12	Global crude oil production, real GDP, real oil price	SVAR	Focusing on the sources of the underlying oil price shocks, the paper finds that the combination of precautionary and global oil demand shocks is the key historical driver of oil price fluctuations. An unexpected oil supply shock leads to a sharp fall in global oil production. An unexpected aggregate demand expansion has a very persistent and significant impact on global real activity, causing a temporary increase in oil production and significant increase in real oil prices
Kilian and Vigfusson (2011*a*)	Responses of GDP and unemployment to the oil price changes	US	1973Q2 – 2007Q4	Real oil price (RAC), real GDP, unemployment	OLS slope-based test, IRF-based test based on censored-variable VARs	Positive oil price shocks pose more detrimental consequence than the negative shocks for the case of US, implying that positive oil price shocks are more influential on the US macroeconomic aggregates compared to the uncensored percentage changes of oil prices
Kilian and Vigfusson (2011*c*)	Testing for nonlinearities in the oil-output relationship	US	1974Q1 – 2009Q4	Real and nominal oil prices (PPI and RAC), real GDP	IRF-based test based on censored-variable VARs	The paper reports the mixed findings in favour of asymmetry in responses. For a typical shock (1 s.d.), the IRFs appear to be well approximated by those of a linear symmetric VAR model, while large shocks reflect evidence that the aggregate responses are asymmetric given that the increase caused by negative oil price innovations are smaller than that predicted by a linear model

4.2 Asymmetric Response to Oil Price Shocks: Theoretical Discussions

We start by illustrating the key elements of our empirical analysis with reference to the oil-producing environment that is characterised by the data across the countries examined. We can explore the sources of asymmetries and their effect on output that vary among the countries by examining the country-specific characteristics which can be established by analyzing the relationship between each country's oil revenue as percentage of GDP, oil production capacity and the share of energy intensity in GDP as well as discussing the possible theoretical channels that account for amplification of oil price shocks that may lead to asymmetry which can be studied from both the demand- and supply-sides.

First, we investigate the country-specific relationship between the share of oil revenue and oil production capacity using annual data obtained from the World Bank spanning 1970 – 2018. Taking a close look at Figure 4.1, the data shows that these countries have experienced fluctuations in their oil production levels and oil revenues as percentage of their GDP over the periods covered which highlights the significant role that the oil sector plays in their economies and underscores the potential impact of oil price shocks on their economic performance. For example, Nigeria and Ecuador have relatively high dependence on oil revenues, with oil revenues accounting for over 50% of their GDP in some years. On the other hand, Bolivia and Malaysia have lower dependence on oil revenues, with oil revenues accounting for less than 10% of their GDP.

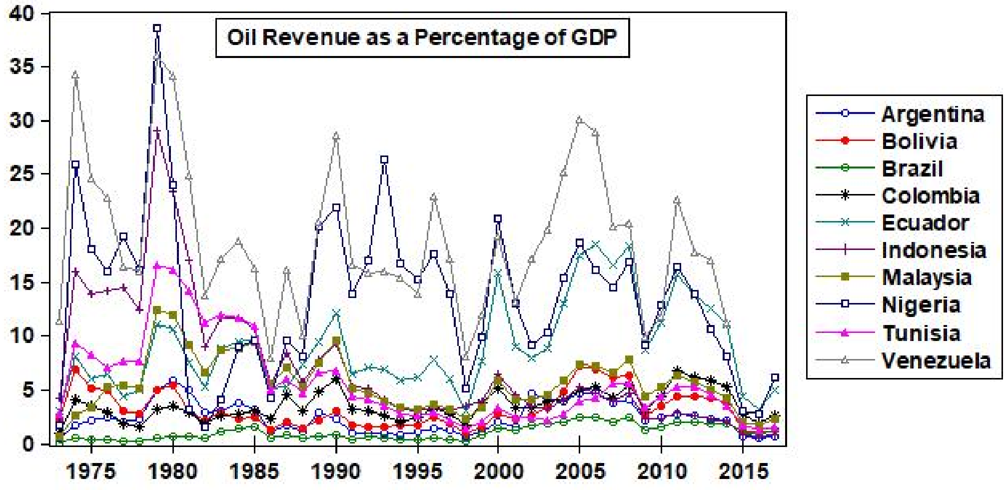


Figure 4.1: Oil Contribution to GDP by Countries
(Author's compilation with data sourced from World Bank)

The differences in dependence on oil revenues can have implications for the potential sources of asymmetries. Countries that have a higher dependence on oil revenues are likely to be more vulnerable to the asymmetric effects on output growth because of the potential macroeconomic imbalances that may arise when oil prices fluctuate. For instance, when oil prices increase, countries with high dependence on oil revenues may experience an increase in inflation and exchange rate appreciation, leading to a decrease in their non-oil exports and aggregate output. On the other hand, the implications of falling oil revenues being a foreign exchange inflow can generally lead to a currency depreciation, and in addition to the structural shifts resulting from the use of oil revenue, a currency depreciation can deteriorate the balance sheets of borrowers relying on foreign currency denominated debt and increase the external risk premium accrued on top of the international interest rate. The ensuing fall in the demand for capital reduces the value of the borrowers' existing capital stock further amplifying the increase in the costs of borrowing and the swings in investment and production.

In addition, the data also reports that these countries have different levels of oil production capacity (Figure 4.2). Nigeria and Indonesia, for example, are among the largest oil producers globally, while Bolivia and Ecuador have smaller oil production capacities. The differences in production capacity can also have implications for the potential sources of asymmetries and their effect on economic activity. This implies that countries with high levels of oil production capacity are more vulnerable to the impact of low oil prices as they have a greater dependence on oil revenue. On the other hand, countries with low levels of oil production capacity may be less vulnerable to the impact of low oil prices as they tend to have a more diversified economy. One possible explanation for the asymmetric response is that the price of oil is a crucial input in the production process. Therefore, when the price increases, the cost of production rises, leading to higher aggregate prices. This triggers the precautionary saving motive due to heightened uncertainty in purchasing power on the demand-side through which this amplifies positive oil shocks and dampens negative oil shocks (Bernanke, 1983; Edelstein and Kilian, 2009).

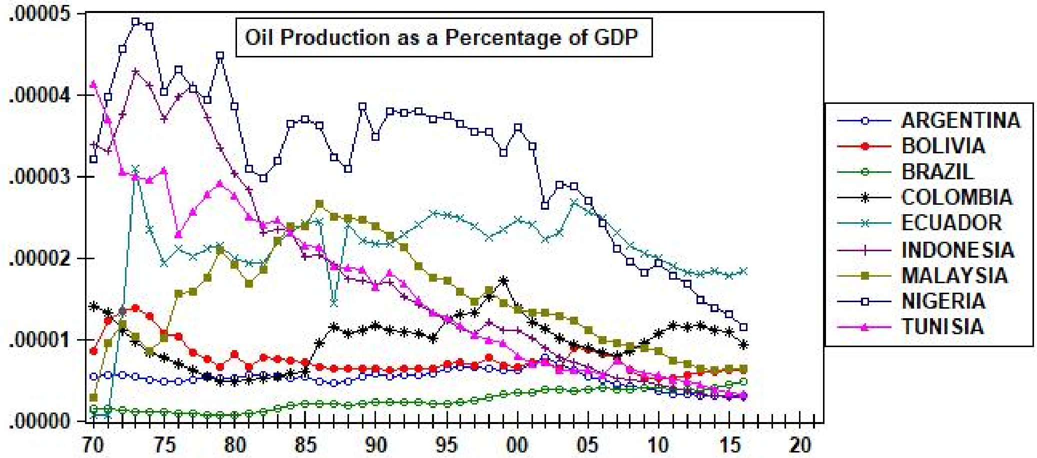


Figure 4.2: Oil Production Capacity by Countries
(Author's compilation with data sourced from BP Statistical Review of World Energy)

We further discuss the possible source of the asymmetric relationship between the impact of positive and negative oil price shocks and economic activity by analyzing energy intensity of our selected countries. Figure 4.3 depicts the data from the World Bank for the same period which shows that some countries have relatively low levels of energy intensity (Bolivia and Malaysia) compared to other countries (Nigeria and Colombia). Energy intensity is an important factor to consider when analyzing the impact of oil price shocks on the economies of major oil-exporting countries as it measures the amount of energy required to produce one unit of GDP, and therefore reflects the energy efficiency of a country's economy. Countries with high energy intensity consume more energy to produce the same amount of economic output than countries with low energy intensity. However, this factor has important implications for the transmission of oil price shocks through the indirect supply-side effect of capital and labour reallocation.

On the one hand, countries with high energy intensity are more vulnerable to oil price shocks because nominal rigidities in the labour market in the most energy-intensive sectors are associated with costly sectoral reallocation from the supply-side (Davis, 1987; Hamilton, 1988). When oil prices rise, the cost of energy increases, leading to higher costs for businesses and households. This can result in a decrease in income transfer through consumption, lower profits, and contract output. The labour market imperfection and reallocation disturbances can amplify the recessionary effect. Also, the RBC model by Finn (2000) postulates that energy is essential to the utilization of capital and there are costs to varying capital utilization which generate amplification of a positive shock to energy prices. On the other hand, countries with low energy intensity are less vulnerable to

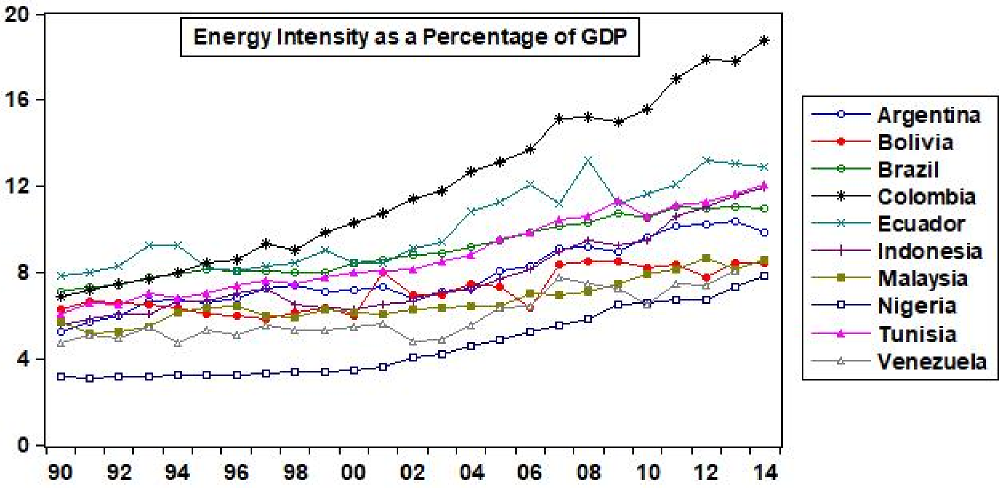


Figure 4.3: Energy Intensity Level by Countries
(Author's compilation with data sourced from World Bank)

oil price shocks because they consume less energy usage per unit of GDP and capital. For example, Malaysia has made significant efforts to reduce its energy intensity by investing in renewable energy and implementing energy-efficient policies. This has helped to reduce the country's dependence on oil and other fossil fuels. Malaysia's diversified economy also helps to mitigate the impact of changes in oil prices on its economy.

Overall, each country's response to oil price shocks is influenced by a variety of country-specific characteristics, including energy intensity, oil production capacity, and the diversification of the economy. Countries with high energy intensity are more vulnerable to oil price shocks, while countries with a more diversified economy are better able to mitigate the impact of changes in oil prices. In addition, these economies usually display weak fiscal, monetary and financial institutional frameworks, and have imperfect access to capital markets. These frailties can lead to sudden and sharp reversals of capital inflows. For example, the presence of significant monitoring costs in credit markets can exacerbate risk premiums faced by domestic borrowers which may substantially amplify the effects of large external disturbances to the domestic economy through these supply- and demand-side effects.

4.3 Time Series Properties of the Data and Methodology

4.3.1 Data Description

Four observable variables at quarterly frequency for Bolivia, Brazil, Colombia, Ecuador, Indonesia, Malaysia, Nigeria and Tunisia are used to estimate the model parameters and impulse responses: real GDP, real government expenditure, real CPI-based oil price and nominal oil price measured in local currency. The data are obtained from the IFS Database of the IMF and available through the various central banks. The data series used in estimation include the percentage change in the real price of crude oil using the OPEC benchmark of Brent crude oil price, the growth rate of real GDP (except for the Nigerian GDP and the transformation of which is discussed in Appendix B.1), and the growth rate of real government expenditure.[4] The oil price series is transformed and deflated using the nominal exchange rate and domestic CPI, while the government expenditure variable is deflated using the domestic CPI.[5] The sample runs from the first quarter of 2000 to the first quarter of 2017.

Considering the lack of reliable data for many developing oil-exporting countries (and oil-importing ones), the paper constructs a database with quarterly data that encompasses 8 developing countries. These countries are oil exporters, non-OECD, developing and emerging economies, and have an average oil contribution to GDP of about 30%-40%. Despite of the relatively small sample size used, there is clear evidence of both positive and negative oil price shocks for the selected period under investigation (see Figure B.2). We subject our data to a wide array of time series tests aimed at studying nonlinearity between oil prices and changes in government spending and GDP.

< Figure B.2 >

The details of data sources and Nigeria's data transformation are given in Appendix B.1. The vector of observable variables that enters in the VAR models below consists of[6]

$$Y^T = \{x_t, y_t\}' = \{oil_t^{obs,real}, y_t^{obs}\}' \tag{4.1}$$

$$Y^T = \{x_t, y_t\}' = \{oil_t^{obs,real}, g_t^{obs}\}' \tag{4.2}$$

4.3.2 VAR Specifications and Methodology

To test for the presence of asymmetries, we first refer to the hypothesis that oil price shocks have nonlinear effects on output. In other words, we impose asymmetry in the estimation so that the DGP is asymmetric. For our relatively small sample, we consider the following

[4]Disintegrating our government expenditure variable into recurrent and capital expenditure would have provided this paper the opportunity to independently analyze their response following an oil windfall, however, this stand to be one of the limitation of our paper given the poor data base of our selected oil-exporting emerging economies only keep record of the aggregated government expenditure variable. Moreover, oil revenue is also a good suggestion in place of government expenditure for fiscal response to oil shocks as oil revenue can have a significant impact on economic growth, particularly in countries where oil exports represent a large share of the economy. Considering that in some cases, there may be a strong correlation between government spending and oil revenue, particularly in countries where oil exports are the primary source of government revenue, this study concludes on employing government spending as the best option available following its acknowledgment of the limitation associated with accessing quarterly data of oil revenue for our selected oil-exporting emerging countries.

[5]The real variables are seasonally adjusted with ARIMA X-12.

[6]As a robustness check, we also estimate our models and carry out our tests using the nominal oil price as an observable

$$Y^T = \{x_t, y_t\}' = \{oil_t^{obs,norm}, y_t^{obs}\}'$$

While it is correct to point out that the real price would be the relevant measure in theoretical models for the oil price shock transmission, it is possible that, as argues by Hamilton (1996) and Hamilton (2003), deflating it by a particular number such as the CPI introduces a new source of measurement error which could affect he forecasting performance. The check aims to access whether this increases (decreases) the evidence of nonlinearity and whether this does or does not reduce the power of our original tests. The results are appended to the results tables and no significant difference has been identified. A further check in Table 4.4 provides a comparison between different (competing) treatments of including contemporaneous regressors (i.e. between the Mork's and Wald tests).

nonlinear specifications for the censoring of the logarithm of oil price series including Mork (1989)'s oil price increase measure and the net oil price increase (NOPI) measure in VAR models as in Hamilton (1996, 2003). An alternative to the NOPI, proposed by Kilian and Vigfusson (2013), defines the net oil price change (NOPC) and has fewer censored observations of the oil price.

To introduce the setup, first consider a linear and symmetric bivariate VAR(p) as the DGP

$$x_t = a_{10} + \sum_{i=1}^{p} a_{11,i}x_{t-i} + \sum_{i=1}^{p} a_{12,i}y_{t-i} + \epsilon_{1,t} \tag{4.3}$$

$$y_t = a_{20} + \sum_{i=0}^{p} a_{21,i}x_{t-i} + \sum_{i=1}^{p} a_{22,i}y_{t-i} + \epsilon_{2,t} \tag{4.4}$$

where x_t is the log growth in the oil price and y_t is the log growth of real GDP. $\epsilon_t \sim (0, \Sigma)$ is uncorrelated orthogonal white noise.

Suppose that the true response of y_t to x_t is asymmetric in positive and negative values. As demonstrated in **?**, the key advantage of the following model is that the dynamic responses are consistently estimated regardless of whether the true DGP is symmetric or asymmetric. Consider now the DGP for each country's GDP series that allows for both oil price increases and decreases to have an effect, but to different extents, which also includes contemporaneous regressors of x_t and x_t^{cen}

$$x_t = a_{10} + \sum_{i=1}^{p} a_{11,i}x_{t-i} + \sum_{i=1}^{p} a_{12,i}y_{t-i} + \epsilon_{1,t} \tag{4.5}$$

$$y_t = a_{20} + \sum_{i=0}^{p} a_{21,i}x_{t-i} + \sum_{i=1}^{p} a_{22,i}y_{t-i} + \sum_{i=0}^{p} b_{21,i}x_{t-i}^{cen} + \epsilon_{2,t} \tag{4.6}$$

where we can test the null hypothesis that $b_{21,0} = b_{21,1} = ... = b_{21,p} = 0$, as in the traditional approach using a Wald test including the contemporaneous regressor for x_t^{cen}.[7] x_t^{cen} is one of these nonlinear transformations of the oil price that provide the censoring of the oil price series

$$x_t^{cen} = OPI_t = \max(0, \ln(o_t) - \ln(o_{t-1})) \tag{4.7}$$

$$x_t^{cen} = NOPI_t = \max(0, \ln(o_t) - \max(\ln(o_{t-1}), ..., \ln(o_{t-4})) \tag{4.8}$$

where $\ln(o_t)$ is the logarithm of the real oil price. In other words, in addition to a one-period increase (4.7), any increases that did not exceed the maximum price observed in the past 4 quarters (Hamilton, 1996) are also censored at zero – i.e. a change of oil price only affects the economy when it deviates substantially from its behaviour in the recent past. As noted, an alternative measure is the NOPC model proposed by Kilian and Vigfusson (2013)

$$x_t^{cen} = NOPC_t = NOPI_t + NOPD_t \tag{4.9}$$

[7]The alternative slope-based test is Mork's test and involves tests of the symmetry of the slope coefficients with a predictive model (Mork, 1989): $H_0 : b_{21,1} = b_{21,2}... = b_{21,p} = 0$. Both tests are carries out based on estimated single-equation regression models using Least Square.

$$NOPD_t = \min(0, \ln(o_t) - \min(\ln(o_{t-1}), ..., \ln(o_{t-4})) \quad (4.10)$$

By construction, models incorporating (4.9) have fewer censored observations of the oil price which is helpful for our relatively small sample size. Estimating the unrestricted simultaneous equations model (Equations (4.5) and (4.6)) nests specifications with symmetric and asymmetric effects of oil price shocks on GDP.

Following the work done by Karaki (2017) and Kilian and Vigfusson (2011*a*), two assumptions are made to identify the nonlinear oil price shocks. First, oil price shocks are assumed to be predetermined with respect to the real GDP growth rate. Second, real GDP growth is assumed to respond contemporaneously to oil prices. As the main purpose of the empirical exercise is to examine the nonlinear impact of oil prices on real GDP growth (and later on government expenditure) under these standard identifying assumptions, the inclusion of additional variables in the our models does not affect the asymptotic properties of the responses of the real variables to oil price innovations. However, we do admit it would be a concern for us if we had a very small sample in which case the accuracy of the responses may be affected.[8]

In what follows, we estimate and compare the three nonlinear configurations for the oil price increase, NOPI and NOPC, respectively, and the linear VAR model, for all the countries in our sample: Model OPI ($x_t^{cen} = OPI_t^1$), Model NI ($x_t^{cen} = NOPI_t^4$), Model NC ($x_t^{cen} = NOPC_t^4$) and the linear model. In our testing procedure, we compare the both types of slope-based tests with the IRF-based test developed by Kilian and Vigfusson (2011*a*) (henceforth KV). The latter applies the simulation methodology computing and comparing the unconditional IRFs for real GDP growth to an oil price shock in the reduced form VAR model for one and two standard deviation (s.d.) oil price shocks. The null hypothesis is the VAR linearity that the IRFs are the same across regimes, i.e. the Wald test of the null of symmetric IRF can be computed as: $H_0 : IRF_y(h, \delta) = -IRF_y(h, -\delta)$. Details of the algorithm are reported in Appendix B.2.

4.4 Empirical Tests and Results

In this section, we use the models to test for two types of asymmetry, in particular, (i) whether positive and negative shocks have different effects on each country's output growth; and (ii) whether typical (measured by 1 s.d.) and large (measured by 2 s.d.) shocks have different effects on the GDP growth. The lag order p is set to capture the dynamic effects of oil price on the real economy and determined by performing residual diagnostic checks on each of the estimated models. Different lag orders have been applied for different countries as reported by the impulse response-based test p-values and this can be associated with the variation in the economic transmission across countries.

The choices of lag length of $p = 6$ and $p = 8$ are chosen based on the following motives. First, Hamilton and Herrera (2004) show that using smaller number of lags leads to underestimating the effects of oil price as the response of real GDP to these shocks is very sluggish. Second, for the results of the nonlinear models to be robust, sufficiently long lags are needed. Finally, linear information criteria such as AIC or BIC, which result in more parsimonious models, lead to misleading results in small samples and invalidate the inference from the nonlinear systems.

[8] See Kilian and Vigfusson (2011*a*) and Kilian and Lewis (2011).

Tables 4.2 and 4.3 report the corresponding p-values for the Wald Test statistics set out in Appendix B.2. Based on the statistics, there is mixed evidence reported as some countries (such as Tunisia, Bolivia, Malaysia, and Indonesia) show strong statistical evidence of asymmetry (thus, rejecting the null hypothesis of symmetry) while others do not clearly show statistical evidence against the symmetry of the IRFs at 5% level (at least for a typical-sized shock).

Next we turn to some robustness checks because we need to know whether our test results may be dependent on using the traditional slope-based tests, the measure of oil prices (real vs. nominal prices)[9] and the magnitude of asymmetry across the projected horizons of our estimated IRFs. We compare the impulse response-based test statistics with two slope-based tests as shown in Table 4.4 as well as providing the cumulative mean square distance as shown in Table 4.5 in the following section.

First, from Table 4.4, it is expected that the Wald test should posit a more predictive power than Mork's test. Based on the statistics reported for the latter, there is no evidence against symmetry for Bolivia, Brazil, Colombia, Ecuador and Nigeria, whereas the Wald test shows the corresponding evidence with the exception of Bolivia, Brazil and Nigeria for which the test strongly rejects the null of symmetry at the 5% level of significance. The difference at this point can be related to Mork's test that exploits extra restrictions in the null hypothesis in the form of incorporating contemporaneous terms of x_t^{cen} due to the construction of a predictive model. On the other hand, countries like Indonesia, Malaysia, Tunisia and Nigeria show strong evidence of asymmetry further affirmed by the Wald test and in consensus with the IRF-based test statistics reported in the previous tables. The additional benefits of both the IRF-based test and the cumulative measure of asymmetry are that they allow us to quantitatively study the degree and effects of asymmetry in the response to a shock. The latter is what we turn to next.

4.4.1 Cumulative Measures of Asymmetry

Following Herrera et al. (2015), we further compute a measure of the difference between the responses to positive and negative innovations: the cumulative distance. Table 4.5 shows the magnitude of asymmetry depicted by countries by reporting the cumulative distance between the computed IRFs in terms of percentage points

$$d_H^m = \sum_{h=0}^{H} |[IRF_y^m(h,\delta)] - [-IRF_y^m(h,-\delta)]| \tag{4.11}$$

where d_H^m measures the distance between the impulse responses accumulated from $h = 0$ to $h = H$. m is the model index. $|[IRF_y^m(h,\delta)] - [-IRF_y^m(h,-\delta)]|$ stands for the Euclidean norm. We present the cumulative of the Euclidean norm for the three nonlinear models as the horizon increases ($H = 1, 4, 8, 12$). We can gain further understanding on (i) the difference of responses to positve and negative shock; (ii) how the cumulative of the Euclidean distance changes over time with the horizon after the shock hits the system, e.g., before and after a year.

Based on the statistics reported, not surprisingly, the table shows that the cumulative differences between the one s.d. shock and two s.d. shock are quite large across all countries. Malaysia reports the largest cumulative distance between the responses to a

[9]The p-values are presented in parentheses and appended to Tables 4.2 and 4.3.

Table 4.2: KV IRF-based Test for Asymmetry

Bolivia Lag=8							**Brazil Lag=6**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**		
Horizon	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
1	0.19	0.08	0.96	0.25	0.06	0.51	0.22	0.11	0.86	0.36	0.10	0.96
	(0.15)	(0.17)	(0.87)	(0.12)	(0.02)	(0.28)	(0.11)	(0.08)	(0.49)	(0.23)	(0.10)	(0.67)
2	0.13	0.08	1.00	0.10	0.01	0.81	0.47	0.14	0.94	0.66	0.10	1.00
	(0.22)	(0.20)	(0.93)	(0.20)	0.00	(0.55)	(0.27)	(0.16)	(0.54)	(0.49)	(0.19)	(0.81)
3	0.09	0.14	1.00	0.01	0.01	0.84	0.12	0.07	0.93	0.23	0.01	1.00
	(0.14)	(0.33)	(0.98)	(0.02)	0.00	(0.69)	(0.02)	(0.01)	(0.70)	(0.09)	(0.01)	(0.92)
4	0.13	0.24	1.00	0.01	0.03	0.91	0.17	0.11	0.64	0.29	0.02	1.00
	(0.21)	(0.49)	(1.00)	(0.02)	(0.01)	(0.83)	(0.04)	(0.02)	(0.38)	(0.15)	(0.01)	(0.75)
5	0.21	0.36	1.00	0.02	0.05	0.93	0.12	0.14	0.77	0.09	0.01	1.00
	(0.31)	(0.63)	(1.00)	(0.04)	(0.02)	(0.90)	(0.04)	(0.03)	(0.43)	(0.03)	(0.01)	(0.79)
6	0.30	0.47	1.00	0.03	0.08	0.95	0.16	0.20	0.84	0.11	0.02	1.00
	(0.43)	(0.75)	(1.00)	(0.01)	(0.04)	(0.94)	(0.06)	(0.04)	(0.54)	(0.03)	(0.01)	(0.86)
7	0.32	0.56	1.00	0.01	0.05	0.95	0.19	0.26	0.89	0.06	0.01	1.00
	(0.48)	(0.82)	(1.00)	(0.02)	(0.01)	(0.97)	(0.06)	(0.07)	(0.66)	(0.02)	(0.01)	(0.92)
8	0.41	0.65	1.00	0.01	0.07	0.97	0.27	0.35	0.90	0.10	0.02	1.00
	(0.59)	(0.88)	(1.00)	(0.03)	(0.02)	(0.98)	(0.10)	(0.10)	(0.76)	(0.03)	(0.01)	(0.96)
9	0.51	0.70	1.00	0.01	0.06	0.98	0.35	0.44	0.94	0.14	0.04	1.00
	(0.68)	(0.92)	(1.00)	(0.04)	(0.02)	(0.99)	(0.14)	(0.15)	(0.78)	(0.05)	(0.01)	(0.98)
10	0.58	0.78	1.00	0.02	0.09	0.99	0.44	0.52	0.96	0.19	0.06	1.00
	(0.77)	(0.95)	(1.00)	(0.06)	(0.04)	(0.99)	(0.19)	(0.20)	(0.85)	(0.08)	(0.02)	(0.99)
11	0.67	0.84	1.00	0.03	0.13	0.99	0.53	0.61	0.98	0.26	0.08	1.00
	(0.83)	(0.97)	(1.00)	(0.06)	(0.05)	(0.99)	(0.25)	(0.27)	(0.90)	(0.11)	(0.04)	(1.00)
12	0.74	0.89	1.00	0.04	0.17	1.00	0.61	0.69	0.98	0.33	0.12	1.00
	(0.88)	(0.99)	(1.00)	(0.09)	(0.07)	(0.99)	(0.28)	(0.34)	(0.92)	(0.15)	(0.06)	(1.00)
Colombia Lag=6							**Ecuador Lag=6**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**		
Horizon	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
1	0.02	0.13	0.91	0.05	0.04	0.87	0.30	0.02	0.13	0.50	0.01	0.37
	(0.02)	(0.11)	(0.61)	(0.03)	(0.01)	(0.37)	(0.44)	(0.00)	(0.06)	(0.60)	(0.00)	(0.15)
2	0.05	0.22	0.85	0.12	0.11	0.92	0.11	0.04	0.28	0.35	0.02	0.66
	(0.03)	(0.12)	(0.55)	(0.06)	(0.04)	(0.46)	(0.15)	(0.02)	(0.14)	(0.33)	(0.00)	(0.34)
3	0.11	0.27	0.95	0.22	0.20	0.98	0.22	0.10	0.39	0.54	0.04	0.78
	(0.06)	(0.21)	(0.74)	(0.11)	(0.07)	(0.66)	(0.28)	(0.04)	(0.26)	(0.52)	(0.00)	(0.52)
4	0.11	0.39	0.95	0.20	0.33	0.99	0.28	0.14	0.41	0.66	0.04	0.89
	(0.08)	(0.29)	(0.82)	(0.12)	(0.13)	(0.80)	(0.36)	(0.06)	(0.41)	(0.63)	(0.00)	(0.68)
5	0.17	0.41	0.98	0.27	0.26	0.99	0.37	0.23	0.55	0.77	0.08	0.95
	(0.14)	(0.37)	(0.86)	(0.18)	(0.11)	(0.89)	(0.44)	(0.11)	(0.55)	(0.73)	(0.00)	(0.81)
6	0.25	0.53	0.99	0.39	0.26	1.00	0.40	0.32	0.64	0.76	0.13	0.98
	(0.21)	(0.49)	(0.89)	(0.27)	(0.15)	(0.93)	(0.41)	(0.17)	(0.66)	(0.64)	(0.01)	(0.88)
7	0.31	0.56	0.99	0.47	0.33	1.00	0.51	0.37	0.75	0.83	0.13	0.99
	(0.30)	(0.56)	(0.86)	(0.37)	(0.21)	(0.91)	(0.50)	(0.24)	(0.77)	(0.70)	(0.02)	(0.93)
8	0.39	0.65	0.99	0.58	0.43	1.00	0.62	0.48	0.83	0.90	0.19	1.00
	(0.37)	(0.65)	(0.92)	(0.47)	(0.29)	(0.94)	(0.60)	(0.33)	(0.85)	(0.79)	(0.03)	(0.96)
9	0.49	0.74	1.00	0.67	0.53	1.00	0.71	0.58	0.88	0.94	0.26	1.00
	(0.47)	(0.74)	(0.95)	(0.57)	(0.38)	(0.97)	(0.70)	(0.42)	(0.89)	(0.86)	(0.05)	(0.98)
10	0.58	0.81	1.00	0.76	0.62	1.00	0.79	0.65	0.92	0.97	0.32	1.00
	(0.57)	(0.82)	(0.97)	(0.66)	(0.47)	(0.98)	(0.78)	(0.50)	(0.92)	(0.91)	(0.06)	(0.99)
11	0.67	0.87	1.00	0.82	0.71	1.00	0.85	0.73	0.95	0.98	0.40	1.00
	(0.65)	(0.87)	(0.99)	(0.74)	(0.56)	(0.99)	(0.80)	(0.59)	(0.95)	(0.94)	(0.09)	(1.00)
12	0.75	0.91	1.00	0.88	0.78	1.00	0.90	0.80	0.97	0.99	0.48	1.00
	(0.73)	(0.92)	(0.99)	(0.81)	(0.64)	(1.00)	(0.89)	(0.67)	(0.97)	(0.97)	(0.13)	(1.00)

Notes: This table reports the p-values at 5% for the Wald test statistic set out in Appendix B.2 with values in parathesis representing the p-values at 5% for the nominal estimation result. For simulating paths of x_t and y_t, we use 10,000 draws of simulations for computing the IRF given the history. For the number of bootstrapping draws over the model, our simulations are based on 10,000 bootstrapped pseudo-series using the estimated coefficients. The lag order is selected for all our models by carrying out residual diagnostics. While including additional lags could result in a reduction in test power, omitting extra lags can give rise to the test outcome of nonlinearity.

Table 4.3: KV IRF-based Test for Asymmetry - Contd.

Indonesia Lag=8							**Malaysia Lag=6**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**		
Horizon	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
1	0.56	0.96	0.87	0.76	0.68	0.82	0.15	0.03	0.33	0.33	0.06	0.38
	(0.85)	(0.88)	(0.82)	(0.99)	(0.94)	(0.93)	(0.14)	(0.07)	(0.15)	(0.22)	(0.06)	(0.23)
2	0.01	0.84	0.84	0.01	0.44	0.91	0.00	0.06	0.61	0.00	0.03	0.68
	(0.08)	(0.92)	(0.92)	(0.05)	(0.90)	(0.96)	(0.00)	(0.11)	(0.35)	(0.00)	(0.03)	(0.45)
3	0.01	0.85	0.95	0.00	0.46	0.98	0.01	0.13	0.52	0.00	0.07	0.81
	(0.06)	(0.73)	(0.90)	(0.02)	(0.85)	(0.77)	(0.00)	(0.22)	(0.42)	(0.00)	(0.07)	(0.62)
4	0.02	0.78	0.99	0.00	0.37	0.99	0.00	0.12	0.69	0.00	0.02	0.90
	(0.10)	(0.63)	(0.90)	(0.01)	(0.50)	(0.87)	(0.00)	(0.19)	(0.54)	(0.00)	(0.02)	(0.71)
5	0.04	0.87	1.00	0.00	0.50	1.00	0.01	0.19	0.81	0.00	0.04	0.96
	(0.17)	(0.72)	(0.95)	(0.03)	(0.56)	(0.93)	(0.01)	(0.28)	(0.67)	(0.00)	(0.03)	(0.82)
6	0.07	0.93	1.00	0.01	0.56	1.00	0.02	0.27	0.89	0.00	0.04	0.98
	(0.25)	(0.81)	(0.98)	(0.04)	(0.53)	(0.96)	(0.02)	(0.40)	(0.76)	(0.00)	(0.04)	(0.88)
7	0.06	0.93	1.00	0.00	0.17	1.00	0.03	0.37	0.92	0.00	0.05	0.99
	(0.22)	(0.77)	(0.97)	(0.00)	(0.20)	(0.98)	(0.04)	(0.49)	(0.85)	(0.00)	(0.05)	(0.93)
8	0.09	0.95	1.00	0.00	0.02	1.00	0.05	0.47	0.94	0.00	0.08	1.00
	(0.29)	(0.80)	(0.99)	(0.00)	(0.03)	(0.99)	(0.05)	(0.56)	(0.91)	(0.00)	(0.09)	(0.96)
9	0.13	0.97	1.00	0.00	0.01	1.00	0.07	0.52	0.97	0.01	0.12	1.00
	(0.37)	(0.87)	(1.00)	(0.00)	(0.02)	(0.99)	(0.09)	(0.56)	(0.95)	(0.01)	(0.13)	(0.98)
10	0.18	0.97	1.00	0.00	0.02	1.00	0.11	0.61	0.98	0.01	0.16	1.00
	(0.46)	(0.88)	(1.00)	(0.00)	(0.03)	(0.99)	(0.13)	(0.65)	(0.97)	(0.01)	(0.17)	(0.99)
11	0.24	0.96	1.00	0.00	0.03	1.00	0.15	0.69	0.99	0.02	0.22	1.00
	(0.55)	(0.92)	(1.00)	(0.00)	(0.04)	(1.00)	(0.18)	(0.74)	(0.98)	(0.02)	(0.23)	(1.00)
12	0.30	0.97	1.00	0.00	0.04	1.00	0.20	0.77	1.00	0.04	0.29	1.00
	(0.64)	(0.95)	(1.00)	(0.00)	(0.07)	(1.00)	(0.23)	(0.80)	(1.00)	(0.02)	(0.30)	(1.00)

Nigeria Lag=6							**Tunisia Lag=6**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**		
Horizon	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
1	0.00	1.00	1.00	0.04	1.00	1.00	0.11	0.02	0.49	0.30	0.03	0.61
	(0.01)	(0.91)	(1.00)	(0.09)	(0.80)	(1.00)	(0.23)	(0.02)	(0.20)	(0.41)	(0.03)	(0.36)
2	0.00	1.00	1.00	0.10	1.00	1.00	0.02	0.04	0.54	0.11	0.07	0.65
	(0.03)	(0.98)	(1.00)	(0.25)	(0.94)	(1.00)	(0.04)	(0.03)	(0.29)	(0.16)	(0.07)	(0.42)
3	0.02	1.00	1.00	0.20	1.00	1.00	0.03	0.09	0.53	0.18	0.11	0.80
	(0.08)	(0.98)	(1.00)	(0.43)	(0.79)	(1.00)	(0.03)	(0.05)	(0.36)	(0.27)	(0.13)	(0.59)
4	0.03	1.00	1.00	0.26	1.00	1.00	0.03	0.11	0.66	0.12	0.11	0.91
	(0.16)	(0.98)	(1.00)	(0.60)	(0.86)	(1.00)	(0.03)	(0.06)	(0.52)	(0.17)	(0.10)	(0.75)
5	0.02	1.00	1.00	0.09	1.00	1.00	0.04	0.12	0.78	0.13	0.03	0.96
	(0.09)	(0.97)	(1.00)	(0.40)	(0.92)	(1.00)	(0.04)	(0.06)	(0.66)	(0.17)	(0.02)	(0.86)
6	0.02	0.10	1.00	0.07	1.00	1.00	0.02	0.11	0.86	0.01	0.00	0.98
	(0.07)	(0.98)	(1.00)	(0.26)	(0.95)	(1.00)	(0.03)	(0.05)	(0.71)	(0.01)	(0.00)	(0.89)
7	0.03	1.00	1.00	0.03	1.00	1.00	0.02	0.16	0.91	0.00	0.00	0.99
	(0.08)	(0.94)	(1.00)	(0.17)	(0.87)	(1.00)	(0.03)	(0.08)	(0.80)	(0.00)	(0.00)	(0.94)
8	0.05	1.00	1.00	0.06	1.00	1.00	0.03	0.21	0.95	0.01	0.00	1.00
	(0.11)	(0.81)	(1.00)	(0.24)	(0.88)	(1.00)	(0.05)	(0.12)	(0.87)	(0.01)	(0.00)	(0.96)
9	0.07	1.00	1.00	0.09	1.00	1.00	0.04	0.27	0.97	0.01	0.00	1.00
	(0.16)	(0.91)	(1.00)	(0.32)	(0.86)	(1.00)	(0.08)	(0.18)	(0.92)	(0.02)	(0.00)	(0.98)
10	0.10	1.00	1.00	0.13	1.00	1.00	0.07	0.27	0.99	0.02	0.00	1.00
	(0.21)	(0.93)	(1.00)	(0.40)	(0.93)	(1.00)	(0.11)	(0.18)	(0.95)	(0.02)	(0.00)	(1.00)
11	0.14	1.00	1.00	0.18	1.00	1.00	0.10	0.35	0.99	0.03	0.00	1.00
	(0.27)	(0.96)	(1.00)	(0.48)	(0.98)	(1.00)	(0.15)	(0.22)	(0.97)	(0.04)	(0.00)	(1.00)
12	0.17	1.00	1.00	0.23	1.00	1.00	0.13	0.40	1.00	0.04	0.01	1.00
	(0.32)	(0.90)	(1.00)	(0.57)	(0.99)	(1.00)	(0.21)	(0.26)	(0.98)	(0.06)	(0.00)	(1.00)

Notes: This table reports the p-values (at 5%) for the Wald test statistic set out in Appendix B.2 with values in parathesis representing the p-values at 5% for the nominal estimation result. For simulating paths of x_t and y_t, we use 10,000 draws of simulations for computing the IRF given the history. For the number of bootstrapping draws over the model, our simulations are based on 10,000 bootstrapped pseudo-series using the estimated coefficients.

Table 4.4: Slope-based Tests for Symmetry

Country	Mork's Test	Wald Test
Bolivia	0.33	0.02
Brazil	0.64	0.03
Colombia	1.00	0.99
Ecuador	0.91	0.56
Indonesia	0.02	0.00
Malaysia	0.01	0.00
Nigeria	0.56	0.00
Tunisia	0.00	0.00

Notes: This table reports the p-values (at 5%) for the Wald test statistic of the joint significance of the lags of x_t^{cen} in Equation 4.6. For Mork's Test: $H_0 : b_{21,1} = ... = b_{21,p} = 0$; For Wald Test: $H_0 : b_{21,0} = ... = b_{21,p} = 0$.

Table 4.5: Cumulative Mean Square Distance For Output Responses

h=1							**h=4**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**		
Countries	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
Bolivia	0.04	0.04	0.01	0.46	0.45	0.11	0.05	0.03	0.01	0.66	0.43	0.17
Brazil	0.06	0.08	0.02	0.47	0.79	0.02	0.13	0.09	0.04	1.13	1.24	0.04
Colombia	0.17	0.06	0.02	1.38	0.89	0.05	0.16	0.05	0.02	1.37	0.62	0.05
Ecuador	0.09	0.08	0.07	0.71	1.02	0.27	0.11	0.06	0.06	0.86	1.00	0.22
Indonesia	0.04	0.00	0.00	0.37	0.11	0.02	0.07	0.01	0.00	0.64	0.10	0.02
Malaysia	0.21	0.10	0.04	1.41	0.90	0.19	0.25	0.07	0.08	1.80	0.92	0.33
Nigeria	0.02	0.01	0.00	0.27	0.21	0.01	0.02	0.02	0.00	0.21	0.26	0.01
Tunisia	0.16	0.05	0.06	1.07	0.53	0.25	0.17	0.06	0.04	1.15	0.60	0.18

h=8							**h=12**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**		
Countries	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
Bolivia	0.05	0.03	0.01	0.64	0.45	0.18	0.04	0.02	0.01	0.59	0.40	0.16
Brazil	0.14	0.09	0.04	1.20	1.05	0.04	0.11	0.07	0.04	1.08	0.88	0.03
Colombia	0.13	0.03	0.02	1.14	0.51	0.08	0.10	0.03	0.02	0.93	0.43	0.09
Ecuador	0.09	0.05	0.04	0.72	0.79	0.17	0.08	0.04	0.04	0.60	0.67	0.14
Indonesia	0.06	0.01	0.00	0.59	0.33	0.02	0.05	0.01	0.00	0.51	0.31	0.02
Malaysia	0.18	0.06	0.06	1.34	0.73	0.29	0.14	0.04	0.06	1.10	0.61	0.24
Nigeria	0.02	0.01	0.00	0.20	0.20	0.02	0.07	0.06	0.02	0.52	0.57	0.06
Tunisia	0.14	0.07	0.05	0.96	0.62	0.18	0.11	0.06	0.04	0.82	0.56	0.15

positive and a negative shock generated by Models OPI and NI, which is again consistent with our results above based on the IRF test and the slope-based tests. With Models NI and NC, nearly all the countries are close to being economically insignificant in terms of their cumulative responses to the typical shock (i.e. $d_H < 10$ percentage points). In almost all countries except for Brazil, the distance measures do not change very much as the horizon increases, suggesting that the degree of asymmetry decreases shortly after the shock for these countries.

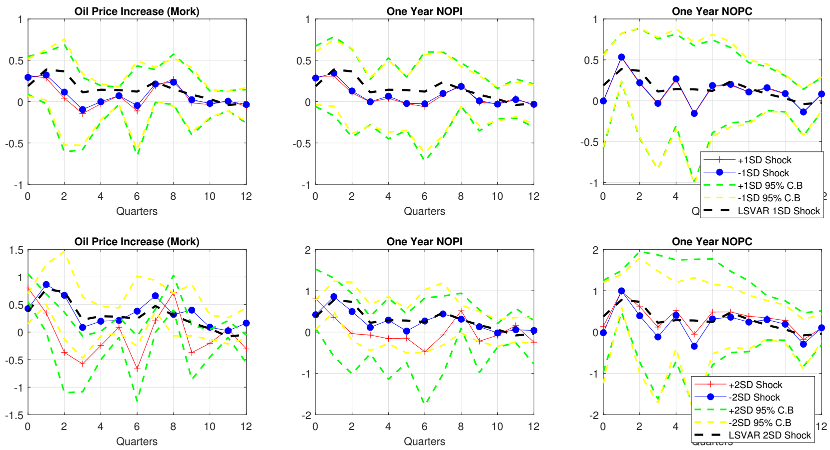
Another notable finding from this exercise is that, apart from the NC specification, all our oil-exporting countries experience some significant degree of asymmetric responses, over the projected horizon, to a large oil price innovation. This is not surprising and becomes much clearer when we look at the estimated IRFs in the next section. Apart from Malaysia, the magnitude of the asymmetry seems to remain strong over time for Colombia, Ecuador, and Brazil where the effect is also amplified after 1 quarter. Intuitively, this could be explained by Figures 4.1 and 4.3, which show that these are the countries that depend heavily on oil in terms of either the production intensity or overall share in GDP.

4.4.2 Impulse Response Analysis for Output Growth

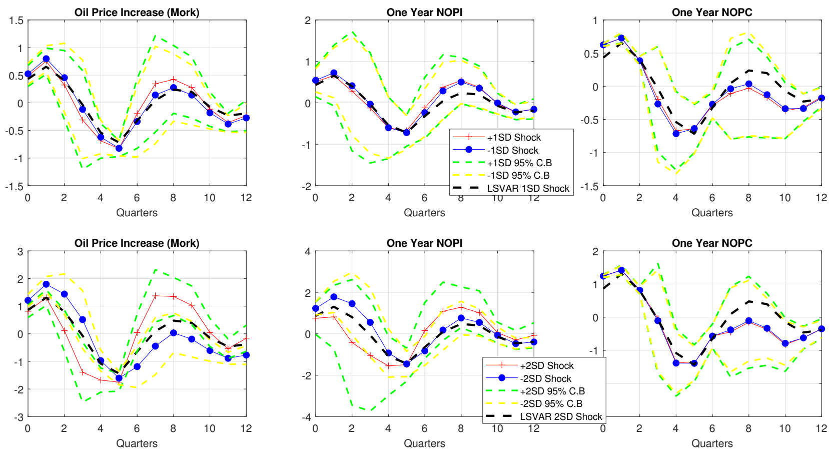
To further investigate the degree of asymmetry in response to a shock, in this section, we study the estimated impulse responses for the oil price shocks. As mentioned, we consider a typical shock of 1 s.d. and a larger shock of 2 s.d., and we depict the responses of a positive and negative oil price shock, respectively, from our estimated models. The variable of interest is the observable GDP growth (in %) in the estimation and each response is for a 12 period horizon (3 years). The aim of this exercise is two-fold. First, we can evaluate (a)symmetry in the response more closely across our three VAR models, *vis-à-vis* the linear responses, by understanding how the IRF trajectories may be affected by the magnitude of the shock and the types of the censored variable. Second, we are interested in assessing the impact of shocks (small and large) on the model dynamics so that we can investigate the importance of shocks to the output growth in order to gain a better understanding of the innovation and forecasting uncertainties and, thus, the model uncertainties faced by policymakers.

Figure 4.4 - Figure 4.7 depicts the mean responses corresponding to a positive/negative-, one/two-standard deviation of the shocks' innovations. A positive oil price shock has the usual negative impact on output (in terms of the level effects) for all the countries. Overall, there is a negative correlation between oil and economic growth such that an oil price increase leads to a decline in growth. For example, it shows that, after just over 1 year, the cumulative (growth) effect of a 1 s.d. positive innovation in oil prices results in an almost 1% contraction of GDP in Malaysia. However, for oil producers, when there is the supply-side effect depending on energy intensity in production (again according to Figure 4.3), oil production often responds with a lag to a positive shock, followed by production contraction in most countries. Nevertheless, this effect dies out relatively rapidly (less than 1 year) when affecting output for all the affected countries.

All oil-producing/exporting countries are also affected by the demand push factor that results in an initial increase in GDP with the lagged effect which again depends on the oil share in GDP (e.g., Ecuador). From the IRF dynamics reported by our estimation, any correlation between the presence or absence of asymmetry and the oil production share in GDP (according to Figure 4.1) appears to be much less notable. Finally, as expected,



(a) Bolivia



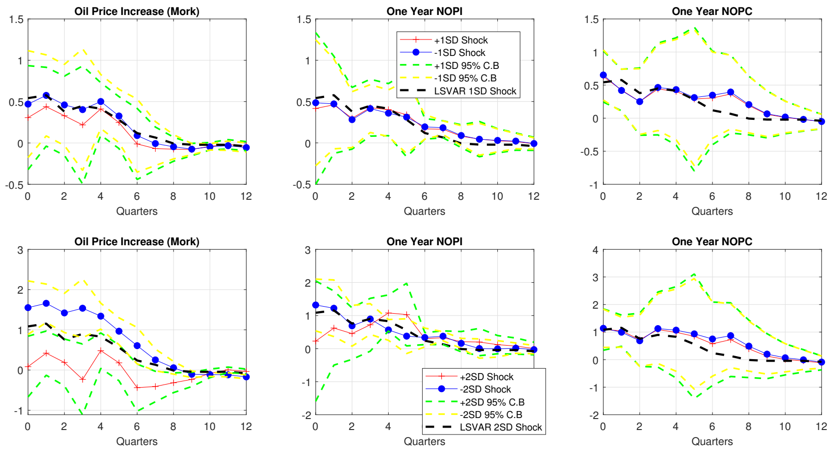
(b) Brazil

Figure 4.4: Impulse Response Functions of GDP Growth

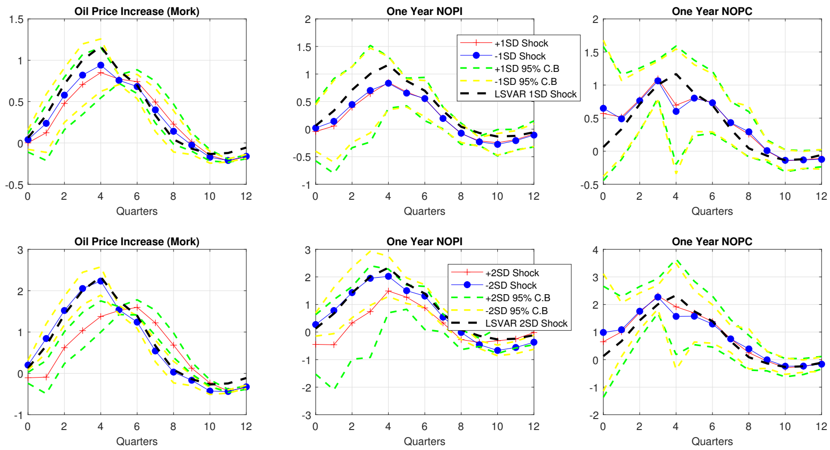
Notes: Each panel plots the mean response corresponding a one and two standard deviation of the shock's innovation. Each response is for a 12 period (3 years) horizon and is the percentage deviation.

there are marked differences in IRFs when there are strong asymmetric effects (in line with the above tables of the statistical tests). The results from the estimated IRFs confirm our key findings discussed above, i.e., there is substantial evidence in the data to support the presence of asymmetry in the real effects of oil price shocks, which can be significantly magnified or altered, depending on certain country-specific characteristics that exacerbate their vulnerabilities to the shock. Such characteristics include high oil dependence, ongoing economic structure changes and high fiscal volatility (Abdih et al. (2010), Barsky and Kilian (2004)).

The impact of oil price shocks on output is not homogeneous across oil-exporting countries for a number of reasons. Now we focus on the individual country and discuss evidence of (a)symmetry and their responses to the shock based on a number of country-specific characteristics (e.g., export volume, income group and sectoral decomposition of GDP). In the case of Malaysia, where, overall, we have seen the smallest p-values



(a) Colombia



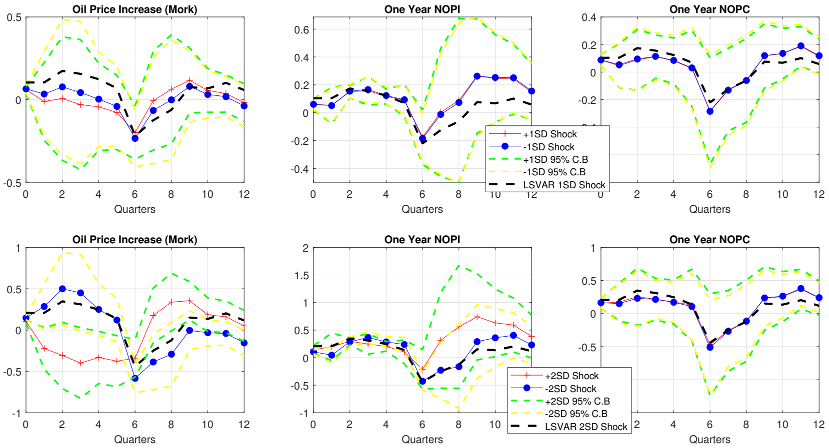
(b) Ecuador

Figure 4.5: Impulse Response Functions of GDP Growth

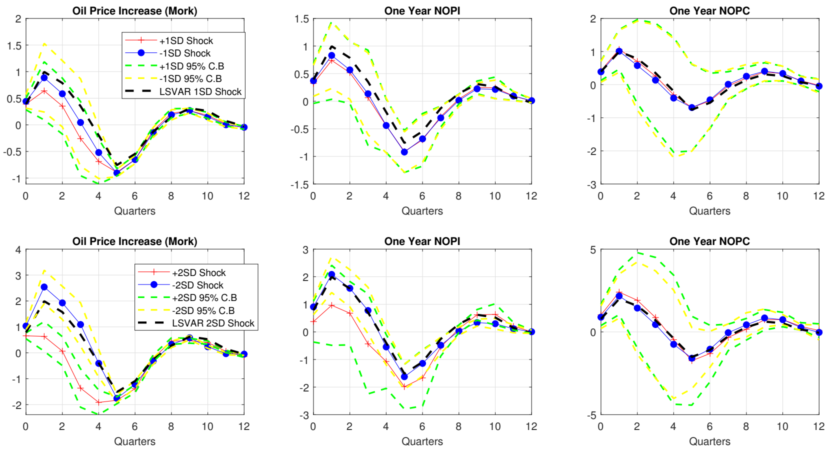
Notes: Each panel plots the mean response corresponding a one and two standard deviation of the shock's innovation. Each response is for a 12 period (3 years) horizon and is the percentage deviation.

associated with oil price shocks, we try and examine closely the estimated IRFs, and discuss the possible reasons behind our results. Our figure shows that an unexpected positive shock tends to increase oil revenue but given that the export volume is small, this effect is small. At the same time, the large oil-dependent industrial sector (36% in Malaysia[10]) tends to be negatively affected. Also, as most of the people work in non-oil-producing sector, aggregate demand is likely to be negatively affected. Thus, the net effect of an oil price increase is contractionary over time. On the other hand, due to the small size of the oil-exporting sector, the impact on aggregate export revenue is negligible. Also, given that the large industrial sector depends on oil production, an oil price increase can promote aggregate demand and hence output (from the supply side). This may explain the initial expansion seen from the GDP responses which seems to be persistent for less

[10]The country-specific data and information presented in this section are obtained from the World Bank database.



(a) Indonesia



(b) Malaysia

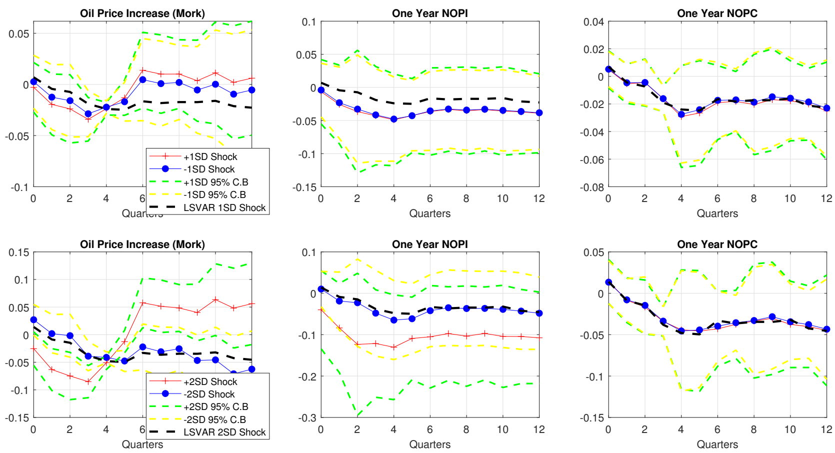
Figure 4.6: Impulse Response Functions of GDP Growth

Notes: Each panel plots the mean response corresponding a one and two standard deviation of the shock's innovation. Each response is for a 12 period (3 years) horizon and is the percentage deviation.

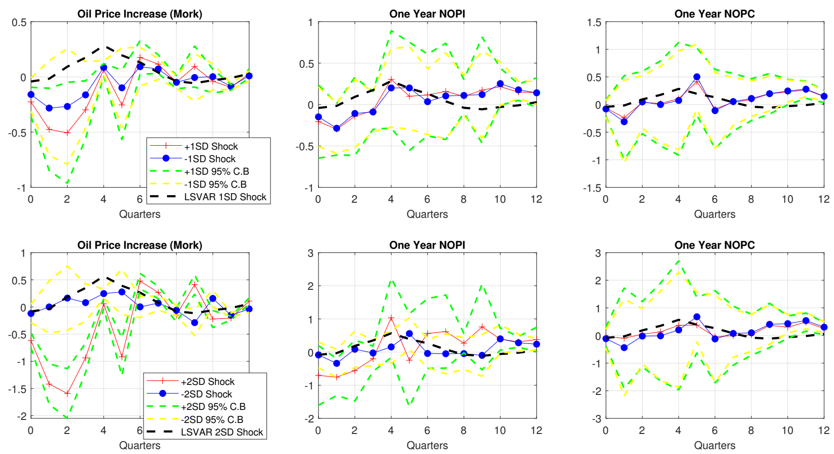
than two quarters, as discussed above.

Another case exhibiting strong nonlinear effect of oil price shocks is Indonesia, in which oil-exporting as percentage of GDP is declining, accounting for about 8% of total exports. The economy is moving toward the service sector (about 45% of GDP). Given the small volume of oil exports, an oil price increase does not tend to play a significant role in improving current account surplus. Rather, due to the substantial industrial sector, an increase in oil price increases production costs. Also, as most of the labour force is employed in the non-oil sector, an oil price increase reduces aggregate demand. Thus, similar to Malaysia, the net effect shows a reduction in output. The effect is greater and more persistent when considering a large oil price shock.

Finally, we look at Ecuador, from which we find, on average, the largest p-values based on almost all our models, forms of tests, and sizes of shocks. The country has a relatively large oil sector in which oil contributes towards 40% of exports. An oil price increase



(a) Nigeria



(b) Tunisia

Figure 4.7: Impulse Response Functions of GDP Growth

Notes: Each panel plots the mean response corresponding a one and two standard deviation of the shock's innovation. Each response is for a 12 period (3 years) horizon and is the percentage deviation.

improves its current account balance and pushes the exchange rate upwards which might negatively affect revenue from the agricultural sector. However, being the major producer of some of the agricultural commodities, this tends to give Ecuador the price setting power. As a result, agricultural revenue may not actually go down. The net effect on output may actually be positive (and persistent for over a year). As most of the people are employed in the service and industrial sectors, a decrease in oil price also acts to boost aggregate demand, and hence, output. As expected, the positive and negative oil price shocks have symmetric effects on output growth.

4.5 Oil Price Shocks and Discretionary Fiscal Policy

Oil price shocks can be associated with disrupting a country's fiscal positions for a number of reasons. Given the fact that many net oil-exporting countries (particularly in the Middle

East and sub-Saharan Africa) are highly dependent on oil, this means that the resource sector provides a major source for the foreign exchange earnings and fiscal revenues. Thus, during the period of negative oil price shocks, it is evident that fiscal policy responses are usually procyclical, witnessed by a decline in government expenditure (unless there is availability of fiscal buffers) as government budgets are strained, hence hindering the long-run economic growth of the country (Lopez-Murphy and Villafuerte, 2010). The macroeconomic impacts of oil price disturbances have been found to be more severe in these economies exhibiting fiscal volatility and procyclicality (Abdih et al. (2010)).

On the other hand, the effect of negative oil price shocks on oil-importing countries are perceived to be weaker in most cases. This implies that oil-importing countries are most likely to profit from the production cost decline and real income gains following the fall in oil prices. Savings made from oil import bills can aid the relaxation of government budgets (Baffes et al., 2015; Lopez-Murphy and Villafuerte, 2010). Notwithstanding, a global supply restriction, weak global demand and tight scope of monetary policy facilitation in these countries might stand as a bottleneck to these benefits (Baffes et al., 2015). For example, geopolitical tensions and conflicts in oil-producing regions can lead to supply disruptions, leading to higher oil prices, and negatively affecting oil-importing countries' economies. This can also increase oil-exporting countries' revenues in the short term, but the long-term impacts on economic growth may be negative, as geopolitical tensions can lead to increased uncertainty, reduced investment, and lower economic growth. Furthermore, the global economic environment can also affect the impact of oil price changes on the economic growth of oil-exporting emerging countries. For example, a global economic downturn can lead to reduced demand for oil, leading to lower oil prices and reduced export revenues for oil-exporting countries. This can further exacerbate the negative impacts of the resource curse and hamper economic growth.

Considering the high level of pre-tax fuel subsidies in most developing and emerging economies (Clements et al., 2014), the response to positive oil price shocks faced prior to the financial crisis of 2008-09 contributes to the pressure mounted on fiscal policy as some countries respond to this shock by increasing price subsidies on local fuels (Coady et al., 2007). Thus, in the phase of sharp oil price decline, it presents an opportunity to ease these subsidies as well as the removal of long-existing alteration attached to them.

Furthermore, in some oil-importing countries where falling oil prices are likely to decrease external financing burden as well as decreasing the medium-term inflation forecast below target, the central bank can intervene by further loosening of monetary policy, which, in turn, is able to support the country's growth. However, in the case of oil-exporting countries, a decline in oil prices given the low policy buffers (that can help hedge spending from the oil sectors fall in tax revenues) is likely to stimulate a sharp currency adjustment, contractionary fiscal policy measures, and re-pricing of sovereign and credit risk.

Therefore, how important is the nature of fiscal cyclicality for understanding the real effects of oil price shocks? Our results show that, for the oil exporters where strong asymmetry is found, a negative oil price shock episode has a negligible effect, even though these countries face a sharp revenue loss, negative impact on non-oil activity and an increased spending pressure. Asymmetric effect on output (i.e. larger output growth in response to a positive shock) seems to depend on the size of government spending even though many of our oil exporters currently have limited fiscal space. Following the sharp oil price reversal during 2008-09, these countries mobilize more government spending to mitigate the adverse effect. In the short run, there is increasing fiscal prudence and the size of the oil price drop may induce large fiscal responses. There are large fiscal responses (stimuli) to a large oil price drop (in the case of recovering from crisis), especially the automatic stabilizer is less effective in our oil-exporters, although size of the fiscal response can depend on country-specific factors.

4.5.1 Testing Asymmetry in Fiscal Responses

To investigate the relationship between the effects of oil price shocks and fiscal policy, we first run the simple univariate unobserved components model set out by the system (B.1)-(B.4). We conduct a preliminary analysis by comparing the slopes of the two variables to find the relationship between real government expenditure and real oil prices.[11] Among the countries analysed, Figure 4.8 shows that four countries (Malaysia, Indonesia, Colombia and Bolivia) tend to exhibit a negative relationship between real government expenditure and real oil prices over time.[12] This is a useful exercise for detecting any possible time series trend/breaks in our sample, and for understanding potentially what we may expect to find in terms of the asymmetric effect from an oil price shock. However, this relationship can be spurious as the methodology is susceptible to a few major criticisms. Firstly, the changes in the slope of real government expenditure can be attributed to various factors besides real oil prices. Secondly, from this preliminary analysis, we cannot draw any conclusion about any nonlinear relationship that may exist between the variables. Thus, to fulfill these pitfalls, we turn to the Kilian and Vigfusson (2011*a*) method for identifying and estimating the IRFs next.

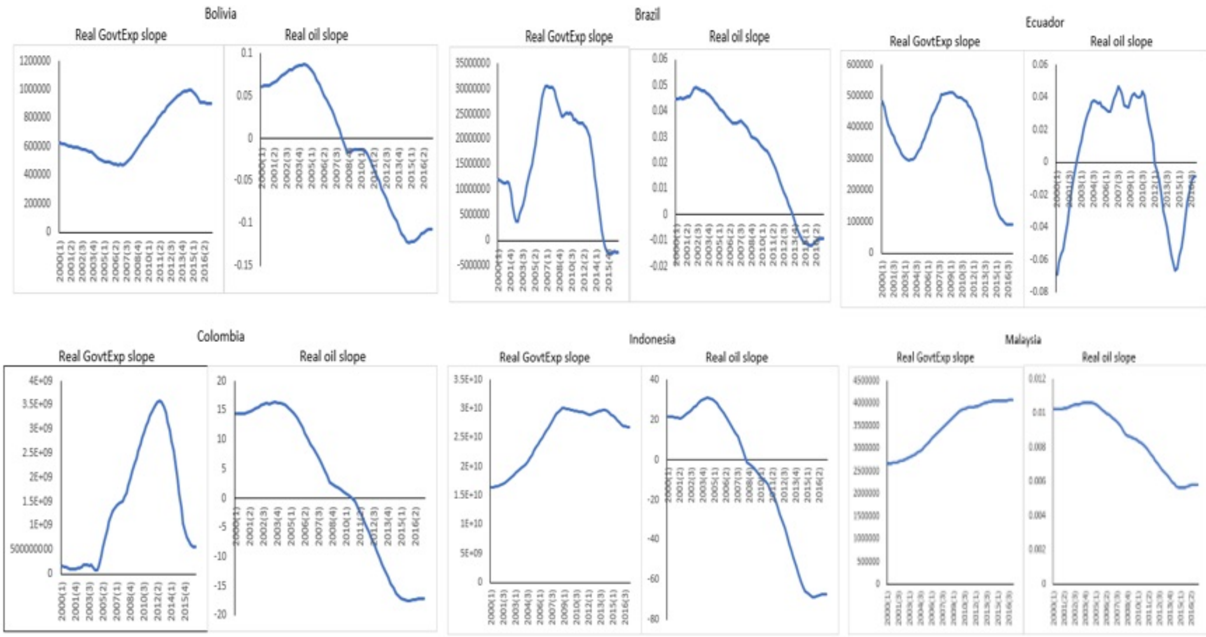


Figure 4.8: Fiscal Slope Test

[11]The slopes have been obtained from an unobserved component model (local linear trend model with a deterministic cycle).

[12]In this analysis, we do not include Nigeria and Tunisia due to the problem with data availability for these two countries.

We use the same bivariate VAR model for the three different nonlinear specifications to test (i) whether positive and negative shocks have different effects on each country's spending growth; and (ii) whether typical (measured by 1 s.d.) and large (measured by 2 s.d.) shocks have different effects on government spending. We focus on explaining the transmission of the oil price shocks to the real economy. Table 4.6 reports the corresponding p-values for the Wald Test statistics.

Table 4.6: KV Test of Fiscal Asymmetry

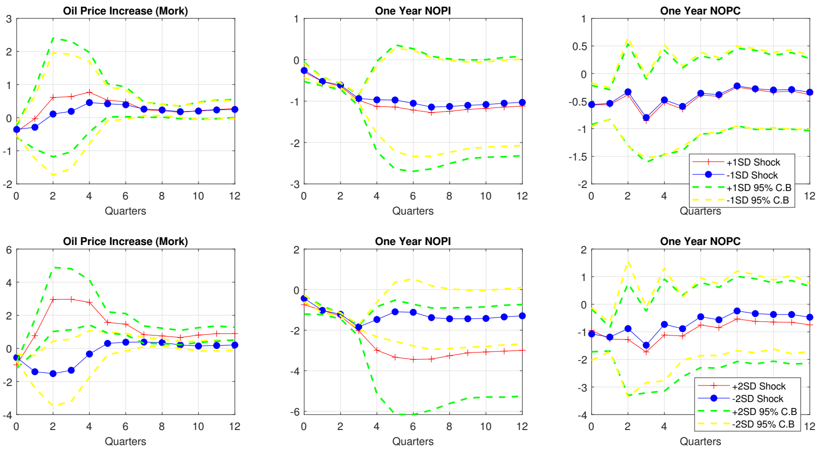
Bolivia Lag=8							**Brazil Lag=6**						**Colombia Lag=6**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**			**Typical Shock**			**Large Shock**		
Horizon	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
1	0.88	0.81	0.63	0.93	0.77	0.44	0.21	0.00	0.30	0.45	0.00	0.68	0.28	0.47	0.90	0.46	0.43	0.98
2	0.03	0.74	0.49	0.00	0.69	0.51	0.13	0.02	0.57	0.30	0.00	0.89	0.21	0.31	0.99	0.46	0.04	0.97
3	0.06	0.89	0.66	0.00	0.86	0.70	0.02	0.04	0.77	0.04	0.00	0.97	0.27	0.50	1.00	0.55	0.08	0.99
4	0.11	0.90	0.81	0.00	0.63	0.81	0.03	0.03	0.89	0.02	0.00	0.99	0.42	0.59	1.00	0.71	0.14	1.00
5	0.17	0.73	0.90	0.00	0.11	0.78	0.04	0.03	0.95	0.01	0.00	1.00	0.48	0.66	1.00	0.77	0.20	1.00
6	0.24	0.56	0.95	0.00	0.06	0.85	0.06	0.05	0.97	0.01	0.00	1.00	0.59	0.74	1.00	0.85	0.16	1.00
7	0.31	0.64	0.98	0.00	0.03	0.91	0.09	0.07	0.99	0.02	0.00	1.00	0.70	0.81	1.00	0.91	0.09	1.00
8	0.41	0.69	0.99	0.00	0.03	0.95	0.14	0.10	1.00	0.03	0.00	1.00	0.79	0.88	1.00	0.95	0.13	1.00
9	0.51	0.78	1.00	0.00	0.05	0.97	0.20	0.14	1.00	0.05	0.00	1.00	0.86	0.87	1.00	0.98	0.19	1.00
10	0.59	0.82	1.00	0.00	0.06	0.98	0.25	0.20	1.00	0.08	0.00	1.00	0.91	0.90	1.00	0.99	0.25	1.00
11	0.68	0.85	1.00	0.00	0.08	0.99	0.31	0.26	1.00	0.12	0.01	1.00	0.95	0.94	1.00	0.99	0.31	1.00
12	0.75	0.90	1.00	0.00	0.12	0.99	0.38	0.32	1.00	0.15	0.01	1.00	0.97	0.96	1.00	1.00	0.39	1.00
Ecuador Lag=6							**Malaysia Lag=6**						**Indonesia Lag=6**					
	Typical Shock			**Large Shock**			**Typical Shock**			**Large Shock**			**Typical Shock**			**Large Shock**		
Horizon	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC	Model OPI	Model NI	Model NC
1	0.38	0.01	0.34	0.51	0.01	0.66	0.61	0.48	0.51	0.79	0.68	0.49	0.66	0.99	0.97	0.78	0.95	0.84
2	0.14	0.03	0.25	0.20	0.01	0.77	0.25	0.66	0.73	0.53	0.50	0.77	0.59	0.98	1.00	0.80	0.99	0.97
3	0.27	0.06	0.38	0.35	0.02	0.87	0.42	0.84	0.89	0.74	0.68	0.86	0.05	1.00	1.00	0.22	1.00	0.99
4	0.41	0.12	0.52	0.50	0.03	0.94	0.54	0.93	0.96	0.83	0.82	0.94	0.06	1.00	1.00	0.25	1.00	1.00
5	0.38	0.20	0.66	0.37	0.04	0.97	0.67	0.97	0.98	0.91	0.91	0.97	0.08	1.00	1.00	0.25	1.00	1.00
6	0.40	0.28	0.78	0.37	0.07	0.99	0.57	0.99	0.99	0.87	0.95	0.99	0.02	1.00	1.00	0.00	1.00	1.00
7	0.28	0.34	0.86	0.12	0.09	1.00	0.28	0.99	1.00	0.48	0.97	1.00	0.04	1.00	1.00	0.00	1.00	1.00
8	0.37	0.43	0.91	0.17	0.11	1.00	0.37	1.00	1.00	0.58	0.99	1.00	0.06	1.00	1.00	0.00	1.00	1.00
9	0.47	0.52	0.95	0.24	0.16	1.00	0.44	1.00	1.00	0.68	1.00	1.00	0.09	1.00	1.00	0.00	1.00	1.00
10	0.56	0.60	0.97	0.32	0.22	1.00	0.54	1.00	1.00	0.77	1.00	1.00	0.12	1.00	1.00	0.01	1.00	1.00
11	0.64	0.67	0.98	0.40	0.28	1.00	0.63	1.00	1.00	0.83	1.00	1.00	0.17	1.00	1.00	0.01	1.00	1.00
12	0.72	0.74	0.99	0.47	0.36	1.00	0.71	1.00	1.00	0.88	1.00	1.00	0.22	1.00	1.00	0.02	1.00	1.00

Notes: This table reports the p-values (at 5%) for the Wald test statistic set out in Appendix B.2 for the case of government spending. For simulating paths of x_t and y_t, we use 10,000 draws of simulations for computing the IRF given the history. For the number of bootstrapping draws over the model, our simulations are based on 10,000 bootstrapped pseudo-series using the estimated coefficients.

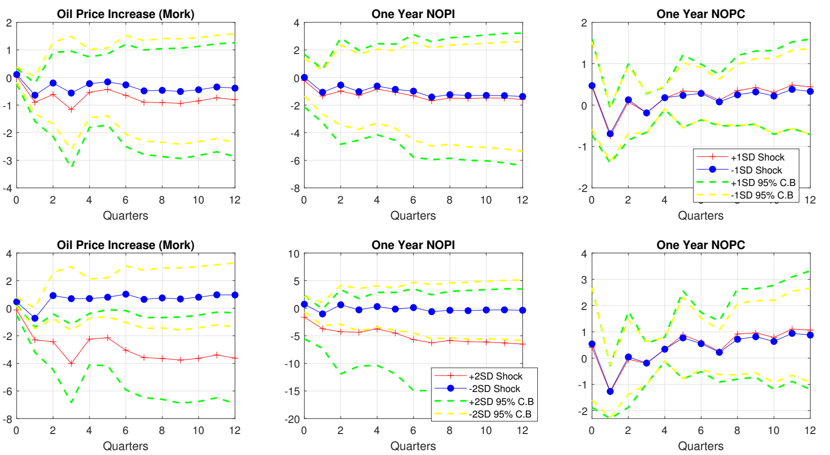
Based on the statistics, there is clear evidence of asymmetry of the IRFs at 5% level for Bolivia and Brazil with other countries (Colombia, Ecuador, Indonesia and Malaysia) depicting no statistical evidence of asymmetry and thus showing evidence of fiscal co-movements with the oil price. This means that, for Bolivia and Brazil, a large, positive oil price shock has a significant effect on government spending whereas a negative shock has a negligible effect. Interestingly, this is mostly in line with the above results that most of the countries displaying the clear time series patterns for a negative relationship between the two variables are the ones where no evidence of nonlinearity is found. However, despite the shock that increases government spending financed by oil revenues that in turn boosts economic growth, there is still a fear of the economy to suffer from negative growth in the long run. We examine the responses of each country in more details.

4.5.2 Impulse Response Analysis for Government Spending

We repeat the exercise conducted in Section 4.4.2 for government spending. Figure 4.9 - Figure 4.11 depicts the mean responses. Indeed, a positive oil price shock has the negative impact effect on government expenditure following an increase in government revenue for half of our sample countries except for Ecuador, Indonesia and Malaysia. Overall, there is a negative correlation between oil prices and government spending such that an oil price increase leads to a decline in government spending in Brazil and Malaysia (exhibiting evidence of a countercyclical fiscal regime when observing the output responses). For instance, the evidence shows that, just after 1 year, the cumulative (growth) effect of a typical shock's (1 s.d.) positive innovation in oil prices results in approximately 1% to 2% contraction in government spending for these countries, exacerbating the effects on output. It is evident that some governments (for example, Malaysia) can restrict fiscal expansion during price booms thus presenting a useful scenario for joint monetary policy evaluation and counterfactual simulations. Not surprisingly, this is again consistent with the result explained in Section 4.4.2 for Malaysia given its economic diversification from the oil sector, and improved financial sector and institutions.



(a) Bolivia

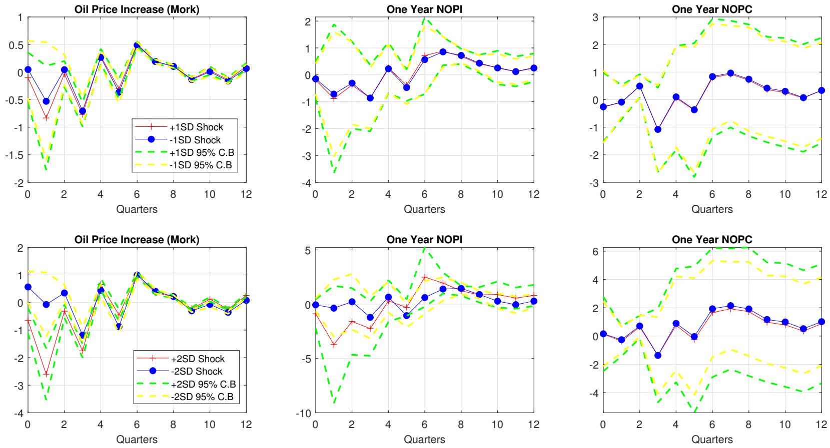


(b) Brazil

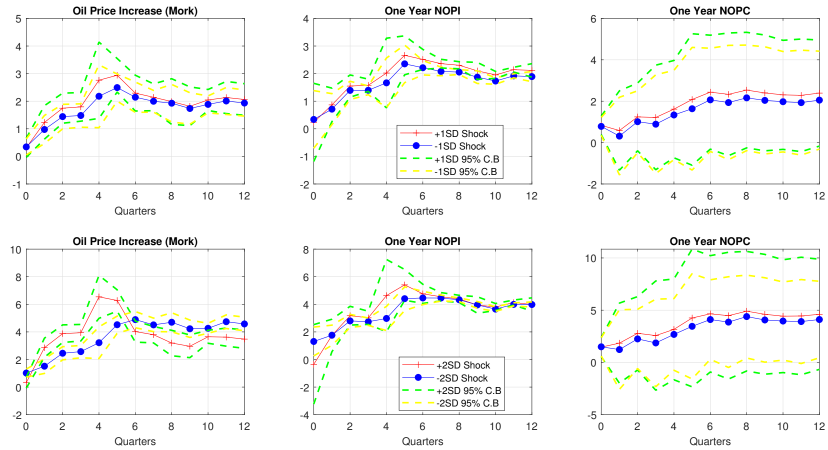
Figure 4.9: Impulse Response Functions of Government Expenditure

Notes: Each panel plots the mean response corresponding a one and two standard deviation of the shock's innovation. Each response is for a 12 period (3 years) horizon and is the percentage deviation.

Our IRF results reveal an interesting finding for Ecuador. There is clear evidence that it follows *laissez-faire* fiscal policy, especially when there is a surge in the international oil price following its 2 s.d. innovation. It is interesting to compare with its significant decline in GDP growth after about 4 quarters shown in Figure 4.4 - 4.7. For Ecuador,



(a) Colombia

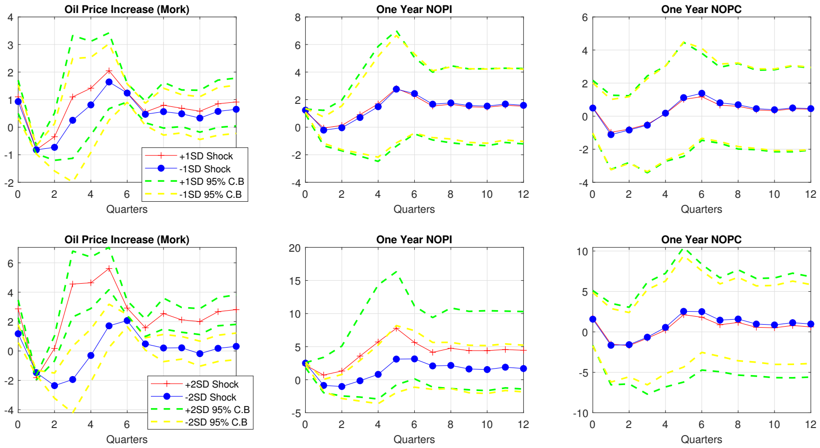


(b) Ecuador

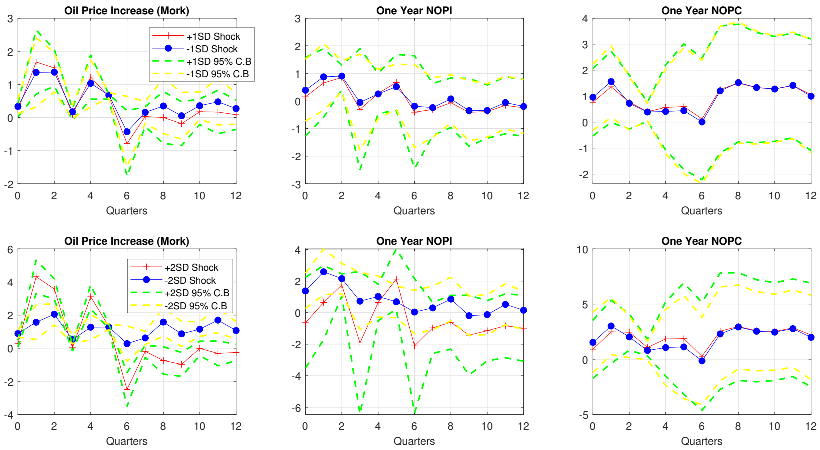
Figure 4.10: Impulse Response Functions of Government Expenditure

Notes: Each panel plots the mean response corresponding a one and two standard deviation of the shock's innovation. Each response is for a 12 period (3 years) horizon and is the percentage deviation.

the effect of the positive shock is expected to pose a positive impact on the economy, as initially, the country's revenue is likely to rise (Bjornland, 2009; Jimenez-Rodriguez and Sanchez, 2005). As a result, the magnitude of investment and consumption is expected to increase and then boost productivity in the service and goods sectors as well as reducing unemployment rate. However, this era of growth is likely to end given the emergence of demand-driven inflation. Examining the demand side effect of oil price shock in oil-exporting developing countries such as Ecuador and the possible reason for the linearity in responses found in these countries can be linked to government's extreme role and its size in their economies. For example, the recent studies of Tazhibayeva et al. (2008) and Frankel (2010*b*) find that the fiscal policy in these countries is often procyclical rather than countercyclical as a positive oil price shock forces governments to engage in excessive spending on investment projects and social programs that may not necessarily contribute (or have little to contribute) to economic growth.



(a) Indonesia



(b) Malaysia

Figure 4.11: Impulse Response Functions of Government Expenditure

Notes: Each panel plots the mean response corresponding a one and two standard deviation of the shock's innovation. Each response is for a 12 period (3 years) horizon and is the percentage deviation.

A similar case is Colombia. Likewise, the economy is on the verge of battling a higher inflation rate resulting from the excessive investment action taken by the government which is more than the economy's absorptive capacity. Moreover, when these countries are faced with a negative oil price shock, most of their state-backed economic activities fail due to the lack of adequate support. This puts their economy under additional pressure as many capital-intensive investment projects are left uncompleted and the government results in running a huge budget deficit financed by borrowing from abroad and respective central banks in order to mitigate any form of political or social unrest and meet any recurrent cost obligations. Such procyclical fiscal spending can further exacerbate the output volatility.

As a result of the fiscal inflexibility, our results demonstrate the typical symptoms of the so-called Dutch disease which can lead to a non-Pareto-efficient outcome, i.e., a positive shock in the oil market may have a detrimental long-term effect on the growth rate. There are clear observations that these two oil-rich exporters tend to experience more macroeconomic instability and clearly this can be partially attributed to weak institutions and the lack of central bank/policy independence. Some studies have explained the effect of oil sector shock on oil-exporting countries using different transmission approaches (such as the quality of institutions and access to credit markets). For example, Sala-i Martin and Subramanian (2003*a*) finds that natural resources have a significantly negative effect on the quality of institutions, which in turn can determine the shifts in the cyclical behavior of fiscal policy, and Van der Ploeg and Arezki (2008) shows that fiscal policies adopted in these resource-rich emerging market countries have indeed performed poorly in terms of stabilizing economic cycles.

Observing the short term fiscal policy responses to oil price shocks for oil exporters operating an oil-based economy implies the need to act and focus on increasing government expenditure temporarily through available policy buffers (by tapping into their net borrowing, liquid assets, and grants). In cases where this action proves unachievable, the government can also look into re-balancing their expenditure as a way to provide relief to non-essential current expenditure where fiscal multipliers are reasonably low. Furthermore, the government can decide to look into generating more resources by removing the energy subsidies that might not be necessary for the maintenance of stable retail energy prices.

However, it is important to also note that the nature and size of fiscal policy response differs across countries as oil exporters can be classified into diverse groups, including the levels of income and economic development. Therefore, the magnitude of fiscal policy response is dependent on country-specific factors, including the availability of policy buffers, level of fiscal space in line with the country's debt sustainability, weight of oil income loss and other macroeconomic policy responses (especially monetary policy that is sometimes restricted as a result of exchange rate (in)flexibility).

On the other hand, considering the medium term, despite the subsiding of the event related to the negative oil price shock (for example, the recent global pandemic - COVID-19), oil exporters need to brace for the continued period of volatile prices as well as their future consequence. For example, in a case where the oil price disturbances are prolonged, the government might need to adopt a medium term fiscal policy response to further brace for upcoming events; this must be guided by strongly upholding a long term objectives towards stabilization, availability and sustenance of financial buffers.

4.5.3 Fiscal Expenditure with Decreasing Oil Prices

In line with the recent trend among emerging economies, many central banks are considering the adoption of inflation targeting, an examination of this regime operating in conjunction with a particular fiscal framework will be of particular interest. Based on the estimated models, Table 4.7 shows evidence of some simulated patterns for the fiscal spending in response to a regime of large decline in oil prices analogous to those of 2008-09 (less persistent) and from the more recent 2013-16 oil episode (prolonged). Our results below suggest an explanation for some notable fiscal responses, given that monetary policy can be unconstrained, as intended, to tackle the heightened inflationary pressure from the exchange rate pass-through to domestic prices, following a severe negative supply shock.

Two results are worth noting. First, Bolivia appears to be an interesting case here. With the accumulated budget surpluses, there seems to be an increase in deficit that comes

Table 4.7: Signs of the $t = 0$ Impact IRFs of $gexp^{obs}$ and y^{obs} to a Large Negative Shock

	Bolivia	Brazil	Colombia	Ecuador	Indonesia	Malaysia
2 s.d. Shock to $gexp^{obs}$	+	–	–	–	–	–
2 s.d. Shock to y^{obs}	–	–	–	–	–	–
Asymmetry in $gexp^{obs}$ IRFs	Y	Y	N	N	N	N
Asymmetry in y^{obs} IRFs	Y	Y	N	N	Y	Y

Note: The blue responses in Figure ?? measure $-[-IRF_y^m(h, -\delta)]|$.

about through a rise in government purchases. The fiscal policy is 'active' for demand stabilization, although this is not an abrupt change in fiscal stance, as the increase stays at a relatively low level, less persistent and more moderate during the period when the oil price falls sharply. This is clearly a case where the country is able to sustain government increased spending even during the periods of oil price falls, in order to sustain growth in the real non-oil sectors for the periods of economic downturn. If the negative shock is large but not persistent, it seems likely to have negligible output effects (confirmed by our tests summarized in Table 4.7), the unconstrained monetary policy is active as intended, then the risk of stagflation is relatively low. It is important to also note that Bolivia's economy has become more diversified, which helps to mitigate the impact of changes in oil prices on its economy. Bolivia is a significant producer of natural gas and has been successful in using its natural gas resources to fuel its government spending and economic growth. In recent years, the country has also made efforts to increase its production of renewable energy, including solar and wind power as well as agricultural products.

Second, Brazil seems to experience a similar scenario except that the impact of fiscal spending falls slightly and rises moderately and subsequently to accommodate the monetary stance. This follows the fact that although, Brazil's economy is highly dependent on the price of oil but the country has also received recognition as a significant exporter of agricultural products, including soybeans, and coffee as well as beef and iron ore which has helped to mitigate the impact of oil price shocks on its economy.

Thus, these countries need to diversify towards non-oil exports and industrialization, and to manage to separate government expenditure from oil revenue therefore reducing the dependence on oil exports. Finally, the countries that seem to have symmetrically followed the net oil export inflows are the ones that procyclically cut fiscal spending after the large price fall (e.g. Ecuador - knowing that this country has a high level of energy intensity, which makes it more vulnerable to oil price shocks. The country's economy is highly dependent on the price of oil, and changes in oil prices can have a significant impact on its government spending habit and overall economic growth). Apart from the temptation or political pressures to adjust spending proportionately, there are several key determinants of cyclicality for explaining procyclical government spending in emerging and developing countries which are identified as financial market imperfections, low degree of financial integration and depth, and weak institutions (Frankel et al., 2013; Fernandez et al., 2021). Our models and applications are able to uncover and describe the distinct co-movements between oil prices and fiscal spending which enable us to evaluate how to address fiscal imbalances and cyclicality. However, their impact on GDP depends on how the expenditure is financed to smooth out the fluctuations in revenue and requires further empirical investigations. This is beyond the scope of the present paper and we leave this for future research.

4.6 Conclusions

Are the real effects of unexpected oil price changes asymmetric and empirically relevant in emerging market oil-exporting economies? How can fiscal spending cyclicality be associated with the asymmetric and macroeconomic response of output to oil price shocks in these economies? In this paper, we tackled these questions by developing and estimating several VAR models based on the censored-variable assumptions for a selection of eight oil-exporting emerging economies. We found ample econometric evidence of asymmetry for three countries and some evidence for a number of other countries in our sample. This is a new result in the empirical literature focusing on testing for null of joint symmetry and nonlinearity in VAR systems coming from global oil price innovations. We carried out a procedure that thoroughly examined the evidence in the data and showed that our tests based on the identified impulse responses and the more conventional slope-based hypothesis testing produced similar results, but the former provided us with a closer inspection on the dynamic responses to an oil price shock and some theoretical explanations for the transmission and magnitude of responses.

Our second contribution focused on studying an explicit role for the government fiscal policy stance in propagating the real effect of the shocks of different magnitudes and under different states of the economy. The main empirical results from the VAR and impulse response analysis withstood various robustness checks. The main check involved the use of the nominal oil price in place of the real price in the VAR specifications. In all cases, this did not affect the main findings. The other extended checks involved the comparison of an exclusive range of models including 3 nonlinear VAR specifications, a linear model, a metric to measure the square distance from responses, and 2 OLS slope-based regressions.

The issue of potential endogeneity in our estimation needed to be taken into consideration because three countries in our sample are either members or former members of OPEC (Ecuador, Indonesia and Nigeria). Historical series of exogenous OPEC events may affect oil prices, for example, the civil unrest in Venezuela in 2002-03 led to a drop in oil production. The potential issue would then be that the assumption of endogeneity may be too strong and one needs to control for the oil-supply shocks driven by OPEC (political) events. This in turn has implications on the measure of oil price shocks that considers price disruptions due to these events. Our simple answer to this is that the individual economies we consider here are all small open economies and the most recent variation in oil prices may be mainly due to changes in aggregate demand. Indeed, given the size of the economy, the issue of endogeneity for the case of the US has been studied by Kilian (2009) which decomposes innovations of oil prices into three components such as oil supply shocks, aggregate demand shocks, and oil-specific demand shocks for the unexpected fluctuations in prices. As another robustness test to assess the possible effect of OPEC oil production, our future work will consider the alternative approach by using Kilian (2009)'s exogenous oil production shock series.

Our results imply that the effectiveness of policy (fiscal and exchange rate policy for example) should depend on the premise that GDP responses are asymmetric in nature after an oil price shock and should be carefully analysed especially considering large oil price shocks. Our empirical findings are robust enough to be relevant for the study of propagation of energy price shocks in open (developing) oil exporters and can help make a clear recommendation for the empirical researchers studying macroeconomic dynamics in resource-rich emerging economies. Our results and analysis motivate further investigation into the roles of oil price fluctuations, foreign exchange inflows and government expenditure cyclicality in understanding the growth process specific to oil-exporting open economy emerging countries.

Discretionary fiscal policy is a key transmission channel for the oil price movements to the real economy, especially for the oil-dependent countries which can benefit from the windfall profits and fiscal revenues from the previous price hikes. The question of whether fiscal stabilization (or the output effects of fiscal policy) is state-dependant is left unanswered. Future work will consider a different way of modelling the nonlinear relationships using a parametric nonlinear VAR to capture the asymmetric fiscal transmission of oil price shocks when fiscal adjustment happens. In particular, we can take into consideration the distinct size of fiscal multipliers, i.e. exogenous variations in government spending on aggregate output in distinct macroeconomic episodes for an oil-dependent country, and construct an identified smooth transition VAR incorporating regime-switching based on major oil price fluctuations that needs to identify the government spending shock so that it provides distinct IRFs for the macroeconomic implications (see, e.g., Auerbach and Gorodnichenko, 2012, Fazzari and Panovska, 2015).

Chapter 5

Conclusion

In this thesis paper, we investigate, from a macro-finance perspective, the relationship between the term structure of interest rates and the macroeconomy. Our key aim is to examine how macroeconomic factors, including the introduction of a global variable, affect the forecasts of the US term structure. We also investigate how institutional quality and the information contained in the yield curve, alongside other growth predictors, impact economic growth in emerging economies, as well as the transmission of oil prices to growth in oil-exporting emerging economies.

The first chapter focuses on investigating the effect of macro fundamentals and a global factor (oil price) on the term structure of interest rates in the US. Examining the dynamics of the US term structure, we investigate the impact of inflation, economic activity, and oil price information on the yield curve horizons. The yield factors (level, slope, and curvature) respond differently to both macro fundamentals and oil price, with responses to macro fundamentals and oil price being more amplified across different horizons. Specifically, the inclusion of oil price into the existing five-factor term structure model to develop an advanced model of a six-factor model, replacing the Ang and Piazzesi (2003) model, shows that oil price plays a significant role in better predicting the term structure, following the Root Mean Square Error (RMSE) comparison reported from the unconstrained VARs of the Yield-only model and Macro model. Additionally, using the RMSE to examine the forecasts of VARs with cross-equation restrictions, the cross-equation forecast for oil reports a lower RMSE with the term structure prediction. The traditional latent factors (level, slope, and curvature) are notably captured by and linked with the observable macro factors, with specific emphasis on inflation and oil accounting for a greater amount of dynamics in slope and curvature factors.

The second chapter focused on identifying economic meaningful factors that account for growth in selected emerging economies. We investigated the predictive ability of traditional predictors of growth alongside other factors such as institutional quality, oil prices, and yield curve information in a modified standard growth model to explain the state of growth for these emerging economies. Using the CLSDV II as the most preferred model for dynamic panel data with (small N and large T) to explain growth dynamics, among other variables employed in the growth model, institutional quality depicts the highest predictive value for the growth of emerging economies. This finding may provide a tangible way of explaining the consistent reports of deteriorating growth in emerging economies with weak institutions compared to their developed counterparts with strong institutions in place. This implies that the government of these emerging economies should take proactive steps towards strengthening their institutional quality, as it appears to be the driving force of other macro fundamentals which translates to growth. However, we find evidence of convergence of emerging economies to experience a faster pace of growth than their developed counterparts and reach a similar level of growth in the long run.

In the third chapter, we explore the asymmetries of oil price shocks and the growth process in oil-exporting emerging economies, as well as investigate the role of fiscal policy response in these selected economies to changes in oil prices. The selected emerging economies (Brazil, Bolivia, Colombia, Ecuador, Indonesia, Malaysia, Nigeria, and Tunisia) are small open economies where oil revenue accounts for about 40% of Gross Domestic Product (GDP) and are either members or former members of the Organization of the Petroleum Exporting Countries (OPEC) (Nigeria, Ecuador, Indonesia). Using censored-regressor nonlinear VARs, we found mixed evidence, as some countries (such as Malaysia, Indonesia, Tunisia, and Nigeria) report strong statistical evidence of asymmetry, while other countries do not show clear evidence against the symmetry of the Impulse Response Functions (IRFs) at the 5% significant level (at least for one standard deviation shocks). This is consistent with our robust check using the cumulative measures of asymmetry with evidence showing one standard deviation shock and two are quite large across countries under consideration. Furthermore, we found fiscal policy to be pro-cyclical during periods of negative oil price shocks, validated with declining government spending in the absence of fiscal buffers, as government budgets become constrained, thereby slowing down growth in the long run. In addition, there is clear evidence of asymmetry of the IRFs at the 5% significant level for Bolivia and Brazil, with no statistical evidence of asymmetry for other countries (Colombia, Ecuador, Indonesia, and Malaysia), thus depicting fiscal co-movements with oil prices.

Achieving sustainable economic growth is crucial for raising the living standards of citizens in emerging countries, which can be achieved through increased productivity of the labor force by increasing the number of hours worked. However, the aftermath of the COVID-19 pandemic coupled with the pressure on public finance has made it difficult for emerging economies, especially oil-exporting ones, to fulfill this objective. Based on the evidence reported across various chapters of this research work, policy implications and recommendations center around policy reforms, economic and export diversification, and institutional reforms to end the era of slow economic performance in small, open oil-exporting emerging economies. We kick off our policy reform campaign by proposing a sustainable monetary and fiscal policy pathway that oil-exporting emerging economies can follow to achieve the desired development results.

Considering that the majority of the oil-exporting emerging economies investigated in this study do experience rapid depreciation of currency and sharp falls in foreign exchange reserves, this study proposes that governments of countries with fixed exchange rate regimes should adopt possible measures towards adopting floating exchange rate regimes for better opportunities to stabilize reserves despite suffering an initial depreciation. Hence, there needs to be consistent effort by monetary authorities in oil-exporting emerging economies to provide adequate support to their currencies in the foreign exchange markets, as well as raising interest rates in periods of sharp currency depreciation to restrain rising inflation. In recent years, rising commodity prices have been a key driver of inflationary pressure in emerging economies, which in turn affects businesses (evidenced from their struggle with rising production costs) and consumers (as they witness falling real incomes). In this case, we call for the independence of the central bank without political interference in delivering their commitment towards adequate monetary policy remit. Furthermore, the central banks of oil-exporting emerging economies need to put up measures to curb tightening liquidity in the banking sector. One way to achieve this is to deploy pension funds and sovereign wealth to mitigate the pressure of banking sector liquidity.

A complementary measure to the monetary policy proposed above is the initiation of appropriate fiscal policy reforms to proffer solutions to the slow growth experienced by the investigated emerging economies. In the wake of low and falling oil prices in recent years, the choice of fiscal policy plays an important role in impacting the economic performance of oil-exporting emerging economies, including their current account balances. No doubt, fiscal policy reforms in oil-exporting economies have faced a number of particular challenges, mainly emanating from oil rent, which forms the larger part of government income in oil-dependent economies. These challenges can be handled in the short-term (with attention to proper fiscal design and macroeconomic stabilization) and long-term (with attention to fiscal sustainability and intergenerational equity) periods.

Despite the expansionary fiscal policy adopted by oil-exporting emerging economies over the years, which in most cases have been concealed by fiscal surpluses, this emphasizes the competing objectives and considerations faced by fiscal policy reform planning. These are significantly linked to specific short-term and long-term fiscal policy challenges in oil-rich countries. For instance, on the one hand, in the short run, the important competing considerations have been cyclical through fiscal control to contain inflation, while on the other hand, it has primarily been distribution-related (i.e., the pressure for instant redistribution of oil rent to respective sectors of the economy), development-related (with respect to spending on social and physical infrastructure), and international-related considerations (through recycling of oil revenue, especially in the global imbalances context). However, in the long-term, financial assets accumulation through persistent savings of a larger proportion of windfall revenue, and fiscal control would be required from the point of view of fiscal sustainability while championing economic diversification.

Nonetheless, there are feasible pathways to curb the existing conflicts between competing considerations and objectives during periods of oil price increase, which include facilitating government expenditure by paying more attention to capital expenditure capable of eliminating economic restrictions while restraining recurrent spending. Given the unprecedented drop in oil prices, governments are faced with a set of new puzzles in the short run as they contemplate whether to adjust their expenditure habits to reduce revenue expectations or to continue with existing initiated expenditure programmes aimed at diversifying the economy and boosting the infrastructural base for sustainable economic progression. Maintaining existing initiated programmes could also be useful in facilitating the domestic economy of the country - but in most cases, this is only achievable for oil-exporting emerging countries that have made efforts towards upholding a low public debt profile and accumulated substantial amounts of foreign assets that can be deployed as a mechanism to escape pro-cyclical fiscal policy and a bridge to navigate through periods of temporary low oil prices which have remained a crucial challenge for oil-exporting emerging economies due to high oil price volatility. On the contrary, given periods of persistent low oil prices, governments of oil-exporting emerging countries are advised to adjust their fiscal policy related to their spending and revenue strategies.

Examining the expenditure perspective, the government can cut down on marginal investment projects without abolishing efforts towards diversification or dampening long-term economic prosperity. In addition, the government can channel their expenditure towards launching policy packages that can aid the pressure on businesses (by cushioning viable businesses including start-ups) and households (by protecting their real income through declining inflation and rising living standards), thereby reducing the threat of oil-exporting emerging economies entering damaging and deep recession resulting from unproductive borrowing, and boosting short-term GDP growth while establishing the foundation for long-term growth that can generate indirect fiscal advantages emerging from increased tax receipts. Although funding these packages might require increased borrowing, its ability to lower inflation in the short-run would help cut down the cost of debt servicing, as well as exploring other channels of raising revenue, making this strategy achievable. On the brighter side, aside from the expansion of taxes, other avenues to generate revenue can emanate from the development of an efficient tax system with rigorous monitoring across various sectors of the economy to sustain fiscal policy and reduce the government's budget reliance on oil revenue as the government begins to take charge of its Internally Generated Revenue (IGR). Unfortunately, this is lacking in the majority of oil-exporting emerging economies, but if put to work, it can produce a significant result nationally, similar to what was highlighted as a record-breaking period at the state level, particularly Lagos State in Nigeria during the reign of Governor Asiwaju Bola Ahmed Tinubu (between the years 1999 and 2007) who increased IGR from 600 million naira to about 30 billion naira generated monthly through tax reforms.

Dealing with the issue of diversification, it has been well established that diversification remains a priority for emerging economies, especially resource-rich countries. Despite several calls for diversification and its recommendation for growth, it remains a severe problem for the governments of oil-exporting emerging economies (with the exception of Malaysia and Indonesia that have taken the initiative to launch into the non-resource sector). These governments continue to handle this growth channel with levity rather than taking immediate actions to kick-off a sustainable blueprint towards achieving this goal. The continuous neglect by the governments of oil-rich dependent economies to initiate diversification has negatively impacted the economic transformation and pace of growth in these countries. They remain vulnerable to external shocks, such as the COVID-19 pandemic that causes oil prices to plummet. It is noteworthy that oil-exporting emerging economies that heavily rely on oil proceeds are likely to experience under-performance in economic activities as they continue to battle foreign exchange and budget funding crises, including national civil unrest sparked by allocative inefficiency. Recognizing the importance of diversification, it is crucial to highlight the dimensions of diversification that can aid structural transformation from a position of low to high productivity. Here, our recommendation pays attention to economic diversification by expanding diverse sectors of the economy, both existing and new ones, to encourage employment and increased productivity, as well as export diversification. It is important to bear in mind that policymakers might act differently in the chase of policy strategies for diversification based on the structural characteristics of individual countries.

Exploring policy recommendations towards economic diversification, it is popularly known that to achieve this, the government needs to establish policy strategies that can enhance the production of diverse goods and services by making the business environment more conducive for both domestic and foreign investment, while reducing macroeconomic volatility in the short run. On the other hand, pursuing export diversification would mean the government implementing policies with the objective of breaking into new geographical markets with new commodities and services added to the existing export portfolio, establishing a strong share of diverse commodities in its export mix. It is obvious that firm fiscal rules, alongside the development of special resource finance, proved abortive in shielding oil-exporting emerging economies from the negative impact of unexpected oil price volatility at the global market following the global pandemic shock. These countries failed to implement clear and effective policy guidelines on how to lift their economies from their dependence on the extractive sector.

To this end, we advise development and policy experts to gain an understanding of the drivers of economic diversification and the public policy knowledge that can foster innovation while adapting to improved technological changes in the course of launching new products. Therefore, initiating a policy strategy for economic diversification begins with proposing measures to move the production base of the economy away from extractive industries by providing adequate support to the non-resource sectors such as manufacturing, real estate, tourism, and agriculture. It is important to rebuild infrastructure and strengthen institutional quality by developing policies targeted at minimizing corruption and promoting government effectiveness, as these are key drivers of economic diversification. This initiative can be referred to as launching into industrialization, centered around export-led industrialization (where Malaysia has recorded success in recent years) with the objective of opening up the local market for international competition while providing incentives to the export sector. Additionally, import substitution industrialization can provide support to local industries in order to increase the production of domestic goods and services to replace foreign imported goods.

Moving on to the third segment of our policy recommendations which focus on institutional quality reform, it is important to state that there is no denying that the popular resource curse paradox linked to resource-rich countries is heavily associated with weak institutional quality in operation in these countries, among other secondary explanations. The center of attention that mostly characterizes weak institutional quality in oil-exporting emerging economies cuts across poor accountability, rule of law, regulatory quality, government effectiveness, prevailing corruption, and civil unrest. If policies are initiated to put appropriate checks and balances to get these indicators under control, it can yield a substantial level of growth in resource-rich countries. This implies that our first two segments of recommendations (policy reforms and diversification strategies) can prove abortive without strengthening the country's institutional quality.

Therefore, while developing sustainable policy reforms and implementing strategies for diversification, the government of oil-exporting emerging economies could curb the unpleasant effects of fluctuating oil revenue by putting measures in place to enhance forward-looking institutions. This can be achieved by setting up short-term techniques such as provision of stabilization funds and engaging in savings habits in periods of high oil prices, with proceeds used to finance capital projects. For the long-term mechanism, the government can set up a Sovereign Wealth Fund (SWF) while taking deliberate actions to cut down on the cost of governance and diverting such funds towards strengthening human capital, property rights, and the judicial system. This would serve as a measure to clamp down on corruption and promote adequate monitoring and proper accountability of both inflows of oil revenue and its prudent use to improve both the lives of the citizens and the economy.

Overall, our paper suggests that oil price dynamics are closely related to determining the information embedded in the US term structure of interest rates as well as explaining the growth situation in emerging economies alongside other predicting factors. Moreover, fiscal policy can explain the growth differential experienced in these countries. Nonetheless, the thesis leaves possible areas for further research. The model developed in the first chapter mainly focuses on building on the existing term structure model to accommodate global factors to better fit the term structure forecasting but has not explicitly investigated the risk premium. Likewise, the model has specifically selected oil price as a signal for representing the global factor without considering other variables such as global liquidity in developing the six-factor model. Following the success of the six-factor model for the US term structure, a similar model with the inclusion of more global predictors can be applied to Eurobond forecasts. Secondly, the exercise of using a modified standard growth model that incorporates institutional quality, oil price, and the term structure of interest together with other traditional growth predictors can be extended to capture more emerging economies for more robust data, as well as comparing the estimation for that of developed economies to tell how growth differs in both classes and identifying the key driving factor if the same or different for developed and emerging economies. Finally, the study investigating the asymmetries of oil price and economic growth, as well as the asymmetry of fiscal policy to oil price shocks, can be enriched by examining the cyclicality of energy prices, foreign exchange inflows, and government expenditure in resource-rich emerging economies. All these limitations are available for future research and documentation of new evidence.

Appendix A

A.1 Maximum Likelihood and Kalman Filter Dynamic Factor Models Estimation

We propose that the economy systematic state is controlled by three dynamic economic factors, X_t, generated in accordance of a first-order vector autoregressive ($VAR(1)$) procedure:

$$X_t = \vartheta X_{t-1} + \sqrt{\Re \varepsilon_t} \tag{A.1}$$

where ϑ accounts for the state vector's interaction and persistence, and ε_t captures the iid standard random vector. The state vector is standardize to have zero long-run mean as well as identifying its covariance matrix per unit time using the stated Eq 2.1, $\Re = I\Delta t$, where Δt represents the frequency of the state vector, which in our estimation is monthly $\left(\Delta t = \frac{1}{395}\right)$.

Let MA_t represent a vector that accounts for N macroeconomic factors released at current time t, related to the three systematic economic indicators using the proposed linear structure:

$$MA_t = HX_t + \varepsilon_t \ , \ R^{MA} = E[e_t e_t^\tau] \tag{A.2}$$

Where, H is a factor loading coefficient matrix of $(N \times 3)$ and e_t represents vector of residual error measurement. We standardized each macro variables to have zero mean and unit standard deviation, and we assume the measurement errors e_t to be mutually independent, however, with distinct variance. In Eq. 2.1 and 2.2, treating the factor dynamics as a state equation and the standardized series relations as measurement equation respectively, the estimated Kalman (1960) filter provides an efficient forecast for the state vector mean and covariance. Hence, we denote $\bar{X}_t$, $\bar{MA}_t$, $\bar{V}_t$, $\bar{A}_t$ to account for time (t–1) forecasts of current time (t) values of the systematic factors, macro factors measurement, the systematic factors covariance matrix, measurement series covariance matrix respectively. The systematic factors and their covariance based on the macroeconomic observations (MA_t) at time (t) is denoted with $\hat{X}_t$ and $\hat{V}_t$. Thus, the prediction step for the state X_t and macroeconomic MA_t factors in our paper is as follows:

$$\bar{X}_t = \vartheta \hat{X}_{t-1}; \bar{V}_t = \vartheta \hat{V}_{t-1} \vartheta^\tau + \Re; \bar{MA}_t = H\bar{X}_t; \bar{A}_t = H\hat{V}_{t-1}H^\tau + R^{MA} \tag{A.3}$$

The estimated Kalman filtering update is defined as:

$$\hat{X}_t = \bar{X}_t + K_t(MA_t - \bar{MA}_t); \hat{V}_t = \bar{V}_t - K_t\bar{A}_tK_t^\tau \quad (A.4)$$

Where $K_t = \bar{V}_t H^\tau(\bar{A}_t)^{-1}$ represent the Kalman gain, and helps to control for the relative impact of the N macro series to the updates of the three economic factors (inflation, economic activity, and oil price). We estimate the parameters of the model using the maximum likelihood technique and we define the likelihood function of measurement series on normally distributed forecasting errors.

A.2 Models Forecast Comparison

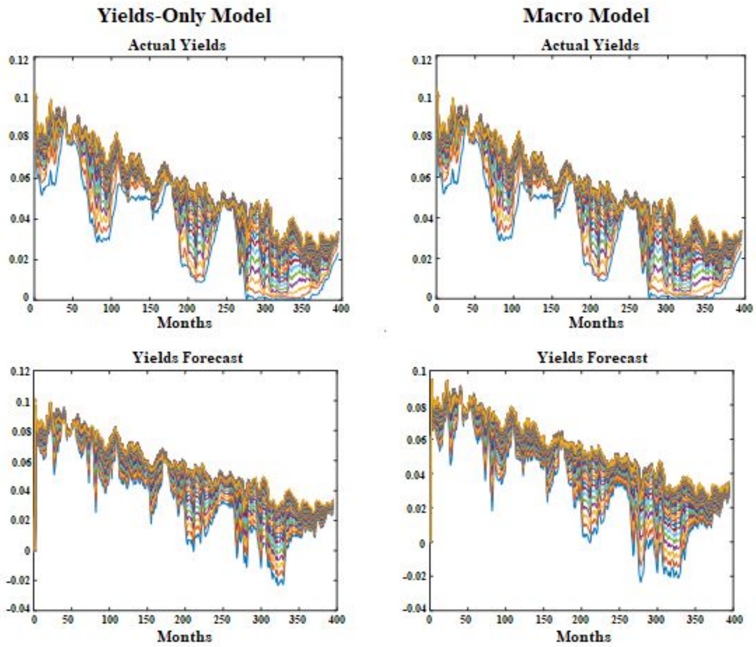


Figure A.1: Forecast Comparison

Appendix B

B.1 Data Sources

The quarterly dataset used in this paper has been extracted from the International Financial Statistics (IFS) for real GDP growth, Consumer Price Index (CPI), and the Nominal Exchange Rate; the Federal Reserve Bank of St. Louis (FRED) for Brent crude oil price; country's Central Banks for government spending; while Nominal and Real Crude oil price, and real Government expenditure are manually computed. All these data are collected for 8 countries that include Bolivia, Brazil, Colombia, Ecuador, Indonesia, Malaysia, Nigeria, and Tunisia. The series description are provided in Table B.1.

Table B.1: Variable Description

Variable	**Definition**	**Measurement**	**Source**
y^{obs}	Real GDP growth rate	$100\log(GDP_t/GDP_{t-1})$	IFS
o_t	Brent crude oil price	USD per barrel	FRED
$gexp^{obs}$	Government expenditure	Billion National currency	Central Banks
e_t	Nominal exchange rate	National currency per USD	IFS
$oil_t^{obs,norm}$	% change in nominal price	Log growth of $(o_t * e_t)$	Authors' compilation
$oil_t^{obs,real}$	% change in real price	Deflated by CPI_t	Authors' compilation
CPI_t	Consumer price index	All items (2010=100)	IFS
o_t^{cen}	Measure of shocks		

The data for Nigeria are obtained from the Central Bank of Nigeria (CBN). The Nigerian GDP data contains breaks/innovations (See Figure B.1). Hence, without taking proper account of breaks in our nonlinear VARs may nullify the stability of the system and also make the results biased. Due to the existence of the breaks, using a simple growth rate may be biased as they may contain the innovations unless shift dummies are incorporated in the VARs. However, this curtails the degrees of freedom if the number of breaks is high. A simple alternative way to obtain a better approximate of the growth rate would be to run a univariate unobserved components model, such as one proposed by Harvey (2006) containing a trend component (u_t), a cyclical (ω_t) and an irregular component (ϵ_t) from which we can obtain the slope parameter of the series (via filtering)

$$y_t = u_t + \omega_t + \epsilon_t \tag{B.1}$$

$$u_t = u_{t-1} + \beta_{t-1} + \eta_t \tag{B.2}$$

$$\beta_t = \beta_{t-1} + \tau_t \tag{B.3}$$

$$\begin{bmatrix} \omega_t \\ \omega_t^* \end{bmatrix} = \rho \begin{bmatrix} \cos\lambda_c & \sin\lambda_c \\ -\sin\lambda_c & \cos\lambda_c \end{bmatrix} \begin{bmatrix} \omega_{t-1} \\ \omega_{t-1}^* \end{bmatrix} + \begin{bmatrix} k_t \\ k_t^* \end{bmatrix} \tag{B.4}$$

where $\epsilon_t \sim NID(0, \sigma_\epsilon^2)$, $\eta_t \sim NID(0, \sigma_\eta^2)$ and $\tau_t \sim NID(0, \sigma_\tau^2)$; ρ is the damping factor, λ_c is the frequency in radians, and k_t and k_t^* are uncorrelated white noise disturbance terms.

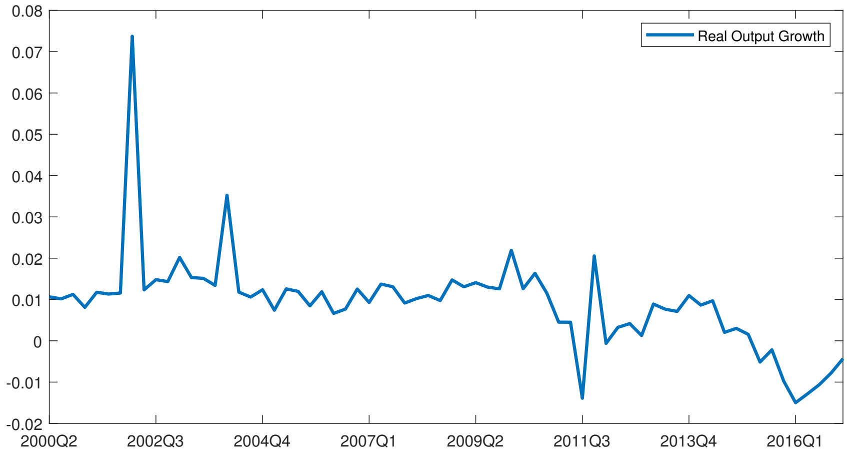


Figure B.1: Real GDP Growth in Nigeria 2000Q2 - 2017Q1

B.2 Impulse Responses-based Test for Asymmetry

Kilian and Vigfusson (2011*a*), Herrera et al. (2011), Herrera et al. (2015) and Herrera and Karaki (2015) apply the simulation methodology computing and comparing impulse response functions (IRF) for real GDP growth for an oil price shock in the reduced form VAR model for one and two s.d. oil price shocks. The null hypothesis is the VAR linearity that the impulse response functions are the same across regimes (i.e. across the NOPI and non-NOPI regimes do IRFs exhibit (a)symmetry). Following closely the online Appendix of Herrera et al. (2011); Kilian and Vigfusson (2011*a*), we describe the implementation of KV's IRF-based test. The following steps compute structural IRFs ($IRF_y(h, \delta, \mathbb{I}_t)$) from estimating the above nonlinear models, where h is the IRF horizon, δ the size of the shock (one or two s.d.) and $\mathbb{I}_t$ the history of x_t and y_t. Due to the censored variables, IRFs depend on δ and $\mathbb{I}_t$. Then, we average over all the histories to obtain the unconditional $IRF_y(h, \delta)$ and construct a Wald test of the joint null hypothesis of symmetric response up to $h = 0, 1, 2, ..., H$ (the test has an asymptotic χ^2_{H+1} distribution):

$$IRF_y(h, \delta) = -IRF_y(h, -\delta)$$

where IRF_y measure the reaction of y_t at $t+h$ to a shock of the disturbance vector of δ conditional on the information available at t which is the set of lagged dependent variable vectors up to lag order p:

$$IRF_y(h, \delta, \mathbb{I}_t) = E[y_{t+h}|\delta_t, \mathbb{I}_t] - E[y_{t+h}|\mathbb{I}_t] \tag{B.5}$$

In particular, the test proceeds as follows:

1. We estimate the model set out by equations (4.5) and (4.6) using ordinary least squares and obtain the estimated coefficients $\hat{A}_1$, $\hat{A}_2$, the residual standard deviations $\hat{s}_1$, $\hat{s}_2$, and the residuals $\hat{\epsilon}_1$ and $\hat{\epsilon}_2$;

2. Take a block of p consecutive values of x_t and y_t to define a history:

$$(x_{t-1}, ..., x_{t-p}; y_{t-1}, ..., y_{t-p}) \in \mathbb{I}_t$$

3. For a given h, conditional on $\mathbb{I}_t$ and the shock size $\delta = (\hat{s}_1, 2\hat{s}_1)$ at t, we compute the conditional IRFs $IRF_y(h, \delta, \mathbb{I}_t)$ by first simulating two time paths of x_t the oil price variable as follows

$$\begin{aligned} x_t^1 &= \hat{A}_1(1, \mathbb{I}_t) + \delta \\ x_t^2 &= \hat{A}_1(1, \mathbb{I}_t) + \epsilon_{1,t} \end{aligned}$$

where $\epsilon_{1,t}$ is resampled from $\hat{\epsilon}_{1,t}$;

4. Given x_t^1 and x_t^2, and the updated information sets including the censored variables, simulate two paths of y_t the log GDP growth:

$$\begin{aligned} y_t^1 &= \hat{A}_2(1, x_t^1, \mathbb{I}_t, x_t^{1,OPI}, x_{t-1}^{OPI}, ...x_{t-p}^{OPI}) + \epsilon_{2,t} \\ y_t^2 &= \hat{A}_2(1, x_t^2, \mathbb{I}_t, x_t^{2,OPI}, x_{t-1}^{OPI}, ...x_{t-p}^{OPI}) + \epsilon_{2,t} \end{aligned}$$

where $x_t^{1,OPI}$ and $x_t^{2,OPI}$ are defined by any of the nonlinear measures from (4.7) – (4.9). The values of $\epsilon_{2,t}$ is resampled from $\hat{\epsilon}_{2,t}$ – the same value is used to generate y_t^1 and y_t^2;

5. We generate new information sets incorporating the generated artificial series x_t^1 and x_t^2 and y_t^1 and y_t^2:

$$(x_t^i, x_{t-1}, ..., x_{t-p+1}; y_t^i, y_{t-1}, ..., y_{t-p+1}) \in \mathbb{I}_{t+1}$$

6. We simulate two time paths of x_{t+1} that are given by

$$\begin{aligned} x_{t+1}^1 &= \hat{A}_1(1, x_t^1, x_{t-1}, ..., x_{t-p+1}; y_t^1, y_{t-1}, ..., y_{t-p+1}) + \epsilon_{1,t+1} \\ x_{t+1}^2 &= \hat{A}_1(1, x_t^2, x_{t-1}, ..., x_{t-p+1}; y_t^2, y_{t-1}, ..., y_{t-p+1}) + \epsilon_{1,t+1} \end{aligned}$$

note that the same value is used as $\epsilon_{1,t+1}$ to generate x_{t+1}^1 and x_{t+1}^1 at this stage;

7. Again, given x_{t+1}^1 and x_{t+1}^1, simulate two future paths of y_{t+1} as above;

8. Repeat Steps 6 and 7 $H+1$ times and find time paths of x_{t+h} and y_{t+h}. For example, $H = 10$ is for an IRF trajectory of 10 periods;

9. After repeating Steps 2-8 R times, the condition IRF is generated as:

$$IRF_y(h, \delta, \mathbb{I}_t) = \frac{1}{R}\sum_{r=1}^{R} y_{t+h,r}^1 - \frac{1}{R}\sum_{r=1}^{R} y_{t+h,r}^2 \tag{B.6}$$

for $h = 0, 1, ..., H$ and the above condition (B.6) is valid according to equation (B.5) if $R \to \infty$ (e.g. we set $R = 10,000$). $y^1_{t+h,r}$ is the time path of y_t after the shock δ while $y^2_{t+h,r}$ is the time path of y_t after $\epsilon_{1,t}$;

10. The unconditional IRF $IRF_y(h, \delta)$ is then generated by repeating the whole process for all possible histories $\mathbb{I}_t, t = 1, 2, ..., T$ and taking the mean over T:

$$IRF_y(h, \delta) = \frac{1}{T} \sum_{t=1}^{T} IRF_y(h, \delta, \mathbb{I}_t) \tag{B.7}$$

Similarly, we can generate $-IRF_y(h, -\delta)$, where the shock to the oil price is negative;

11. Finally the Wald test statistic of the H_0 of symmetric impulse responses of y_t to positive and negative oil price shocks of the same magnitude ($\delta = (\hat{s}_1, 2\hat{s}_1)$), for $h = 0, 1, ..., H$, is computed as[1]

$$H_0 : IRF_y(h, \delta) = -IRF_y(h, -\delta)$$

$$W = (\mathbf{R}\widehat{\mathbf{I}}_y)'(\mathbf{R}\widehat{\mathbb{V}}\mathbf{R}')^{-1}(\mathbf{R}\widehat{\mathbf{I}}_y) \sim \chi^2_{H+1}$$

where

$$\underset{2(H+1)\times 1}{\widehat{\mathbf{I}}_y} = \begin{bmatrix} IRF_y(0,\delta) \\ \vdots \\ IRF_y(H,\delta) \\ -IRF_y(0,-\delta) \\ \vdots \\ -IRF_y(H,-\delta) \end{bmatrix} \qquad \underset{(H+1)\times 2(H+1)}{\mathbf{R}} = \begin{bmatrix} 1 & \dots & 0 & 1 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 1 & 0 & \dots & 1 \end{bmatrix}$$

B.3 Tables and Figures

[1] The variance–covariance matrix of the vector sum of IRFs $[IRF_y(h, \delta), -IRF_y(h, -\delta)]$ can be estimated by bootstrap simulation. Given $\hat{A}_1$, $\hat{A}_2$, $\hat{s}_1$, $\hat{s}_2$, $\hat{\epsilon}_1$ and $\hat{\epsilon}_2$, the system is used to generate artificial series of the same length of the data, given an arbitrary chosen history $\mathbb{I}^n_t$; repeat all steps to get n the unconditional IRFs, both for δ and $-\delta$, from which the variance covariance matrix $\mathbb{V}$ is computed that has a size of $2(H + 1) \times 2(H + 1)$.

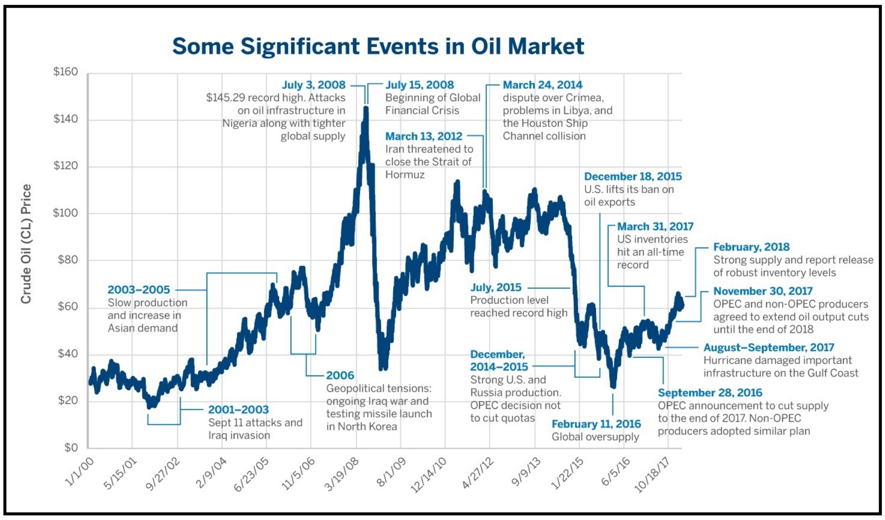


Figure B.2: Oil Shocks Identification
(Source: Adapted from Chicago Mercantile Exchange (CME) Group (2018))

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