A Short-Term Forecasting Model for Brent Oil Prices

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Key Points

The KAPSARC Oil Market Outlook (KOMO) provides a comprehensive overview of world oil markets, including supply and demand balances, crude oil inventories, and Brent crude oil prices. Its goal is to provide readers with a timely source of data, forecasts and analysis of world oil markets, including an understanding of the key factors affecting world oil prices.

Using publicly available data on 195 countries and regions, we develop detailed country- and region-specific statistical models of oil demand, supply, inventories and oil prices. KOMO takes a critical look at all of the major factors affecting world oil markets, including:

- financial variables such as interest rates and gross domestic product (GDP);

- seasonal variables, such as regional temperatures;

- physical production considerations, such as reservoir characteristics for conventional and unconventional oil;

- investment decisions and timelines;

- the influence of trading and speculation;

- and geopolitical factors such as trade wars, sanctions, and complex international relations.

The KOMO model will be re-estimated on a quarterly basis. The outlook will provide a detailed analysis of the future consequences of anticipated and unanticipated country-specific economic and geopolitical factors, and variables that may impact oil prices and the future of oil markets. This paper gives a detailed description of the scope of KOMO, including the models and methodology used in the analysis.

Figure 1. Figure 1. Brent crude oil prices, estimated versus actual.

Source: KAPSARC.

Summary

The KAPSARC Oil Market Outlook (KOMO) has been designed to provide readers with a timely source of data, forecasts and analysis of world oil markets, including an understanding of the key factors affecting world oil prices. This paper gives a detailed description of the scope of KOMO, including the models and methodology used in the analysis.

There is no shortage of information on world oil markets, given the multiple outlooks from a number of sources including the International Energy Agency (IEA), the Energy Information Administration (EIA), OPEC, and the Organization for Economic Cooperation and Development (OECD). Through KOMO, KAPSARC is adding value to existing outlooks by publishing a quarterly short-term report that takes a closer look into the Gulf Cooperation Council (GCC) region. This paper provides an overview of KOMO's assumptions and methodology. We intend to be the first Middle Eastern organization to make its oil price forecasts publicly available, and make the output and methodology transparent to interested readers.

KOMO considers 195 countries, and their respective territories, in locations including Africa, the Americas, Asia, Eurasia, Europe and the Middle East. To simplify the comparison between developing and non-developing countries and to highlight future demand and supply prospects, the dichotomy between OECD and non-OECD consuming nations is embedded in the analysis. OPEC and non-OPEC producing nations have also been included as distinct and separate regional groupings.

The base model structure for KOMO includes the following models and sub-models:

- A demand model

- A supply model
- A crude oil inventory and price forecasting model
- A Delphi survey model for geopolitical risk
- The Brent crude oil confidence interval

On the demand side, KOMO investigates 31 individual countries and six regions, divided into two main categories – OECD and non-OECD nations. The KOMO autoregressive distributed lag (ARDL) model is a statistical model in which the main or dependent variable (crude oil demand) depends on lagged values of itself, and a combination of lagged and current values of a number of other explanatory variables including gross domestic product (GDP), interest rates and oil prices.

The statistical forecast is based on the standard ARDL for the list of countries where quarterly data is available. For the countries where only yearly data is available, the demand model integrates three tools: trend cycle seasonality, oil demand growth and a weather influencer.

The forecasts are augmented by several sub-models that incorporate the effects of temperature change and geopolitical risk. The implications of increases in temperature on oil demand differ from country to country. KOMO's short-term outlook investigates the implications of temperature changes (i.e., a temperature rise) on individual countries, not regions. Despite consisting of a change of only 43,000 barrels of oil a day (0.04% of total), we have incorporated the impact of increasingly extreme weather events on our short-term demand forecast. While the amount seems small, our future work on long-term demand will likely see a larger influence from incorporating this methodology. KOMO integrates this layer of added values into oil demand in 2020, and it only

uses a multiplier to estimate the changes in demand in extreme cases in which temperature increases may go beyond 1 or 2 degrees Celsius (°C) per country per month.

The seasonality component of the model utilizes historical data from 2002 to 2017. The seasonality sub-model utilizes historical data and compares each month against its yearly average as a percentage output. The percentages are calculated for every month from 2002 to 2017. They are then averaged across the sample years to provide the monthly changes in each year.

On the supply side, the KOMO model is intentionally kept simple. The basic function of the aggregate supply model is to provide a liquid production level in response to an input Brent price. The Rystad Ucube (Rystad Energy 2010) database for individual projects worldwide is used to convert country-specific and regional production profiles into quarterly data. Some simple logic is used to adjust production levels to changes in the Brent oil price. Finally, we apply manual adjustment factors to account for potential risks that are not captured in a purely technical analysis.

The basis logic may be summarized briefly as follows:

Static projects are immune to price changes. This is due to the nature of the data (historical), and a lack of exposure to oil prices (refinery gains, biofuels, gas-focused developments).

Functionally static projects are ones that have long development times and may be produced for reasons that are not directly linked to the oil price. These are primarily unconventional developments such as oil sands and kerogen, and the small amount of associated liquids from projects like coal bed methane.

For capacity-limited projects, we make the assumption that within the two-year window all projects that will come online are known, and new projects are unlikely to be approved, developed, and begin production.

Dynamic projects have short development cycles (months instead of years), and as such are capable of increasing or decreasing production within our two-year window. To account for this, we observe two important benchmarks: the all-in breakeven price and lifting cost. If the oil price is below the lifting cost then production is shut off, and if it is above the all-in breakeven price listed by asset, then production is added.

Finally, manual adjustments are made to the net production values based on expert inputs. These adjustments include non-market supply risks such as geopolitical issues (e.g., elections in Nigeria, and the United States [U.S.] sanctions on Iran, among others).

The crude oil inventory and price forecasting model provides the dynamic component of KOMO, and consequently the price forecasts for Brent crude oil. The model is based on a simple, competitive market structure. The equilibrium, or market clearing price, is achieved when supply minus demand is equal to a normal inventory build so that inventories are at their target level. Relative inventories are defined as the difference between the real level of inventories and the level of industry players' target inventories to meet contractual obligations and cushion the industry against unanticipated changes in the demand or supply of crude. Relative inventories are equal to zero when inventories are at their target level so that there is no positive or negative pressure on world oil prices. When real inventories are below or

above the target level, there is positive or negative pressure on world oil prices, respectively. This relationship forms the theoretical basis for the relationship between Brent oil prices and world oil market fundamentals and is the foundation for the econometric model we use to forecast world oil prices.

The result is a dynamic short-term forecast of Brent oil prices based on OECD inventories and a lagged value of the Brent oil price. This is a simple tool that can easily be estimated and updated using readily available data. It can also be completely specified in an Excel spreadsheet, or a similar software package, such as EViews.

KOMO includes two additional models that account for geopolitical risk and the effects of trading and speculation on world oil prices. These are a Delphi survey model for geopolitical risk and the Brent crude oil interval.

The Delphi survey model for geopolitical risk

KOMO analyzes specific variables (including economic and geopolitical, among others) that may impact Brent prices or the oil markets with issues ranging from elections, political conflict, infrastructure challenges, etc. To address these issues, the team used a Delphi method along with different methodologies to estimate their impacts.

The Brent crude oil confidence interval

One of the most popular methods of forecasting crude oil prices is observing the forward and futures curves, which aggregate contemporary market views from speculators worldwide. These curves have traditionally provided poor forecasts, but they do illustrate the price at which it is possible to buy or sell a futures contract at a future date for a price agreed upon today. While futures curves reflect present market views, they do not take into account physical limitations such as market liquidity and imperfections in capital markets. To compensate for these deficiencies, and market volatility and uncertainty, KAPSARC has constructed a confidence interval, used in KOMO, derived from options market information (CME Group) for at-the-money options contracts.

The KOMO modeling suite is based on a simple statistical and econometric framework and publicly available data that can easily be updated, and it is readily available to policymakers on a timely basis. The model framework might be extended to investigate a number of interesting issues, including the possibility of asymmetric behavior. Asymmetric behavior refers to a scenario in which the relationship between oil prices, excess supply and inventories is different in different market states, such as extreme backwardation or contango, and under different geopolitical scenarios, such as a war in the Gulf, or an environmental crisis or disaster.

Introduction

Oil supply and demand balances play a predominant role in assessing world oil prices. Their forecasts determine market futures and commodity prices over the long term. In the short term, they help oil companies predict near-term cash flows. Due to the importance of these outlooks, multiple outlooks are published periodically by organizations including the International Energy Agency (IEA), the Energy Information Administration (EIA), and OPEC. Energy producing companies, banks, energy organizations and a wide variety of think tanks all formulate views on the oil market. Some are published and others remain confidential. Some outlooks are national and few are international, with some overlooking specific regions such as the Gulf Cooperation Council (GCC).

Given the multiple outlooks already being produced, KAPSARC has endeavored to differentiate its outlook by publishing a quarterly short-term report that takes a closer look into the GCC region and provides a transparent overview of its assumptions and methodology. We intend to be the first Middle Eastern organization to publicly publish its outlooks, and make the output and methodology transparent to interested readers.

The GCC region is often considered to be a region of exporters with relatively limited demand growth; rest assured that this is not the case. Despite the recent lull in oil prices, there are fast-paced policy changes and large technology investments, with mega projects in the pipeline. Economic and social changes are expected to take place and, as such, the old models for determining this region should be revised. Along with factoring gross domestic product (GDP) into the forecast oil prices, other variables can play an important role in forecasting the region's oil demand. Countries within the GCC have taken large strides recently to diversify their economies. Saudi Arabia has also lifted the ban on women

driving, which has helped to change the basic demand structure of the region. As a result, KOMO has analyzed these countries closely and integrates some assumptions such as policy and economic changes in the forecasts.

The methodologies used to determine supply and demand balances differ from one organization to another. While some may use econometric models, others prefer to use specialist insights or fixed economic models that are run regularly. The same applies to price determination. In many cases, the methodologies used are not transparent and the reports are not published. Indeed, knowing how a specific number was determined would support researchers in developing their assumptions on supply/demand or price. Moreover, in some cases the raw data used to determine these variables comes from paid sources and cannot be published. As a result, withholding information on the methodologies used to generate outlooks results in broader insecurity about prices. Hence, this paper sets out to explain the approaches used by KOMO to determine supply, demand, inventories and prices.

KOMO is KAPSARC's short-term outlook and looks at a two-year quarterly horizon.

The long-term outlook is currently being developed and is expected to be published at a later date.

KAPSARC is determined to continue to strive to improve its estimates and to provide transparency on its methodologies and approaches. It is also open to feedback and constructive criticism that could improve future outlooks.

This section outlines KAPSARC's approach to regional grouping, demand, supply, inventories and prices.

Regional grouping

KAPSARC considers 195 countries, including their respective territories, in Africa, the Americas, Asia, Eurasia, Europe and the Middle East. To simplify the comparison between developing and non-developing countries, and to highlight future demand and supply prospects, a dichotomy between OECD and non-OECD countries, as well as a clear separation between OPEC and non-OPEC members, is embedded in KOMO.

Demand

Demand tends to follow a historical seasonality and is influenced by GDP, prices and population growth. Since the population does not change significantly year over year, it was excluded from our analysis, but will be incorporated in the long-term forecast. Hence, GDP and prices remain the most significant factors determining demand in the short-term. However, climate conditions and certain policies can impact demand in unexpected ways. The demand model published by KOMO for the short term uses an ARDL model to estimate demand on a quarterly basis. When faced with only yearly data, it uses three different models aggregated into one. A seasonality model is used for countries and regions where no quarterly data is available, comprising an ARDL econometric growth model (Joutz 2012) and a weather influencer. The forecasts are based on publicly accessible historical data extrapolated to determine the most probable outcomes for the next two years.

Supply

The supply side of the KOMO model is relatively simple compared with the demand side. The module is designed to accept an input oil price from the previous period and generate a production

level dependent on the operational expense of projects that is, later on, passed on to the supply/demand balance and price formation modules. To accomplish this, we analyze the global population of projects from the bottom-up as they appear in an existing database (Rystad Ucube). First, a series of production profiles at different oil price levels are collected for each project. Second, this annual data is converted into quarterly values with quadratic spline interpolation using EViews, an econometrics program. Third, logic rules are applied to different project types based on their response to price changes. For example, refinery gains are static and unresponsive to price, while tight oil projects are very dynamic with existing capacity dropping quickly, and new capacity capable of growing rapidly in response to the price conditions. Lastly, manual adjustments are made to the net production values based on expert inputs. These adjustments include non-market supply risks such as geopolitical issues (e.g., elections in Nigeria).

Inventories and prices

This section presents a short-term quarterly forecasting model of Brent crude oil prices using supply-demand fundamentals, EIA crude oil inventory levels, and supply and demand data. The model is based on the fundamental relationship between commodity inventory levels, determined by economic regression analysis, and publicly available data (Ye, Zyren, and Shore 2002). The main body of this section is organized as follows. The first section, “Fundamentals of the world oil market,” explains the fundamental relationship between market structure, oil prices and inventories. The second section, “Empirical results,” presents the results of the statistical analysis, and robustness tests. Finally, the conclusion gives a summary of the results and outlines areas for future research. KAPSARC evaluates all three major price forecasts

Regional Grouping Model

For this paper, KAPSAC has combined countries with their respective territories. For example, Anguilla, Bermuda, and the British Virgin Islands represent British territories and are considered part of the United Kingdom, even though they are in the Americas geographically. Though Monaco has United Nations status as an independent country, it is also considered as a territory of France. Moreover, countries with limited international recognition of their sovereignty, such as Kosovo or Western Sahara, are also categorized under the countries they are separating from (in this case, Serbia and Morocco, respectively).

There are two reasons for using such methodologies. The first is to simplify the geographical distribution, since most territories do not represent a significant margin of oil production

and/or consumption. The second relates to the availability of public data on these territories. The reader is referred to Appendix 1 for more details. Hence, each country's demand or supply numbers also represent its territories.

Furthermore, not every country is calculated individually in KOMO's calculations, because the objective is to provide insights into where demand and supply, as well as prices, are going. Hence, many of these countries tend to be lumped together due to their geographical locations. For example, when considering Africa's demand, KOMO estimates the outlook for both Egypt and South Africa. The remaining countries are combined as the "rest of Africa." The same applies to Russia and the "rest of Eurasia."

Figure 3. KOMO's global demand regional representation.

Source: Tableau, Open Street Map, 2019.

Under the oil demand umbrella, countries are distinguished further into OECD and non-OECD countries. This distinction is drawn due to the countries' respective levels of development. This is gauged by factors such as average vehicle usage and mileage, the growth in vehicle purchases, use of liquefied petroleum gas (LPG) for cooking and heating rather than electricity, population and birth rates, among others. Consumption would be expected to continue to decrease in the long run for OECD countries and to continue to gradually increase for non-OECD countries. This distinction helps identify where growth comes from and where new trends develop. Refer to Appendix 2 for more details on the oil demand country grouping.

In the supply module, the data is collected by country and follows the same rough geographic groupings for regions as the demand module, for reporting purposes. Outside of these comparisons, the supply module distinguishes between OPEC (and OPEC+) vs. non-OPEC countries to highlight the differences in market responses to oil prices. Non-OPEC members respond primarily to price in a purely economic manner, while OPEC and partner countries work more strategically.

Though some OECD member countries may follow the pattern of developing countries due to their stage of economic development, the distinction between OECD and non-OECD countries remains the most commonly used.

Demand

Introduction

Energy demand has been studied since the early twentieth century. However, it garnered more attention during the emergence of the oil crisis in the early 1970s, which also resulted in the establishment of the IEA in 1973. Before the 1970s, the understanding of energy demand and demand response due to external shocks was very limited (Pindyck 1979). As a result, energy demand models started to appear, such as those by Hartman (1979), Bohi (1981), Zimmerman (1984), and Craig (2002), among others. Nevertheless, most of these studies were focused on OECD members. With the economic emergence of developing economies in the early 1980s, new studies such as Bhatia (1987), Shukla (1995), and Urban (2007) began to shed light on the developing world. Other studies focused on elasticity surveys in the hope of providing more accurate results. These include Dahl (1991, 1994), Espey (1998), Cooper (2003), and Bhattacharyya (2009), among others. These studies have become the building blocks of oil demand analysis. KOMO endeavors to build on these econometric studies and add extra tools to estimate the impacts of interest rate changes, seasonality extrapolation, and other factors on the oil market.

There are a wide variety of methods to estimate global oil demand. However, in the short run, it would be safe to assume an underlying seasonal pattern of GDP and price pressures. Nevertheless, acquiring accurate historical data on developing countries is challenging due to a lack of availability (Pindyck 1979). As such, developing a forward-looking outlook on demand from developing countries has to rely less on historical data. Furthermore, the developing world is experiencing evolving economic transitions and is implementing new mitigation measures to tackle climate change, such as energy efficiency measures, technological developments and policy

changes (Worrel 2002). Including an add-factor to our forecasts is therefore justifiable, as an econometric model would not be able to capture these new changes.

Dummy variables are sometimes embedded in ARDL model forecasts as an add-factor to capture the mentioned changes.

KOMO's demand model analyzes 31 countries and six regions. The countries are distinguished between OECD and non-OECD (refer to Appendix 2). Moreover, the forecast is based on the ARDL model when quarterly data is available. However, when only yearly data is available, the demand model integrates three tools: trend cycle seasonality, oil demand growth and a weather influencer.

Determining growth on a quarterly basis can be challenging due to the limited availability of data for many countries and regions. Some countries have more granular data in quarterly or even monthly values, while others only have annual values available that require processing because KOMO is dedicated to providing quarterly forecasts. To this end, and following the regression model to estimate growth, we have constructed a seasonality step to estimate quarterly values for the growth numbers that are reported on an annual basis, including an extra layer that takes weather patterns into account.

Estimating demand growth is determined econometrically. The model considers “a linear dynamic single equation model. The autoregressive distributed lag (ADL) model begins with a regression of the variable of interest on lagged values of itself and current and lagged values of the explanatory variables.” (Joutz 2012)

If there is limited yearly data available, we add an extra layer of seasonality based on monthly

historical data, averaged out for each year on a monthly basis. This demonstrates how countries' consumption patterns change every month, either due to factors such as the harvest season, driving season and cold weather, among others.

Finally, the weather influencer is a simple model that either increases or decreases total consumption based on expected temperature changes. For example, if there is a higher average temperature in winter for country X, its consumption of LPG or gas oil for heating might decrease. KOMO uses three temperature influencers: northern, equatorial and southern. The equatorial model takes into account warmer countries, such as those in the Middle East and Mexico.

Net supply/demand is not the only factor that influences price, but it should be and remains the most important fundamental. Excess demand raises the price of the commodity and supply increases push prices down. However, it is also safe to assume that market speculation tends to exaggerate prices, which explains why oil prices often increase or decrease by a couple of dollars over a few days, even with unchanged net supply/demand. Despite the extensive literature on speculation, KOMO decided to focus on fundamentals and not include speculative behavior. However, there is scope for future studies to integrate other factors into the model.

Determining demand growth

Demand can either be estimated using a top-down or a bottom-up approach. The goal of every demand model is to develop a comprehensive approach that takes everything into account, from car sales and petrochemical output to the use of LPG per household. However, short-term demand outlooks tend to be periodic (i.e., monthly, quarterly, and so

forth), and data availability at such a granular level is not always available. The conventional demand model tends to fall within one of the three categories defined by Lipinsky (1990): complexity, dynamics and uncertainty. For the sake of this paper, we will follow the categorization of Bhattacharyya (2009).

Simple approach: This is less common in academic literature, but it serves the purpose of forecasting as it takes into account growth rates, particularly income elasticities, unit consumption and energy intensity.

Sophisticated approaches: These can be both bottom-up and top-down models and are based on econometrics or engineering economy. Other sophisticated models may include input-output models, process models (Labys 1990; Munasinghe 1993), and scenario approaches (Ghanadan 2005), among others.

KOMO's model uses an econometric approach that establishes a logarithmic, linear relationship between the dependent variable, logged demand, and chosen independent variables by analyzing historical data. The independent variables used for KOMO's equation are logged GDP, logged prices, interest rates, a lagged value of logged demand to support autoregressive distributed lag (ARDL) format, and a number of dummy variables for seasonality and to capture shocks:

$$y_t = \alpha_0 + \sum_{i=1}^p \alpha_i y_{t-i} + \sum_{j=0}^m \beta_j z_{t-j} + \varepsilon_t \quad (5)$$

According to Joutz (2012), the model is "referred to as an ADL (p,m), because it contains p lagged dependent variables and m lagged explanatory variables. In the single equation case, we are implicitly assuming a conditional model where the z variables are assumed to be exogenous." The z also

represents the dummy and seasonal variables.

As a result, we end up with equation (6)

$$y_t = \alpha + \beta_0 z_t + \beta_1 z_{t-1} + \beta_2 y_{t-1} + \varepsilon_t \quad (6)$$

By applying this model, the short-run multiplier is indicated as coefficient β_0 , yet the total effect of independent variable z is the sum of $(\beta_0 + \beta_1)$ and the long run impact of a change in z would be $(\beta_0 + \beta_1) / (1 - \beta_2)$. Hence, KOMO's model simultaneously takes into account both the short run and long run. The sum of the total coefficients for the same variable work as adjusting factors to one another.

Prices have an inverse relation to demand; however, a few price coefficients for different countries and regions were positive. However, applying $(\beta_0 + \beta_1)$ gives a negative coefficient, which helps justify our assumption that the lag works as an adjuster to the coefficient multiplier.

Data analysis

It has been a norm since the 1970s, when economists started looking into the relationship between energy and other economic variables, to use GDP as an independent variable (Pindyck 1979). Price is another factor that plays an important role in determining demand (Hartman 1979). The economics of world oil prices is relatively straightforward. As prices decrease, demand for the commodity becomes more attractive and vice versa. Interest rates, however, are a different matter. Economic activity for many OECD countries and emerging markets within the developing world are sensitive to the fiscal sector and interest rates, so KOMO includes it as a future tool in case it is

required to determine the impact of fiscal policy on a specific country's oil demand.

Furthermore, KOMO's dummy variables either provide seasonality for quarterly regressions or capture shocks. For example, KOMO has included dummy variables for all countries and regions to capture the exceptional impact of the 2008 economic crisis. This is for two reasons: the first is to sharpen the coefficients as it eliminates that period from the equation's norm. The second reason is so that it can be used as an input in the forecast to capture future changes. We can consider its inclusion in the forecast as an 'add-factor.'

Finally, KOMO uses the log function to model the dependent variable due to its ability to successfully capture the relationship between oil demand, GDP, interest rates and oil prices (refer to the table below for further details).

Data analysis:

KOMO uses the log function to model its dependent and independent variables due to its flexible properties in normalizing data and reducing/eliminating heteroscedasticity (Wirl 1990).

The model uses an ordinary least square (OLS) method where we manually input lags in the equation to capture the differences. However, some of the variables may have roots close to unity and may be integrated to a degree. This can come with a non-standard distribution of coefficient estimates, the autocorrelation of explanatory variables, non-stationary error process, and endogeneity problems. However, tests show that this is not the case.

KOMO's test of the data concluded the following:

- 11% of the total variables exceeded +/-1 in skewness (mostly GDP and interest rate variables).
- 7.5% of the total variables failed/exceeded 4 in the kurtosis test.
- 34% of the total variables failed the Jarque-Bera probability test supporting the null hypothesis of normal distribution* (only five countries were dependent variables [Argentina, Brazil, Canada, Chile, and Turkey].**)
- No failed unit root tests. Where an explanatory variable supported the null hypothesis of a unit root in an Augmented Dickey-Fuller test, it would not support the null hypotheses in a Phillips-Perron test, and vice versa.

KOMO also agrees with Harvey (1997) when he argued that "The use [of]... associated unit root tests forces the researcher into a specific way of modeling which effectively excludes forecasting and decomposition procedures which may be more effective and have a more natural interpretation." This is why KOMO stuck to its methodology to have unity in procedures and used the same data sources for all countries and regions.

* Because the variables are real historical data and most of them are explanatory variables, KOMO decided to continue with the regressions.

**The five countries represent only 7.5% of global oil demand, which is not significant enough to analyze these countries separately.

Hence, KOMO's complete model is as follows:

$$\begin{aligned} \ln DM_t = & \alpha + \beta_0 \ln GDP_t + \beta_1 \ln GDP_{t-1} + \beta_2 \ln Pr_{t-1} \\ & + \beta_3 \ln Pr_{t-2} + \beta_4 r_t + \beta_5 r_{t-1} + \beta_6 D1 + \beta_7 D2 \\ & + \beta_8 D3 + \beta_9 DV + \beta_{10} \ln DM_{t-1} + \varepsilon_t \end{aligned} \quad (7)$$

In	Logged function	
<i>DM</i>	Oil demand	<i>y</i>
<i>GDP</i>	Gross domestic product (IMF-Oxford Economics)	
<i>Pr</i>	Brent prices (historical)	
<i>r</i>	Interest rates (future projections use an autoregressive model that includes a time series) (historical)	
<i>D1, D2, D3</i>	Seasonal variables to capture the quarterly changes.	
<i>DV</i>	Dummy variables (representing the 2008 financial crisis and other aberrations, which would be specific to each country/region).	
<i>t</i>	Time period	<i>z</i>

Refer to Appendix 4 for further details. It shows the data and regression results for each country/region.

Note:

1. The model is dynamic, so KOMO's price output is also its input. Furthermore, once all of the countries and regions are accounted for, they become aggregated to produce the forecast for global oil demand on a quarterly basis.

Figure 4. KOMO's fitted data .

Source: IEA's MOD August 2019.

2. The fitted data from the country/regional models can be reproduced using free historical data. Since KAPSARC prides itself in providing free data, there is potential for KOMO to reproduce historical oil demand data upon request. However, further cleanups and inclusions of dummy variables would be necessary to capture historical shocks.
3. Equation 7 represents the complete formula. However, based on the availability of data, such as interest rates, some variables become omitted. In other cases, independent variables are omitted to strengthen the equation.

KOMO uses the mentioned function based on the availability of historical data to produce quarterly numbers. However, most developing countries, data tends to be yearly. KOMO uses the equation while segregating the seasonality factors to determine growth, then adds two layers to its forecast. The first layer extrapolates new growth to determine seasonality and the second adjusts the seasonality in line with expected temperature changes.

Determining seasonality

Before prices and economic impacts are factored into demand, each country has a baseline annual consumption pattern, dependent on temperature changes, economic cycles, beginning/end of the harvest season, holiday season, and refining maintenance, among others. Based on the occasion, the consumption of oil products changes in response to national demands, including heating, transportation and cooling. Hence, there is an implied seasonality embedded in each month and quarter. It is necessary to capture this seasonality to understand when and why the net supply/demand changes within the year, influencing prices to go higher, lower, or stagnate.

The seasonality is based on historical monthly data. KOMO used the IEA's data for OECD countries, the Joint Organisation Data Initiative (JODI) for non-OECD countries, and official data from countries that produce data periodically, such as India.

The baseline seasonality model utilizes data from 2002 to 2017. In cases where country-specific data is not available for specific months in a year, the year in question is omitted from the calculations. The seasonality method captures historical data and compares each month to its yearly average as a percentage output. Once these percentages are calculated for each year, they are then averaged between themselves in the span of the sample years to provide average monthly changes in each year.

In numerical terminology, the model for each country/region starts by taking the average of each year (from January to December):

$$x_n = \frac{(y_{1n} + y_{2n} + \dots + y_{mn})}{m}$$

x = Yearly average

y = Actual historical month of period m at the year of n

n = The number of the year

m = Month

Once the yearly average is attained, the number is then compared to the actual month, where the actual month is deducted from the yearly average, and the outcome is divided by the yearly average. This equation is constructed to see the difference between specific months and the yearly average.

$$i_{mn} = \frac{(y_{mn} - x_n)}{x_n} \quad (2)$$

i = The difference between each month and its yearly average, divided by the yearly average.

This process is repeated for every month of every year, and we are left with:

$i_{1,2002}$

$i_{2,2002}$

.....

$i_{12,2002}$

$i_{1,2003}$

.....

$i_{12,2017}$

Once all the data has been calculated, the model starts to average each i_{mn} of every year together:

$$z_1 = \frac{(i_{1,2002} + i_{1,2003} + \dots + i_{1,2017})}{w}$$

z_1 = The difference between January and the average of the year.

(1) w = The number of years of the sample model.

Demand

The model goes on to calculate z_1 “January” up to z_{12} “December” for each country/region individually.

To which these numbers are multiplied by the average anticipated demand of the coming year:

$$A_{1n+1} = (z_1 + 1) * b_{n+1} \quad (4)$$

Country’s “m” demand for January of the year “n” is A_{1n} .

b_n = Yearly average demand for the new year n.

The outcome of this methodology provides a seasonal outlook for every country/region. Figure 5 shows KOMO’s estimation of the seasonal changes in Saudi Arabia’s oil demand using JODI’s historical data from 2009-2017. Burning oil, including heavy fuel oil and diesel, accounts for 46.3% of Saudi Arabia’s electricity generation (ECRA 2017).

The summer season sees more oil consumed by transportation during the driving season and air conditioning consuming large quantities of electricity, predominantly generated via burning oil. The graph indicates Saudi Arabia’s oil consumption is up to 17% higher in August than its yearly average, gradually decreasing as the cooler weather arrives.

In Figure 6, India’s oil consumption is not as smooth as Saudi Arabia’s. This tempts the question, What is the reason for this difference?

India’s financial year ends in March and starts in April (PPAC 2019). In February, the inventory of goods and services is pushed up to maximize gross profits. This makes balances look more attractive by the end of the financial year in March. After this strong push, demand cools in April as the country starts its new financial year and accumulates stock

Figure 5. Saudi Arabia’s average seasonality.

Sources: JODI, KAPSARC 2019.

Figure 6. India's average seasonality.

Sources: JODI, KAPSARC 2019.

for the coming monsoon season in June. The heavy rain during this season means that demand for oil starts to decrease in June. The decrease continues until the harvest season ends, and in September festivities start, promoting higher consumption.

These are a few examples of how seasonality plays an important role in defining quarterly changes in oil demand. This paper will not go into detail about each country's seasonality but provides a transparent overview of how the demand for countries/regions was estimated and what data was used in the process. For further details, refer to Appendix 3.

Note that the impact of temperature rises or extreme weather events can influence demand. The next section explains the methodology used to determine this.

Similarly, this methodology, although focused on total oil demand, can go into more granularity and apply the same concepts on the secondary products to have an output such as in Figure 7.

When KOMO analysts applied this methodology at a granular level and compared it with its actual historical aggregated monthly OECD numbers, they noticed some monthly variations. The estimation errors ranged between -20 to 43 barrels between KOMO's methodology and the actual numbers. However, a range of 60 barrels a day for each month, compared with 14 million barrels a day, is insignificant.

This paper has already introduced how the seasonality tool works and, through equation (4), we multiply each month's percentage to the yearly average number to estimate the demand for each country/region by month. However, can this be influenced by weather changes or extreme weather events?

Figure 7. OECD Europe's consumption changes by product.

Source: KOMO, 2019.

Estimating the impact of temperature rises

The concept of estimating the implications of an increase in temperature on oil demand differs from country to country. In its short-term outlook, KOMO analyzes the impact of temperature rises on individual countries without looking at the regions as a whole. Furthermore, the impact is modeled for the year 2020, and only considers extreme cases in which temperature rises may go beyond 1°C or 2°C per country per month. KOMO analysts decided to incorporate the impact of such extreme weather changes into its forecasts, despite the aggregated impact of only 43,000 additional barrels a day per year, representing only 0.04% of total global oil demand.

KOMO is a simplistic model with three different variable inputs for Northern, Equatorial and

Southern countries that depend on each country's location.

Cold weather countries tend to consume more LPG and fuel oil for heating in winter, so when temperatures rise, this consumption pattern goes down. Moreover, if temperatures rise in early summer or at the end of spring, then the chance of higher consumption of diesel and motor gasoline for transportation also rises.

Warmer countries tend, like most developing countries, to be more reliant on fossil fuels year round. However, they have heavier consumption in summer than winter as they are used for transportation and cooling.

Finally, the Southern Hemisphere countries tend to follow the same pattern as colder countries, albeit their seasons are opposite to those in the Northern Hemisphere.

Methodology

The model takes the monthly average temperature between 1991 and 2015 of the aforementioned countries and benchmarks them to the Representative Concentration Pathway (RCP) 4.5 scenario. If the temperature rise is above 1°C in winter, we add a multiplier of -1% to the country's global oil demand. If it is less, we use a weaker multiplier, and vice versa in hot weather.

Representative Concentration Pathway (RCP).

"The RCP 4.5 scenario is a stabilization scenario, which means the radiative forcing level stabilizes at 4.5 W/m² before 2100 by employment of a range of technologies and strategies for reducing greenhouse gas emissions." (NOAA 2018)

It is also the commonly recognized pathway to stabilizing the average global temperature rise to below 2°C above pre-industrial levels.

The methodology repeats itself for the other months, using different multipliers based on the season. Due to the nature of simplifying the model, the same multipliers apply for the aggregated countries' groups based on location, as detailed in Appendix 1. However, the model is only applied to the individual countries which have been calculated.

Sources

The data was taken from the International Monetary Fund's (IMF's) website as monthly average temperatures per country. The same applied to the IMF's RCP models to which KOMO went with the 4.5 scenario. The multipliers were created in-house by KAPSARC.

The RCP 4.5 projection is for the period between 2020 and 2039, which is why this model was aggregated to 2020 onward.

Note: Although the model is in its early stages and does not take into account the changes in electricity generation or social changes for each country, the aggregated outcome is minuscule. However, it does provide insight into how a country would react to a global temperature rise. Indeed, when applying the model, we notice that countries such as China and Brazil are estimated to decrease consumption, whereas others such as the U.S. and India tend to increase consumption. Future work would be needed to develop this section, such as integrating an econometric model to determine seasonal factors, supplying each country with individual multipliers, or finding other methods.

Future research could come from KOMO complementing the X-11, developed in the 1960s by the U.S. Census Bureau.

Supply

KOMO supply module

The supply module for the KOMO model is intentionally kept simple. The basic function for the larger model is to provide a liquid production level in response to an input Brent price. To accomplish this, we pull data from the Rystad Ucube (Rystad Energy 2010) database for individual projects worldwide, convert the production profiles into quarterly data with a transformation in EViews (IHS Markit 2019), and add some simple logic to adjust production levels based on the price. Lastly, we apply some manual adjustment factors to account for potential risks that are not captured in a purely technical analysis. The results of the module provide an overall liquid production level. They can also be used to create graphs that show different behaviors by country or project type.

Input data

The base production model is powered by the Rystad Ucube database, a standard oil and gas industry database used by several international organizations including the IEA. This database is updated daily and represents a reasonable snapshot of what is known about the market at the time the data is downloaded. It is much more efficient to use this existing resource for our input data, as KAPSARC does not have such a mature product or the expertise required to develop such a resource. Ucube is an industry standard database that many large players, including energy firms, governments, and think tanks, use as a reference.

Due to the very large data sets required to run KOMO, we tried to reduce the total population by applying a few simple assumptions based on empirical observations:

- Some liquids sources are immune to oil price changes.

- Conventional projects are slow to add production, but they can reduce production if the price is low enough.

- Unconventional products (tight oil, etc.) can rise and fall quickly in response to price changes.

We tested these assumptions in the Ucube system based on \$30, \$70, and \$100 price scenarios. We refined our categories accordingly:

- Static** production is immune to any oil price changes:
  - Historical values (0% change)
  - Refinery gains (fuel volumes gained in the refining process) (0% change)
  - “Other liquids” (biofuels and alcohols) (0% change)
  - Dedicated gas fields (<1,000 barrels change)
- Functionally Static** production is immune to price changes within our two-year window:
  - Kerogen oil shale projects (<1% change)
  - Oil sands (mining and in-situ) (<1% change)
  - Coal bed methane (net change <1,000 barrels)
  - Conventional gas-condensate fields (<1% change)
- Capacity-limited** production is immune to upward price changes within the two-year window:
  - Conventional oil fields
  - Heavy oil plays
- Dynamic** production is fully responsive to price changes:
  - Tight liquid plays
  - Shale oil plays
  - Shale gas plays (associated liquids)
  - Tight gas (associated liquids)

Static projects are immune to price changes. This is due to the nature of the data (historical), and their lower direct exposure to oil prices (refinery gains, biofuels, gas-focused developments). For the gas projects, we make an assumption that the gas price is not connected to the oil price for the sake of simplicity, but in practice this is not the case. However, the liquids portion of these projects is so small as to be irrelevant (<1000 barrels).

Functionally static projects are ones that have long development times and may be produced for reasons that are not directly linked to the oil price. These are primarily unconventional developments such as oil sands, kerogen, and the small amounts of liquids from projects like coal bed methane. The reasons for the continued uneconomic production of these projects is often due to the conditions in the local market, byproducts from gas production, lack of energy access or another goal. On a longer timeline, we would adjust their production levels, but within our two-year window the projects are known and are unlikely to be halted or to have additional projects approved and come online. The gas price is the primary driver of the gas condensate projects, with associated liquids as a bonus revenue stream that is a driver. However, the latter is less important for the breakeven of the project in the short run.

For capacity-limited projects, we assume that within the two-year window all projects that will come online are known, and new projects are unlikely to be approved, developed, and begin production. This indicates that there is a known maximum production level, and the oil price will dictate if and when uneconomic production will be temporarily shut off (when the price is below the lifting cost).

Dynamic projects have short development cycles (months instead of years), and as such are capable of increasing or decreasing production within our

two-year window. To account for this, we observe two important benchmarks, the all-in breakeven price and the lifting cost. If the oil price is below the lifting cost, then production is shut off, and if it is above the all-in breakeven price listed by asset, then production is added.

Working with the assumptions above, the data taken from Ucube is as follows:

1. For all data, history from 2000 is collected until one year after our reporting period.
  - a. For example for Q1 2019, we must take data until 2022.
2. For static and functionally static projects:
  - a. Production data is rolled up by country and liquid type (China, crude/China, condensate/etc.).
  - b. This is to reduce the processing burden on the model.
3. For capacity-limited projects:
  - a. Production data is collected for each project by liquid type.
  - b. Price assumptions for production are very high (\$120 per barrel [b]).
  - c. The lifting cost is also collected to signal when production may be halted.
4. For dynamic projects:
  - a. Production data is collected for each project by liquid type.
  - b. The price scenarios are high (\$120/b) and low (\$30/b) to establish boundaries.
  - c. The lifting and breakeven costs are collected to indicate the behavioral limits for added or halted production.

Data processing

The Ucube system has very good depth of project coverage but only reports production levels in annual increments. KOMO requires data in quarterly frequency, and as such needs to convert the base Ucube data. There are a few different methods to interpolate low-frequency to high-frequency data, and we have selected an academically accepted method, ‘averaging quadratic spline’ (Demko 1977). This method interpolates the quarters from the annual data and ensures that the average production rate for all quarters is equal to the original annual dataset.

Due to the high volume of data to be converted, we require the use of a software package to automate much of this work. EViews, an econometrics tool, is used because the conversion is very simple to implement for a large number of series (in this case, several thousand). As illustrated in Figure 5, below, the results of this transformation appear to produce a reasonable set of outputs from dummy data. While this does not produce perfect results on an individual project basis, the aggregate results are quite satisfactory.

Figure 8. Example of quadratic spline interpolation with dummy data.

Source: Dummy data, EViews interpolation.

Logic and operation for the base production profile

The supply module of KOMO is designed to act as a relatively simple function that takes a series of oil prices and produces production levels based on that series. The initial outputs are referred to as the ‘technical’ or ‘base’ production levels. These are the production levels that would occur if there were no influence or impact on the market other than price.

To generate this base production profile, we implement a basic set of assumptions based on experience, selected literature (Arezki et al. 2017; Fattouh 2016), and empirical testing within the Ucube system:

1. Projects cannot respond to future prices, or price trends less than a quarter in duration.
  - a. We assume that the average price for the prior quarter is a reasonable driver.
2. Static and functionally static projects do not change within our two-year window.
  - a. This data is unaltered and does not require logic.
3. Capacity-limited projects produce fully unless their lifting cost is not met.
  - a. IF($\text{Brent} < \text{lifting cost}$) production = OFF, else production = ON.
  - b. IF(production = ON) production level = MAX.
  - c. The behavior of some producers to continue operating for short periods despite uneconomic conditions is assumed to be minimal, as our input price is an average for the prior quarter.
4. Dynamic projects respond to price on a continuum, within bounds.
  - a. IF($\text{Brent} < \text{lifting cost}$) production = MIN, else production = ON.

- b. IF(production = ON) production level = prorated between MAX and MIN by price.
- c. To prevent artificially large gains or losses due to high price volatility, maximum growth and decline rates are applied as seen in the MAX and MIN cases.

After each project has solved for its own production level, a rolled-up value is produced by country and liquid type. This is the result of the base production profile.

Logic and operation for the adjusted production profile

After the base production profile has been generated, we must apply some factors for the real oil market that are not accounted for in the base model. These factors include ‘non-economic’ influences that can change production profiles for reasons other than price. The reasons for the maximum production level for a given price not being achieved (or exceeded) can include political, technical, economic, or other factors (Smith 2009).

For this model, we have aggregated our impacts into three broad categories:

1. OPEC+ behavior

In cases where production cuts are applied, the current production value for a member of the OPEC+ group is assumed to be the maximum target going forward. Different members can either exceed or fall short of the official target, so current behavior is a reasonable indicator of future behavior. Exempt members produce at their base profile rate before risks are applied. If the base profile indicates that a member has difficulty maintaining this production level in the future price environment, then the base profile determines their production.

2. Consistent under/over reporting

Consistent trends in under and over reporting were evident when we benchmarked our historical results against official sources (EIA/IEA/JODI). The impacts were minimal on average (<4% overall), but could impact some of the smaller producers disproportionately. To account for this, a review of the average deviations for the last three years was observed and applied to the base profile if reasonably consistent.

3. Supply risk factors

We collect the results from the supply section of our Delphi survey (Gordon 2007). When we ask for the risk level of an oil producing nation or entity (e.g., OPEC supply cuts), this can include anything from political risks (e.g., elections) to wars, trade disputes, and weather events, among other impacts. As explained in Appendix 7, we generate a risk profile over time and the number of barrels at risk to approximate the total impact. A historical review of prior disruptions is taken into account to prevent an over-estimation of these risk factors. Due to limitations concerning a reasonable survey length, we restrained the risks to the largest oil producers. Estimating specific risks for smaller sources is the responsibility of KAPSARC researchers, either themselves or by seeking guidance from an outside expert.

Interactions between these three adjustment factors can be complicated but are summarized as follows:

1. Non-OPEC+ producers
  - a. Produce at their base profile.
  - b. Under/over reporting adjustment is applied.
  - c. Risks are applied directly.

2. OPEC+ members with exemptions

- a. Produce at their base profile.
- b. Under/over reporting adjustments are not applied, as prior cuts skew the data.
- c. Risks are applied directly.

3. OPEC+ members without exemptions

- a. Produce at their base profile, or at the cut level, whichever is lower.
- b. Under/over reporting adjustments are not applied, as prior cuts skew the data.
- c. Risks are applied only if they exceed the buffer between the base and cut levels.

4. The OPEC+ cut risk

- a. Allows the maximum production level to rise by a percentage of the barrels held off the market by each member.

After these factors are applied to each country, the result is rolled up into a global production value that is fed into the supply/demand balance and price formation modules.

Reporting

Lastly, once the final numbers are generated, there are several reporting functions and graphs generated by the model that are useful for the KOMO quarterly reports. The outputs can include:

1. OPEC+ crude production vs. all other liquids
2. Regional production trends
3. Production trends by project type (conventional, offshore, etc.)
4. OPEC spare capacity estimates
5. Comparisons with other supply forecasts

Inventories and Price

Introduction

The relationship between crude oil prices and inventories is well documented. Indeed, the original Working curve, originated by Holbrook Working in 1933, was the first curve to illustrate the relationship between the basis of crude oil to inventories. It has often been referred to as a stylized fact for the industry and remains highly controversial to this day (Carter et al. 2007; Working 1933; Kaldor 1939).

Under normal market conditions, when the crude oil market is balanced, crude oil prices are generally in a state of contango. Futures prices trade above the spot price, factoring in the costs of storing a commodity, including warehousing costs, the costs of foregone interest, and a convenience yield on inventory (Fama 1987). When this is not the case, and futures prices trade below the spot price, the market is said to be in backwardation. Firms hold minimal, or just-in-time inventories, and tend to increase production to meet demand. The concepts of contango and convenience yield are defined in Appendix 6.

Pindyck (1994), and Dale et al. (1996) estimate the empirical relationship between inventories and commodity prices for agricultural commodities and energy markets, including heating oil. Carter et al. (2007) examine the Working curve when markets are in backwardation. Horsnell (1993) studies world oil markets and the factors underlying Brent crude oil prices, including factors underlying the futures market for oil, OPEC, taxation and forward markets.

Williams et al. (1991) study the economic theory underlying the relationship between the storage, prices and production of commodities. They investigate the role of storage on commodity markets and question whether storage or international trade is more effective as a buffer.

They also investigate the role of strategic reserves and commercial inventories in balancing world commodity markets. Working (1933) looks at the utility of futures trading and finds that there is a lot of dissent on the value of futures trading. These differences of opinion can be traced to several 'imperfect' concepts that emerged in connection with early academic writings on the subject.

More recently, Chambers et al. (1996) studied price fluctuations of storable commodities using a rational expectations equilibrium model. Miranda et al. (1993) combine stochastic-dynamic programming and disequilibrium maximum likelihood methods to estimate a dynamic nonlinear rational expectations model. Their study shows that government intervention in buffer stock activities has disequilibrating implications for world oil markets. It also shows that expectations concerning world oil prices have a direct effect on private supply and inventory decisions. Zhao et al. (2015) examine the relationship between commodity prices and the convenience yield. They show that convenience yields calculated assuming that commodity prices follow a mean-reverting process gives a better approximation than assuming prices follow geometric Brownian motion.

Blinder et al. (1991) study the history of economic thought underlying inventory behavior from the 1950s to the early 1990s. They find that the standard role of inventories in business cycle theory has changed significantly from the standard production smoothing (or buffer stock), but that investment in inventories remains a primary determinant of business cycles. Considine (1997) examines the determinants of inventory investment. The paper shows that the cost savings from holding inventories and changes in marginal production costs are important factors in the convenience yield and the structure of forward markets. Short-run price

and inventory dynamics are affected by the complex interactions between marginal production costs and inventories. Considine and Larson (2001) study the relationship between crude oil prices and inventories and find empirical evidence of the presence of risk premiums. Risk premiums rise sharply with price volatility, explaining backwardation in crude oil prices.

Several of these models provide valuable insights into the relationship between inventories and crude oil prices. However, the data requirements and complex theoretical formulations are well beyond the scope of what is required for a simple, and state-of-the-art forecasting method for crude oil prices that can be useful for policymakers. This study follows the work done by Ye (2002), which presents a short-term monthly forecasting model of West Texas Intermediate (WTI) crude oil spot prices using OECD inventory levels. The study is based on the simple observation that petroleum inventories reflect the balance between supply and demand and, as a result, provide an excellent indicator of the future direction of crude oil prices.

Fundamentals of the world oil market

This study is based on the premise that there is a direct and simple relationship between crude oil inventories and world oil prices. Specifically, changes in inventories provide an excellent measure of the level of excess supply (or demand) on world oil markets. Inventories will rise when crude oil supplies exceed demand, and they will fall when demand exceeds supply (Ye 2002). Assuming no losses or slippage, the following equation must necessarily hold:

$$I_t - I_{t-1} = S_t - D_t \quad (1)$$

Where:

$I_t \equiv$ The level of crude oil inventories at time t .

$S_t \equiv$ The level of crude oil supplies at time t .

$D_t \equiv$ The level of crude oil demand at time t .

Figure 9 illustrates the theoretical relationship between supply, demand, inventories and world oil prices. There is an immediate drawdown in inventories when oil markets are in disequilibrium, and crude oil demand exceeds supply. The excess demand places upward pressure on crude oil prices and downward pressure on inventories.

The extent of the pressure on crude prices will depend on the magnitude of the imbalance. Given the nature of world oil markets, there is a regular seasonal and trend component of the demand for inventories. The demand for oil tends to increase during the winter, so inventories are drawn down during this time and are replenished during the spring months. The trend component reflects the long-term economic growth rate. In short, there is a normal or desired level of inventories that is expected every year, and this target level has a significant seasonal component that tends to be considerably higher in the winter months. Prices can only be expected to respond positively if inventories are not being built to their desired levels (Ye 2002).

It is important to note that the level of target inventories is a theoretical construct. It reflects the aggregated 'normal' level of inventories that the industry desires in order to meet contractual obligations, provide a cushion for a complex supply chain that tends to deliver the product in 'batches,' and buffer unanticipated changes in the supply and demand for crude oil. Target inventories are derived from real OECD inventory data using a trend component reflecting long-term economic growth

and a component reflecting seasonal influences, such as the winter heating season, and the summer driving and cooling seasons.

In this model, the equilibrium price is achieved when the supply minus demand is equal to a normal inventory build, so that inventories are at their desired level. Relative inventories are defined as the difference between actual and desired inventories and are equal to zero when inventories are at their desired level, so that there is no pressure (positive or negative) on world oil prices. When actual inventories are below or above the desired level, there is positive or negative pressure on world oil prices. This relationship forms the theoretical basis for the relationship between Brent oil prices and world oil market fundamentals, and it is the foundation for the econometric model we use to forecast world oil prices.

Following Ye (2002), desired inventories (I_t^*) are assumed to grow at a constant pace and are defined as:

$$I_t^* = a_o + b_1 t + \sum_{i=2}^5 b_i \gamma_k \quad (2)$$

Where a_o , b_i $\equiv$ estimated coefficients, and a_o , b_i are the constant of the regression and the trend coefficient, respectively. b_i are estimated coefficients of three seasonal dummy variables. A geopolitical tension dummy variable, (γ_k) , $i, k = 2, 3, 4, 5$, reflects periods when the level of desired inventories rises due to the rise of geopolitical tensions.

Relative inventories (RI_t) are defined as the difference between desired and actual inventories:

$$RI_t = I_t - I_t^* \quad (3)$$

Figure 9. Theoretical relationship between supply, demand, inventories and world oil prices.

Source: KAPSARC, 2019.

References

The proposed econometric model to forecast oil prices follows the work done by Ye (2002). It uses an ARDL model to estimate the relationship between relative inventories and Brent crude oil prices.

Specifically,

$$P_t = \alpha + \sum_{i=0}^3 \beta_i RI_{t-i} + \vartheta P_{t-1} + \varepsilon_t \quad (4)$$

Where $\alpha, \beta_i, \vartheta \equiv$ estimated coefficients of the regression and $i=0,1,2,3$. $P_t \equiv$ Brent oil price at time t , and ε_t is the error term of the ordinary least squares regression.

Note: An ARDL model is a standard least squares econometric model that uses lagged values of the dependent and independent variables for estimation purposes (Greene 2003).

To reduce the level of multicollinearity, equation 4 was transformed as follows:

$$P_t = \alpha + \sum_{i=0}^2 \beta_i RI_{t-i} + \beta_3 RI_{t-3} + \vartheta P_{t-1} + \varepsilon_t \quad (5)$$

Equation 4 illustrates a basic econometric model that can be used to provide a dynamic short-term forecast for Brent oil prices, based on OECD inventories, and a lagged value of the Brent oil price. This is a simple model that can easily be estimated and updated using readily available data. It can also be completely specified in an Excel spreadsheet, or a similar software package, such as EViews.

Empirical results

To estimate this equation, it is necessary first to estimate I_t^* from the basic relationship described in equation 1. The results of the regression using

quarterly data on OECD inventories from March 2002 to December 2018 are reported in Table 1 (IEA 2018). The regressions were estimated using OLS with heteroskedasticity and autocorrelation corrected (HAC) standard errors and covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0). The estimated coefficients are all the right sign, which aligns with our *a priori* expectations, and the coefficient on the constant and trend variable is statistically significant at the 5% level. Appendix 5 summarizes the unit root and Jarque-Bera tests for all the variables used in this paper.

The Durbin-Watson statistic showed clear signs of autocorrelation, so the regressions were re-run using an alternative formulation, a generalized linear model (Newton-Raphson/Marquardt steps) which improved the significance of the estimated coefficient significantly. As there was no change in the estimated coefficients, the results are not reported here. The F-statistic and Wald F-statistic suggest that we can reject the null hypothesis that none of the variables in the regressions can be used to explain the variation in the dependent variable at the 1% level.

Table 1 illustrates the regression results for the Brent price forecasting relationship described by equation 4. The regression uses quarterly Brent crude oil price and OECD inventory data from March 2002 to December 2018 (IEA 2018). The equation was estimated using OLS with HAC standard errors and covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0). The coefficients α, ϑ , and β_i are statistically significant at the 5% level. The Durbin-Watson statistic shows no sign of autocorrelation, and the F-statistic and Wald F-statistic suggest that we can reject the null hypothesis that none of the variables in the regressions can be used to explain the variation in the dependent variable at the 1% level.

Table 1. Estimating desired inventories.

$$I_t^* = a_0 + b_1 t + \sum_{i=2}^5 b_i \gamma_k$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
a_0	3889.5980***	30.2148	128.7315	0.0000
b_1	8.9944***	1.1626	7.7361	0.0000
b_2	27.3116	19.2725	1.4171	0.1615
b_3	40.6475**	19.8657	2.0461	0.0450
b_4	-8.9209	17.5646	-0.5079	0.6133
b_5	125.5607***	18.2022	6.8981	0.0000
R-squared	0.7765	Mean dependent var	4222.0490	
Adjusted R-squared	0.7585	S.D. dependent var	202.4726	
S.E. of regression	99.4999	Akaike info criterion	12.1223	
F-statistic	43.0871	Durbin-Watson stat	0.2778	
Prob(F-statistic)	0.0000	Wald F-statistic	35.7226	
Prob(Wald F-statistic)	0.0000			

Note: **, and *** indicate that these estimated coefficients are statistically significant at the 10%, 5% and 1% levels respectively.

Source: KAPSARC, 2019.

Note: S.E. = standard error; var = variable; stat = statistic; std. = standard; prob = probability.

Table 1 illustrates the regression results for the Brent price forecasting relationship described by equation 4. The regression uses quarterly Brent crude oil price and OECD inventory data from March 2002 to December 2018 (IEA 2018). The equation was estimated using OLS with HAC standard errors and covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0). The coefficients α , ϑ , and β_1 are statistically significant at the 5% level. The Durbin-Watson statistic shows no sign of autocorrelation, and the F-statistic and Wald F-statistic suggest that we can reject the null hypothesis that none of the variables in the

regressions can be used to explain the variation in the dependent variable at the 1% level.

Figure 10 shows the actual values of Brent crude oil prices from June 2003 to December 2018. The generalized linear model can provide a dynamic forecast using lagged prices, and actual and lagged OECD inventories as reported by the EIA. The EIA provides monthly forecasts of these inventories in its Short-Term Energy Outlook (EIA 2019). The model can easily be updated, and the data is readily available to policymakers on a timely basis.

Figure 10. Brent crude oil prices (forecast vs. actual).

Source: KAPSARC, 2019.

Note: The slight lag in crude oil prices is justified by the dynamic nature of the crude oil industry, and the time it takes supply, demand and inventories to adjust to variations in the crude oil prices. These variations include changes in physical orders, demand and supply, and the time it takes to transport oil from production basins to stockpiles. The ARDL model structure accommodates both the sensitivity of the model to prices and the natural lags in the crude oil supply chain.

This analysis can be extended to provide a forecast of EIA inventories, using KAPSARC forecasts of supply and demand variables. The model used for this relationship is a simple extension of the original inventory model. That is to say, there is a direct and simple relationship between crude oil inventories and world oil prices. Changes in inventories provide

an excellent measure of the level of excess supply or demand in world oil markets:

$$I_t = I_{t-1} + S_t - D_t \quad (6)$$

This is a simple rearrangement of equation 0. The forecast equation for this relationship is

$$I_t = \alpha + \beta * I_{t-1} + \gamma * (S_t - D_t) + \sum_{i=2}^4 b_i \gamma_k + \varepsilon_t \quad (7)$$

Where α, β, γ estimated coefficients of the regression, b_i are estimated coefficients of 3 seasonal dummy variables; (γ_k) , $i, k = 2, 3, 4$ and ε_t is the error term of the ordinary least squares regression.

Table 2. Forecasting Brent oil prices.

$$P_t = \alpha + \sum_{i=0}^2 \beta_i RI_{t-i} + \vartheta P_{t-1} + \varepsilon_t$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
α_0	10.87319**	5.3563	2.0300	0.0470
β_1	-0.090618	0.0633	-1.4310	0.1579
β_2	-0.065807***	0.0232	-2.8332	0.0064
β_3	-0.018138	0.0241	-0.7524	0.4549
β_4	-0.005538	0.0201	-0.2754	0.7840
ϑ	0.856444***	0.0775	11.0481	0.0000
R-squared	0.8733	Mean dependent var		72.4546
Adjusted R-squared	0.8622	S.D. dependent var		27.5702
S.E. of regression	10.2357	Akaike info criterion		7.5800
F-statistic	78.5634	Durbin-Watson stat		1.7871
Prob(F-statistic)	0.0000	Wald F-statistic		206.7131
Prob(Wald F-statistic)	0.0000			

Note: **, and *** indicate that these estimated coefficients are statistically significant at the 10%, 5% and 1% levels respectively.

Source: KAPSARC, 2019.

Note: S.E. = standard error; var = variable; stat = statistic; std. = standard; prob = probability.

Table 3 illustrates the regression results for the estimation of actual OECD inventories described in equation 6. The regression uses quarterly OECD inventory data and IEA estimates of excess supply from March 2002 to December 2018 (EIA 2019). The equation was estimated using OLS with HAC standard errors and covariance (Bartlett kernel, Newey-West fixed bandwidth = 4.0). The coefficients α , β , b_3 and γ are statistically significant at the 5% level.

The Durbin-Watson statistic shows no sign of autocorrelation, and the F-statistic and Wald

F-statistic suggest that we can reject the null hypothesis that none of the variables in the regressions can be used to explain the variation in the dependent variable at the 1% level.

Figure 3 shows the actual versus the estimated values of OECD inventories from September 2003 to December 2018. The model can provide a reasonable dynamic forecast of IEA estimates of excess supply, and lagged values of OECD inventories as reported by the EIA. Once again, the model can easily be updated, and the data is readily available to policymakers on a timely basis.

Table 3. Estimating actual inventories.

$$I_t = \alpha + \beta * I_{t-1} + \gamma * (S_t - D_t) + \sum_{i=2}^4 b_i \gamma_k + \varepsilon_t$$

Variable	Coefficient	Std. Error	t-Statistic	Prob.
α	237.9207**	102.4320	2.3227	0.0236
β	0.94786***	0.0245	38.6812	0.0000
b_1	21.03686	13.2725	1.5850	0.1182
b_2	9.412993	10.9431	0.8602	0.3931
b_3	-64.63931***	11.6856	-5.5315	0.0000
γ	33.8772***	5.0584	6.6973	0.0000
R-squared	0.9726	Mean dependent var		4229.8970
Adjusted R-squared	0.9703	S.D. dependent var		200.2535
S.E. of regression	34.5151	Akaike info criterion		10.0072
F-statistic	425.6070	Durbin-Watson stat		1.8358
Prob(F-statistic)	0.0000	Wald F-statistic		354.4767
Prob(Wald F-statistic)	0.0000			

Note: *, **, and *** indicate that these estimated coefficients are statistically significant at the 10%, 5% and 1% levels respectively.

Source: KAPSARC, 2019.

Figure 11. Forecast vs. actual OECD inventories.

Sources: EIA; KAPSARC, 2019.

Conclusion

This paper presents a dynamic model to forecast Brent crude oil prices, based on a direct and simple relationship between crude oil inventories and world oil prices. Changes in inventories provide an excellent measure of the level of excess supply or demand in world oil markets. The results of this study show that this basic relationship between supply and demand and inventories holds between June 2003 and December 2018. This is an era that includes a period of extreme volatility on world oil markets. The estimation period encompasses several different market states, including the extreme US\$120 per barrel oil price of 2007, and the financial crisis and subsequent rapid decline of world oil prices in 2008.

The model is based on a simple econometric framework and publicly available data that can easily be updated, and it is readily available to policymakers on a timely basis. In the future, the model's framework might be extended to examine the formulation of desired commercial and strategic inventories, and to investigate the possibility of asymmetric behavior. The proposition is that the relationship between oil prices, excess supply and inventories differs in different market states, such as extreme backwardation or contango, and under different geopolitical scenarios, such as a war in the Gulf, or an environmental crisis or disaster.

Other Models Included in KOMO

The Delphi method

The Delphi method was developed in the 1950s by Olaf Helmer and Nicholas Rescher. It is based on the assumption that group judgment is more valid than individual judgment. For example, a panel of experts would, according to their theory, give better predictions on specific cases or scenarios.

As such, KOMO prepares a series of questions on specific topics related to either supply or demand. The questionnaire is then sent to experts in the oil market and gathered for numerical assessment (Appendix 7).

KOMO analysts will conduct the survey biannually and quantify the responses received.

The questions measure two aspects: certainty and impact.

Experts provide their judgment on the likelihood of an incident taking place in a specific period and choose between seven levels of certainty, ranging from impossible to certain. Furthermore, experts determine the possibility of the issue happening in four different timeframes, each representing six-month increment.

The experts also determine the potential impact of the incident in question, and if it would impact total production or only exports. The impacts are determined as strong, medium or low, and respondents can indicate whether they think the magnitude of the impacts will gradually increase or decrease.

For supply:

An election in country A will take place in the second half of 2019 and, as a result, the opposition

creates shortages or leaks supply production to tilt elections their way. However, the elections in country A are settled in February 2020.

Nevertheless, the current regime has been in power for 20 years, and expectations of unrest are eminent if the current regime wins the elections. There is only one pipe in the opposition's territory. It can produce 250 thousand barrels per day (Kb/d), and they are heavily reliant on it.

Country A produces 1 million barrels per day (MMb/d), exports 400 Kb/d and consumes the rest.

We could assume, based on the majority of expert responses, that the impact of the election will be low. We also expect that any disruption will diminish over time, so it will gradually decline and end in H2 2020.

For demand:

Demand numbers are calculated individually for each issue. Some are based on historical multipliers, while others depend on the changes of the independent variables in response to the shocks in the econometric model. Hence, the impact on demand will vary widely. As the questionnaire progresses, the numbers for all impacts on demand will be narrowed down (>1 MMb/d, > 500 Kb/d, >200 Kb/d, >100 Kb/d, >50 Kb/d and >10 Kb/d).

Putting numbers on the Delphi model

Certainty

Certainty is classified into five groups, each reflecting a degree of certainty. These numbers are calculated from the normal distribution (2, 1, 0, -1, -2).

Table 4. Survey certainty levels.

	Certainty
Almost certain	98% (+2 σ)
Probable	84% (+ σ)
Even chance	50%
Unlikely	16% (- σ)
Remote	2% (-2 σ)

Source: KAPSARC, 2019.

Demand

Four methods are used to calculate demand risk:

Multiplier: This method allows us to see the impact of a historic incident such as the 2008 economic crisis. Once we can see the level at which oil demand rises or falls in response to the crisis/incident, we can apply it to the forecast. However, to create a range of outcomes, we multiply the impact by the highest and lowest confidence percentages given in the Delphi model.

Econometrics: This method allows us to use the existing model as a tool. Most incidents that may occur can have an economic consequence, or certain policies can have an impact on interest rates or GDP. For example, the ongoing economic trade war between the U.S. and China could affect oil demand. Since trade between the two countries has a numerical value, it can be deducted from the GDP of both in the year t giving a new demand (d) as d^* . The result would be $(d - d^*)_t$. The range can be applied as detailed previously, by multiplying the difference between the confidence percentages.

Historic literature: This methodology does not forecast an impact but applies the historical recorded impact to a future scenario.

Temperature rise impact tool: For extreme weather events, the same tool, either included in method one or as included under the section of demand, can also be used.

Supply

The supply risk portion of the model is relatively simple, in that it merely multiplies certainty/probability by the likely impact. We benchmark these risks against historical events to ensure that they are within reasonable bounds. Future surveys will likely include targeted risk questions for newsworthy events, and recurring events such as hurricanes in the Gulf of Mexico.

Once KOMO has an output of prices, it benchmarks these to a confidence interval at 50%, 68% and 95% certainties, to ensure its forecast remains within the upper and lower limits of confidence intervals.

Brent Crude oil price confidence intervals

Perhaps one of the most popular methods of forecasting crude oil prices is to use the forward and futures curves, which aggregate contemporary market views from speculators worldwide. This method has traditionally provided poor forecasts, but the curves do illustrate the price at which it is possible to buy or sell a futures contract at a future date, for a price agreed upon today. Standard American-style options (call and put) can be exercised at any time during the lifetime of the option. An American-style option is always

at least as valuable as its counterpart. While futures curves reflect current market views, they do not take into account physical limitations such as market liquidity and imperfections in capital markets. To compensate for these deficiencies, and market volatility and uncertainty, KAPSARC has constructed a confidence interval, used in KOMO, derived from options market information (CME Group) for at-the-money options contracts. An additional paper on the confidence interval calculator and the Cox-Rubinstein binomial model used for pricing American-style options is expected to be published by KAPSARC at a later date, since this model is not only used for KOMO.

Figure 12. KAPSARC internal calculations of the Brent crude oil price and 68% confidence intervals.

Source: KAPSARC internal calculations, based on MYMEX data, CME Group, FINCAD, March 2019.

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Other sources:

Demand: KOMO's historical base comes from the IEA's demand figures for 2017. The growth for 2018 is based on the IEA's data for 2017 demand growth, deducted from KOMO's demand numbers for 2018. Demand projections for 2019 and 2020 are generated by KOMO.

Gross domestic product (GDP): Quarterly GDP figures come from Oxford Economics, and yearly GDP figures are taken from the IMF. They are described as nominal prices (purchasing power parity, billions of international dollars). <https://www.imf.org/external/datamapper/PPPGDP@WEO/OEMDC/ADVEC/WEOWORLD?year=2018> (accessed May 2019).

Price: Historical Brent prices come from the EIA and are available on KAPSARC's Data Portal. <https://datasource.kapsarc.org/explore/?q=brent+prices&disjunctive.theme&disjunctive.country&disjunctive.iso-region&disjunctive.publisher&disjunctive.keyword&sort=modified> (accessed May 2019).

Oxford Economics

Long-term interest rates: The long-term interest rate time series includes quarterly values for government bonds for all countries from the International Financial Statistics (IFS) database (interest rate selected indicators, government bonds, percent per annum)

(Smith and Galesi 2014). The data from Q2 1979 to Q4 2016 are taken from Mohaddes and Raissi (2018). The numbers from Q4 2016 to Q3 2018 are taken from the IFS ("IMF Data" 2018). IFS data for interest rates, government securities, and government bonds are used to extend the series in 2016 for all countries except India for which long-term interest rate data are available: Australia, Canada, France, Germany, Japan, South Korea, New Zealand, Norway, South Africa, the United Kingdom, and the United States. 2016 long-term interest rates are extended using these series from Q2 2013 to Q4 2016.

For India, the 10-year government bond yield from the Reserve Bank of India was used from Q2 1996 to Q3 2018. For the Eurozone, the 1979-2016 dataset was extended to 2018 using the quarterly growth rates for the European Union Convergence Criteria. Maastricht criterion bond yields (mcby) are long-term interest rates used as a convergence criterion for the European Monetary Union, based on the Maastricht Treaty ("Eurostat - Data Explorer" 2019). For Australia, Canada, Japan, Norway, New Zealand, and the United States the data set was extended to the 2018 vintage using quarterly growth rates from the 10-year government bond yield from the Federal Reserve Bank of St Louis (FRED 2019).

Post-2018 data for all countries has gone through an autoregressive model that included a time series to capture continuity.

Historical temperatures:
http://sdwebx.worldbank.org/climateportal/index.cfm?page=downscaled_data_download&menu=historical

Temperature projections:
http://sdwebx.worldbank.org/climateportal/index.cfm?page=downscaled_data_download&menu=futureGCM

Notes

A yellow geometric graphic consisting of several overlapping triangles and polygons, located in the top-left corner of the page.

Notes

Appendix 1. Country and territory groupings

Countries		Countries	
Africa	Algeria	Africa	Sierra Leone
Africa	Angola	Africa	Somalia
Africa	Benin	Africa	South Africa
Africa	Botswana	Africa	South Sudan
Africa	Burkina Faso	Africa	Sudan
Africa	Burundi	Africa	Tanzania
Africa	Cameroon	Africa	Togo
Africa	Cape Verde	Africa	Tunisia
Africa	Central African Republic	Africa	Uganda
Africa	Chad	Africa	Zambia
Africa	Comoros	Africa	Zimbabwe
Africa	Democratic Republic of Congo	Americas	Antigua and Barbuda
Africa	Djibouti	Americas	Argentina
Africa	Egypt	Americas	Bahamas
Africa	Equatorial Guinea	Americas	Barbados
Africa	Eritrea	Americas	Belize
Africa	Eswatini (Swaziland)	Americas	Bolivia
Africa	Ethiopia	Americas	Brazil
Africa	Gabon	Americas	Canada
Africa	The Gambia	Americas	Chile
Africa	Ghana	Americas	Colombia
Africa	Guinea	Americas	Costa Rica
Africa	Guinea-Bissau	Americas	Cuba
Africa	Ivory Coast	Americas	Dominica
Africa	Kenya	Americas	Dominican Republic
Africa	Lesotho	Americas	Ecuador
Africa	Liberia	Americas	El Salvador
Africa	Libya	Americas	Grenada
Africa	Madagascar	Americas	Guatemala
Africa	Malawi	Americas	Guyana
Africa	Mali	Americas	Haiti
Africa	Mauritania	Americas	Honduras
Africa	Mauritius	Americas	Jamaica
Africa	Morocco	Americas	Martinique
Africa	Mozambique	Americas	Mexico
Africa	Namibia	Americas	Nicaragua
Africa	Niger	Americas	Panama
Africa	Nigeria	Americas	Paraguay
Africa	Republic of Congo	Americas	Peru
Africa	Rwanda	Americas	St. Kitts and Nevis
Africa	Sao Tome and Principe	Americas	St. Lucia
Africa	Senegal	Americas	St. Vincent and the Grenadines
Africa	Seychelles	Americas	Suriname

Appendix 1. Country and territory groupings

	Countries		Countries
Americas	Trinidad and Tobago	Asia	Vietnam
Americas	United States and territories	Eurasia	Albania
Americas	Uruguay	Eurasia	Armenia
Americas	Venezuela	Eurasia	Azerbaijan
Asia	Afghanistan	Eurasia	Belarus
Asia	Australia	Eurasia	Bosnia and Herzegovina
Asia	Bangladesh	Eurasia	Bulgaria
Asia	Bhutan	Eurasia	Croatia
Asia	Brunei	Eurasia	Cyprus
Asia	Cambodia	Eurasia	Former Yugoslav Republic of Macedonia
Asia	China	Eurasia	Georgia
Asia	Chinese Taipei	Eurasia	Kazakhstan
Asia	Cook Islands	Eurasia	Kosovo
Asia	Fiji	Eurasia	Kyrgyzstan
Asia	India	Eurasia	Lithuania
Asia	Indonesia	Eurasia	Malta
Asia	Japan	Eurasia	Moldova
Asia	Kiribati	Eurasia	Montenegro
Asia	Korea DPR	Eurasia	Romania
Asia	Lao People's Democratic Republic	Eurasia	Russia
Asia	Malaysia	Eurasia	Serbia
Asia	Maldives	Eurasia	Tajikistan
Asia	Marshall islands	Eurasia	Turkmenistan
Asia	Micronesia (Federated States of)	Eurasia	Ukraine
Asia	Mongolia	Eurasia	Uzbekistan
Asia	Myanmar	Europe	Austria
Asia	Nauru	Europe	Belgium
Asia	Nepal	Europe	Czech Republic
Asia	New Zealand	Europe	Denmark
Asia	Pakistan	Europe	Estonia
Asia	Palau	Europe	Finland
Asia	Papua New Guinea	Europe	France
Asia	Philippines	Europe	Germany
Asia	Republic of Korea	Europe	Greece
Asia	Samoa	Europe	Hungary
Asia	Singapore	Europe	Iceland
Asia	Solomon Islands	Europe	Ireland
Asia	Sri Lanka	Europe	Italy
Asia	Thailand	Europe	Latvia
Asia	Timor-Leste	Europe	Luxembourg
Asia	Tonga	Europe	Norway
Asia	Tuvalu	Europe	Poland
Asia	Vanuatu	Europe	Portugal

Countries		Territories		
Europe	Slovak Republic	Africa	Mayotte	France
Europe	Slovenia	Africa	Réunion	France
Europe	Spain	Africa	Western Sahara	Morocco
Europe	Sweden	Americas	Anguilla	United Kingdom
Europe	Switzerland	Americas	Aruba	Netherlands
Europe	The Netherlands	Americas	Bermuda	United Kingdom
Europe	Turkey	Americas	British Virgin Islands	United Kingdom
Europe	United Kingdom	Americas	Virgin Islands	United States
Middle East	Bahrain	Americas	Cayman Islands	United Kingdom
Middle East	Iran	Americas	Curaçao	Netherlands
Middle East	Iraq	Americas	French Guiana	France
Middle East	Israel	Americas	Guadeloupe	France
Middle East	Jordan	Americas	Montserrat	United Kingdom
Middle East	Kuwait	Americas	Netherlands Antilles	Netherlands
Middle East	Lebanon	Americas	St. Pierre et Miquelon	France
Middle East	Oman	Americas	Turks And Caicos Islands	United Kingdom
Middle East	Qatar	Asia	French Polynesia	France
Middle East	Saudi Arabia	Asia	Guam	United States
Middle East	Syria	Asia	Hong Kong (China)	China
Middle East	United Arab Emirates	Asia	New Caledonia	France
Middle East	Yemen	Asia	Niue	New Zealand
		Europe	Gibraltar*	Spain
		Europe	Andorra	Spain
		Europe	Monaco	France
		Europe	San Marino	Italy

Not a Member of the UN

Recognized as a country by some

International recognition of sovereignty

OECD Member

* Other Non-OECD European members

Note: DPR = Democratic People's Republic

Appendix 2. Country groupings for global oil demand

Americas	OECD	United States	Middle East	OECD	Israel
		Canada		Non-OECD	Bahrain
		Mexico			Iraq
		Chile			Kuwait
	Non-OECD	Argentina			Oman
		Brazil			Saudi Arabia
		Venezuela			Qatar
		Rest of (RO) Latin America			United Arab Emirates
Europe	OECD	Germany	Africa	Non-OECD	Iran
		France			RO Middle East
		United Kingdom			Egypt
		Poland			South Africa
		Turkey			Other Africa
		RO OECD Europe	Eurasia	Non-OECD	Russia
Asia-Oceania	OECD	Australia			RO Eurasia
		Japan			
		Republic of Korea			
		New Zealand			
	Non-OECD	China			
		India			
		Indonesia			
		RO Asia			

Appendix 3. Data sources for estimating oil demand seasonality

Countries/Regions	From	To	Source	Exemption 20-	Note
United States	2005	2017	IEA	2,3,5,8,9,13,15,17 17	Years avoided due to data availability. Years avoided due to strong disruptions.
Canada	2005	2017	IEA		
Mexico	2005	2017	IEA		
Chile	2005	2017	IEA		
Argentina	2002	2017	JODI		
Brazil	2002	2017	JODI		
Venezuela	2002	2017	JODI		
RO Latin America	2002	2017	JODI		
Germany	2005	2017	IEA		
France	2005	2017	IEA		
United Kingdom	2005	2017	IEA		
Poland	2005	2017	IEA		
Turkey	2005	2017	IEA		
RO OECD Europe	2005	2017	IEA		
Australia	2005	2017	IEA		
Japan	2005	2017	IEA		
Republic of Korea	2005	2017	IEA		
New Zealand	2005	2017	IEA		
China	2004	2017	JODI	16	Reviewed 18-10-2018 Years avoided due to data availability.
India	2002	2017	PPAC		
Indonesia	2006	2017	JODI		
RO Asia	2007	2017	JODI		
Israel	2005	2017	IEA		
Bahrain	2015	2017	JODI		
Iraq	2009	2017	JODI		
Kuwait	2009	2017	JODI		
Oman	2009	2015	JODI		
Saudi Arabia	2009	2017	JODI		
Qatar	2009	2017	JODI		
UAE	2009	2017	JODI	11,12	Years avoided due to data availability. This is an estimation.
Iran	2009	2017	JODI		
RO Middle East	2002	2017	EI-OMI		
Egypt	2002	2017	JODI		
South Africa	2002	2017	JODI		
Other Africa	2009	2017	JODI		
Russia	2002	2017	JODI		
RO Eurasia	2003	2017	JODI		

Note: RO = rest of; IEA = International Energy Agency; JODI = Joint Organisations Data Initiative; PPAC = Petroleum Planning & Analysis Cell; EI-OMI = Energy Intelligence.

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

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Regression results

Prices

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Summary statistics and unit root tests

									Critical values					
	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob				1%	5%	10%
LN-Pr	4.060	4.143	4.940	2.991	0.520	-0.336	1.959	0.09	ADF	-1.94	0.3121	-3.5	-2.9	-2.6
									PP	-1.90	0.3287	-3.5	-2.9	-2.6

Note: LN-Pr = Logged price; Std. dev. = standard deviation; JB-prob = Jarque-Bera probability test; T-stat = t-statistic; Prob = T-stat probability.

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Countries

Argentina

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB- prob.	T-stat Prob.		1%	5%	10%	
LNDM	6.471	6.502	6.671	6.125	0.161	-0.556	1.992	0.03	ADF	-0.84	0.80	-3.5	-2.9	-2.6
									PP	-1.05	0.73	-3.5	-2.9	-2.6
LNGDP	11.378	11.415	12.033	10.154	0.536	-0.612	2.282	0.04	ADF	-0.91	0.78	-3.5	-2.9	-2.6
									PP	-1.05	0.73	-3.5	-2.9	-2.6
R	0.033	0.030	0.094	0.010	0.016	1.380	6.185	0.00	ADF	-2.49	0.12	-3.5	-2.9	-2.6
									PP	-2.94	0.05	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/09/19 Time: 10:53

Sample (adjusted): Q3 2000 – Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.457	0.276	1.653	0.103
LNGDP	0.082	0.035	2.374	0.021
LNGDP(-1)	-0.074	0.032	-2.315	0.024
LOG(PR(-1))	0.016	0.021	0.755	0.453
LOG(PR(-2))	0.007	0.021	0.322	0.748
R	-0.626	0.337	-1.854	0.069
R(-1)	0.662	0.332	1.995	0.050
D1	0.029	0.010	3.028	0.004
D2	0.044	0.011	4.169	0.000
D3	0.023	0.009	2.467	0.016
DV	-0.014	0.011	-1.221	0.227
LNDM(-1)	0.899	0.074	12.148	0.000

R-squared	0.974
Adjusted R-squared	0.970
S.E. of regression	0.028
Sum squared residual	0.048
Log likelihood	166.222
F-statistic	213.801
Prob (F-statistic)	0.000

Mean dependent variable	6.475
S.D. dependent variable	0.161
Akaike information criterion	-4.168
Schwarz criterion	-3.795
Hannan-Quinn criterion	-4.019
Durbin-Watson statistic	2.328

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Australia

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	6.910	6.901	7.112	6.680	0.117	-0.219	2.017	0.160	ADF	-1.36	0.60	-3.5	-2.9	-2.6
									PP	-0.92	0.78	-3.5	-2.9	-2.6
LNGDP	12.355	12.554	12.899	11.432	0.478	-0.680	2.099	0.015	ADF	-1.73	0.41	-3.5	-2.9	-2.6
									PP	-1.51	0.52	-3.5	-2.9	-2.6
R	0.010	0.011	0.017	0.003	0.004	-0.290	1.839	0.070	ADF	-0.96	0.76	-3.5	-2.9	-2.6
									PP	-0.73	0.83	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/06/19 Time: 11:23

Sample (adjusted): Q3 2000 – Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.943	0.604	1.559	0.124
LNGDP	0.082	0.033	2.476	0.016
LOG(PR(-1))	-0.006	0.032	-0.194	0.847
LOG(PR(-2))	-0.020	0.027	-0.726	0.471
R	-3.264	5.850	-0.558	0.579
R(-1)	2.666	6.123	0.435	0.665
D1	-0.041	0.012	-3.342	0.001
D2	-0.016	0.012	-1.282	0.205
D3	-0.020	0.012	-1.696	0.095
DV	0.002	0.015	0.138	0.890
LNDM(-1)	0.737	0.083	8.922	0.000

R-squared	0.918
Adjusted R-squared	0.905
S.E. of regression	0.036
Sum squared residual	0.081
Log likelihood	147.383
F-statistic	70.467
Prob (F-statistic)	0.000
Mean dependent variable	6.914
S.D. dependent variable	0.116
Akaike information criterion	-3.686
Schwarz criterion	-3.344
Hannan-Quinn criterion	-3.549
Durbin-Watson statistic	1.911

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Bahrain

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%
LNDM	3.773	3.951	4.234	3.178	0.416	-0.255	1.272	0.141	ADF	-0.67 0.84	-3.7	-3.0	-2.6
									PP	-0.78 0.81	-3.7	-3.0	-2.6
LNGDP	3.452	3.437	4.320	2.521	0.567	-0.039	1.652	0.332	ADF	-0.97 0.75	-3.7	-3.0	-2.6
									PP	-0.90 0.77	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00 0.00	0.0	0.0	0.0
									PP	0.00 0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 09:41

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.123	0.185	0.665	0.514
LNGDP	1.555	0.832	1.868	0.076
LNGDP(-1)	-1.441	0.788	-1.828	0.083
LOG(PR(-1))	0.030	0.057	0.532	0.600
LOG(PR(-2))	-0.076	0.047	-1.625	0.120
LNDM(-1)	0.889	0.130	6.841	0.000
DV	-0.006	0.059	-0.104	0.918

R-squared	0.918
Adjusted R-squared	0.905
S.E. of regression	0.036
Sum squared residual	0.081
Log likelihood	147.383
F-statistic	70.467
Prob (F-statistic)	0.000

Mean dependent variable	6.914
S.D. dependent variable	0.116
Akaike information criterion	-3.686
Schwarz criterion	-3.344
Hannan-Quinn criterion	-3.549
Durbin-Watson statistic	1.911

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Brazil

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	7.851	7.862	8.112	7.580	0.166	-0.052	1.412	0.018	ADF	-1.07	0.72	-3.5	-2.9	-2.6
									PP	-0.74	0.83	-3.5	-2.9	-2.6
LNGDP	12.730	12.942	13.433	11.60	0.574	-0.535	1.784	0.016	ADF	-1.22	0.66	-3.5	-2.9	-2.6
									PP	-1.23	0.66	-3.5	-2.9	-2.6
R	0.031	0.030	0.056	0.015	0.010	0.421	2.602	0.253	ADF	-1.13	0.70	-3.5	-2.9	-2.6
									PP	-0.87	0.79	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/09/19 Time: 11:11

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.434	0.211	2.052	0.044
LNGDP	0.039	0.023	1.698	0.095
LNGDP(-1)	-0.018	0.030	-0.594	0.555
LOG(PR(-1))	0.007	0.013	0.575	0.568
LOG(PR(-2))	-0.009	0.013	-0.722	0.473
R	-1.461	0.794	-1.840	0.071
R(-1)	0.803	0.820	0.979	0.332
D1	-0.035	0.005	-6.986	0.000
D2	0.016	0.005	3.086	0.003
D3	0.028	0.005	5.633	0.000
LNDM(-1)	0.914	0.040	22.670	0.000
DV	-0.005	0.007	-0.765	0.447

R-squared	0.993
Adjusted R-squared	0.992
S.E. of regression	0.015
Sum squared residual	0.013
Log likelihood	213.998
F-statistic	835.763
Prob (F-statistic)	0.000

Mean dependent variable	7.857
S.D. dependent variable	0.165
Akaike information criterion	-5.459
Schwarz criterion	-5.086
Hannan-Quinn criterion	-5.310
Durbin-Watson statistic	2.351

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Canada

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB- prob.	T-stat		Prob.	1%	5%	10%
LNDM	7.744	7.761	7.847	7.577	0.071	-0.831	2.788	0.012	ADF	-1.07	0.72	-3.5	-2.9	-2.6
									PP	-0.74	0.83	-3.5	-2.9	-2.6
LNGDP	12.713	12.853	13.048	12.10	0.319	-0.814	2.209	0.006	ADF	-1.22	0.66	-3.5	-2.9	-2.6
									PP	-1.23	0.66	-3.5	-2.9	-2.6
R	0.005	0.003	0.013	0.000	0.004	0.734	2.374	0.018	ADF	-1.13	0.70	-3.5	-2.9	-2.6
										-0.87	0.79	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/05/19 Time: 08:49

Sample (adjusted): Q4 2000 - Q4 2018

Included observations: 73 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	2.488	0.533	4.671	0.000
LNGDP	0.106	0.072	1.474	0.146
LNGDP(-1)	0.058	0.072	0.806	0.424
LOG(PR(-1))	-0.043	0.018	-2.382	0.020
LOG(PR(-2))	0.003	0.023	0.123	0.903
LOG(PR(-3))	0.005	0.015	0.341	0.735
R	9.872	3.733	2.645	0.010
R(-1)	-8.278	3.862	-2.143	0.036
D1	-0.015	0.007	-2.131	0.037
D2	-0.032	0.007	-4.444	0.000
D3	0.015	0.009	1.791	0.078
LNDM(-1)	0.428	0.115	3.708	0.001
DV	-0.004558	0.0082	-0.55612	0.58

R-squared	0.921
Adjusted R-squared	0.905
S.E. of regression	0.020
Sum squared residual	0.024
Log likelihood	189.559
F-statistic	58.191
Prob (F-statistic)	0.000

Mean dependent variable	7.750
S.D. dependent variable	0.065
Akaike information criterion	-4.837
Schwarz criterion	-4.429
Hannan-Quinn criterion	-4.675
Durbin-Watson statistic	1.892

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Chile

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	5.727	5.788	5.996	5.429	0.161	-0.486	1.814	0.024	ADF	-1.80	0.38	-3.5	-2.9	-2.6
									PP	-1.60	0.48	-3.5	-2.9	-2.6
LNGDP	10.637	10.810	11.263	9.723	0.515	-0.592	1.837	0.013	ADF	-1.14	0.70	-3.5	-2.9	-2.6
									PP	-0.94	0.77	-3.5	-2.9	-2.6
R	0.011	0.010	0.023	0.002	0.005	0.552	3.148	0.141	ADF	-3.13	0.03	-3.5	-2.9	-2.6
									PP	-2.83	0.06	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/05/19 Time: 12:21

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.900	0.320	2.814	0.007
LNGDP(-1)	0.096	0.038	2.549	0.013
LOG(PR(-1))	-0.037	0.034	-1.082	0.283
LOG(PR(-2))	0.028	0.035	0.802	0.425
R	1.986	2.829	0.702	0.485
R(-1)	-2.005	2.697	-0.743	0.460
D1	0.056	0.016	3.571	0.001
D2	0.056	0.017	3.405	0.001
D3	0.029	0.015	1.910	0.061
LNDM(-1)	0.665	0.104	6.377	0.000
DV	0.039	0.027	1.445	0.153

R-squared	0.929
Adjusted R-squared	0.917
S.E. of regression	0.045
Sum squared residual	0.130
Log likelihood	129.790
F-statistic	82.095
Prob (F-statistic)	0.000
Mean dependent variable	5.734
S.D. dependent variable	0.158
Akaike information criterion	-3.211
Schwarz criterion	-2.868
Hannan-Quinn criterion	-3.074
Durbin-Watson statistic	2.017

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

China

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	9.004	9.012	9.494	8.392	0.324	-0.269	1.945	0.108	ADF	-1.01	0.75	-3.5	-2.9	-2.6
									PP	-1.12	0.70	-3.5	-2.9	-2.6
LNGDP	13.942	14.071	15.125	12.46	0.835	-0.251	1.595	0.030	ADF	-1.74	0.41	-3.5	-2.9	-2.6
									PP	-1.33	0.61	-3.5	-2.9	-2.6
R	0.007	0.006	0.012	0.005	0.002	1.301	4.335	0.000	ADF	-1.93	0.32	-3.5	-2.9	-2.6
									PP	-1.70	0.43	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/07/19 Time: 11:52

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.939	0.273	3.433	0.001
LNGDP	0.109	0.031	3.508	0.001
LOG(PR(-1))	0.067	0.026	2.543	0.013
LOG(PR(-2))	-0.085	0.027	-3.134	0.003
R	-1.259	5.896	-0.213	0.832
R(-1)	-2.778	6.453	-0.431	0.668
D1	0.011	0.013	0.817	0.417
D2	0.015	0.012	1.291	0.201
D3	-0.019	0.012	-1.612	0.112
LNDM(-1)	0.739	0.075	9.808	0.000
DV	0.011	0.023	0.476	0.636

R-squared	0.990
Adjusted R-squared	0.988
S.E. of regression	0.034
Sum squared residual	0.072
Log likelihood	151.399
F-statistic	615.126
Prob (F-statistic)	0.000

Mean dependent variable	9.020
S.D. dependent variable	0.313
Akaike information criterion	-3.795
Schwarz criterion	-3.452
Hannan-Quinn criterion	-3.658
Durbin-Watson statistic	2.162

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Egypt

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	6.417	6.444	6.777	6.045	0.242	-0.063	1.628	0.318	ADF	-0.82	0.80	-3.7	-3.0	-2.6
									PP	-0.84	0.79	-3.7	-3.0	-2.6
LNGDP	6.302	6.281	7.168	5.430	0.550	-0.061	1.681	0.346	ADF	-0.65	0.84	-3.7	-3.0	-2.6
									PP	-0.18	0.93	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 14:04

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.565	0.707	2.213	0.039
LNGDP	0.534	0.497	1.076	0.296
LNGDP(-1)	-0.311	0.487	-0.638	0.531
LOG(PR(-1))	-0.019	0.025	-0.740	0.468
LOG(PR(-2))	0.020	0.025	0.802	0.433
LNDM(-1)	0.536	0.199	2.688	0.015
DV_REV	-0.024	0.042	-0.562	0.580
TS_CURRENCY	-0.040	0.015	-2.701	0.014

R-squared	0.981
Adjusted R-squared	0.974
S.E. of regression	0.038
Sum squared residual	0.027
Log likelihood	55.034
F-statistic	140.024
Prob (F-statistic)	0.000
Mean dependent variable	6.441
S.D. dependent variable	0.233
Akaike information criterion	-3.484
Schwarz criterion	-3.100
Hannan-Quinn criterion	-3.370
Durbin-Watson statistic	1.697

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

France

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	7.525	7.525	7.662	7.394	0.080	0.059	1.684	0.063	ADF	-0.57	0.87	-3.5	-2.9	-2.6
									PP	-2.95	0.04	-3.5	-2.9	-2.6
LNGDP	13.268	13.350	13.568	12.70	0.247	-1.144	3.042	0.000	ADF	-2.34	0.16	-3.5	-2.9	-2.6
									PP	-1.85	0.35	-3.5	-2.9	-2.6
R	0.004	0.003	0.012	-0.003	0.004	0.192	1.612	0.037	ADF	-1.49	0.54	-3.5	-2.9	-2.6
									PP	-0.77	0.82	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/05/19 Time: 13:39

Sample (adjusted): Q4 2000 - Q4 2018

Included observations: 73 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	3.273	0.831	3.937	0.000
LNGDP	0.075	0.091	0.826	0.412
LNGDP(-1)	-0.038	0.091	-0.418	0.678
LOG(PR(-1))	-0.022	0.024	-0.931	0.356
LOG(PR(-2))	0.049	0.032	1.549	0.127
LOG(PR(-3))	-0.049	0.023	-2.139	0.037
R	7.674	5.757	1.333	0.188
R(-1)	0.554	6.747	0.082	0.935
D1	0.024	0.009	2.504	0.015
D2	-0.032468	0.01017	-3.1923	0.002
D3	0.021403	0.00997	2.14752	0.036
DV	-0.01626	0.01895	-0.8581	0.394
LNDM(-1)	0.507567	0.11068	4.58576	0

R-squared	0.901
Adjusted R-squared	0.881
S.E. of regression	0.028
Sum squared residual	0.045
Log likelihood	165.818
F-statistic	45.608
Prob (F-statistic)	0.000

Mean dependent variable	7.522
S.D. dependent variable	0.080
Akaike information criterion	-4.187
Schwarz criterion	-3.779
Hannan-Quinn criterion	-4.024
Durbin-Watson statistic	1.968

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Germany

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%
LNDM	7.829	7.814	7.999	7.733	0.066	0.525	2.349	0.09	ADF -1.33	0.61	-3.5	-2.9	-2.6
									PP -3.30	0.02	-3.5	-2.9	-2.6
LNGDP	13.568	13.650	13.845	13.04	0.232	-0.992	2.768	0.00	ADF -1.98	0.30	-3.5	-2.9	-2.6
									PP -1.49	0.53	-3.5	-2.9	-2.6
R	0.004	0.003	0.012	-0.003	0.004	0.192	1.612	0.04	ADF -1.49	0.54	-3.5	-2.9	-2.6
									PP -0.77	0.82	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/05/19 Time: 13:01

Sample (adjusted): Q4 2000 - Q4 2018

Included observations: 73 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	6.598	1.224	5.389	0.000
LNGDP	0.039	0.090	0.436	0.664
LNGDP(-1)	-0.041	0.089	-0.461	0.647
LOG(PR(-1))	-0.027	0.023	-1.170	0.247
LOG(PR(-2))	0.052	0.032	1.638	0.107
LOG(PR(-3))	-0.036	0.023	-1.559	0.124
R	-2.951	5.763	-0.512	0.610
R(-1)	13.081	6.497	2.013	0.049
D1	-0.027	0.010	-2.818	0.007
D2	-0.015153	0.0117	-1.295	0.200
D3	0.028152	0.01099	2.56065	0.013
DV	-0.066555	0.01849	-3.5996	0.001
LNDM(-1)	0.162983	0.11823	1.37854	0.173

R-squared	0.846
Adjusted R-squared	0.815
S.E. of regression	0.028
Sum squared residual	0.046
Log likelihood	165.397
F-statistic	27.384
Prob (F-statistic)	0.000
Mean dependent variable	7.825
S.D. dependent variable	0.064
Akaike information criterion	-4.175
Schwarz criterion	-3.767
Hannan-Quinn criterion	-4.013
Durbin-Watson statistic	1.939

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

India

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	8.080	8.076	8.499	7.707	0.233	0.126	1.840	0.107	ADF	-0.57	0.87	-3.5	-2.9	-2.6
									PP	-2.95	0.04	-3.5	-2.9	-2.6
LNGDP	12.612	12.709	13.466	11.58	0.585	-0.352	1.715	0.033	ADF	-2.34	0.16	-3.5	-2.9	-2.6
									PP	-1.85	0.35	-3.5	-2.9	-2.6
R	0.016	0.016	0.023	0.009	0.003	-0.187	2.231	0.314	ADF	-1.49	0.54	-3.5	-2.9	-2.6
									PP	-0.77	0.82	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/07/19 Time: 12:18

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.783	0.239	3.271	0.002
LNGDP	0.132	0.040	3.276	0.002
LOG(PR(-1))	-0.043	0.019	-2.274	0.026
LOG(PR(-2))	0.009	0.018	0.470	0.640
R	-0.639	1.803	-0.355	0.724
R(-1)	1.789	1.745	1.025	0.309
D1	-0.012	0.008	-1.499	0.139
D2	-0.034	0.011	-3.182	0.002
D3	-0.092	0.011	-8.135	0.000
DV	-0.001575	0.00987	-0.1596	0.874
LNDM(-1)	0.716824	0.08626	8.31022	0.000

R-squared	0.991
Adjusted R-squared	0.989
S.E. of regression	0.024
Sum squared residual	0.035
Log likelihood	178.002
F-statistic	684.094
Prob (F-statistic)	0.000
Mean dependent variable	8.088
S.D. dependent variable	0.230
Akaike information criterion	-4.514
Schwarz criterion	-4.171
Hannan-Quinn criterion	-4.377
Durbin-Watson statistic	2.391

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Indonesia

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	7.273	7.263	7.519	6.744	0.162	-0.428	2.719	0.277	ADF	-2.46	0.13	-3.5	-2.9	-2.6
									PP	-2.32	0.17	-3.5	-2.9	-2.6
LNGDP	11.773	11.971	12.484	10.60	0.625	-0.491	1.733	0.017	ADF	-1.73	0.41	-3.5	-2.9	-2.6
									PP	-1.26	0.64	-3.5	-2.9	-2.6
R	0.017	0.015	0.036	0.008	0.007	1.145	3.516	0.000	ADF	-1.80	0.38	-3.5	-2.9	-2.6
									PP	-1.92	0.32	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/07/19 Time: 13:02

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	3.213	0.725	4.434	0.000
LNGDP	-0.065	0.242	-0.269	0.789
LNGDP(-1)	0.196	0.250	0.784	0.436
LOG(PR(-1))	0.036	0.068	0.527	0.600
LOG(PR(-2))	-0.063	0.068	-0.917	0.363
R	-0.952	4.586	-0.208	0.836
R(-1)	-1.841	4.620	-0.399	0.692
D1	0.031	0.032	0.953	0.344
D2	0.036	0.032	1.111	0.271
D3	0.025567	0.03104	0.82374	0.413
LNDM(-1)	0.366041	0.12066	3.03362	0.004
DV	-0.04188	0.03372	-1.242	0.219

R-squared	0.790
Adjusted R-squared	0.753
S.E. of regression	0.080
Sum squared residual	0.393
Log likelihood	88.851
F-statistic	21.200
Prob (F-statistic)	0.000

Mean dependent variable	7.280
S.D. dependent variable	0.160
Akaike information criterion	-2.077
Schwarz criterion	-1.703
Hannan-Quinn criterion	-1.928
Durbin-Watson statistic	1.894

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Iran

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB- prob.	T-stat		Prob.	1%	5%	10%
LNDM	7.579	7.592	7.624	7.488	0.046	-0.748	2.228	0.49	ADF	-1.93	0.31	-4.1	-3.1	-2.7
									PP	-1.80	0.36	-4.1	-3.1	-2.7
LNGDP	7.216	7.195	7.410	7.076	0.115	0.604	2.135	0.58	ADF	-0.72	0.80	-4.1	-3.1	-2.7
									PP	-0.62	0.83	-4.1	-3.1	-2.7
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 10:22

Sample: 2007 - 2018

Included observations: 12

Variable	Coefficient	Std. error	t-statistic	Prob.
C	2.654	3.106	0.854	0.432
LNGDP	-0.026	0.441	-0.060	0.955
LNGDP(-1)	0.248	0.386	0.643	0.549
LOG(PR(-1))	-0.031	0.049	-0.623	0.560
LOG(PR(-2))	0.061	0.058	1.051	0.341
LNDM(-1)	0.422	0.399	1.056	0.339
DV	0.056	0.056	0.999	0.364

R-squared	0.469
Adjusted R-squared	-0.169
S.E. of regression	0.050
Sum squared residual	0.012
Log likelihood	24.272
F-statistic	0.735
Prob (F-statistic)	0.645

Mean dependent variable	7.579
S.D. dependent variable	0.046
Akaike information criterion	-2.879
Schwarz criterion	-2.596
Hannan-Quinn criterion	-2.983
Durbin-Watson statistic	2.004

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Iraq

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	6.427	6.354	6.815	6.001	0.263	0.141	1.647	0.434	ADF	-0.05	0.94	-3.9	-3.0	-2.7
									PP	-0.39	0.89	-3.8	-3.0	-2.7
LNGDP	5.650	5.834	6.514	4.387	0.731	-0.576	1.921	0.336	ADF	-7.38	0.00	-3.9	-3.1	-2.7
									PP	-1.46	0.53	-3.8	-3.0	-2.7
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 09:54

Sample (adjusted): 1999 - 2018

Included observations: 20 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.813	0.963	0.844	0.414
LNGDP	-0.040	0.187	-0.214	0.834
LNGDP(-1)	0.091	0.185	0.492	0.631
LOG(PR(-1))	0.048	0.093	0.514	0.616
LOG(PR(-2))	0.000	0.088	-0.002	0.999
LNDM(-1)	0.806	0.192	4.194	0.001
DV	-0.101	0.146	-0.692	0.501

R-squared	0.853
Adjusted R-squared	0.785
S.E. of regression	0.124
Sum squared residual	0.199
Log likelihood	17.742
F-statistic	12.558
Prob (F-statistic)	0.000
Mean dependent variable	6.435
S.D. dependent variable	0.267
Akaike information criterion	-1.074
Schwarz criterion	-0.726
Hannan-Quinn criterion	-1.006
Durbin-Watson statistic	1.317

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Israel

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	5.434	5.451	5.690	5.187	0.112	-0.608	3.631	0.322	ADF	-2.76	0.08	-3.7	-3.0	-2.6
									PP	-3.01	0.05	-3.7	-3.0	-2.6
LNGDP	5.034	5.020	5.817	4.105	0.508	-0.181	1.915	0.454	ADF	-2.32	0.17	-3.7	-3.0	-2.6
									PP	-3.01	0.05	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/07/19 Time: 11:00

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	2.587	0.646	4.006	0.001
LNGDP	0.104	0.048	2.153	0.043
LOG(PR(-1))	0.000	0.039	0.004	0.997
LOG(PR(-2))	-0.082	0.032	-2.523	0.020
LNDM(-1)	0.480	0.127	3.769	0.001
DV	0.129	0.039	3.286	0.004

R-squared	0.709
Adjusted R-squared	0.640
S.E. of regression	0.056
Sum squared residual	0.065
Log likelihood	43.008
F-statistic	10.225
Prob (F-statistic)	0.000

Mean dependent variable	5.452
S.D. dependent variable	0.093
Akaike information criterion	-2.741
Schwarz criterion	-2.453
Hannan-Quinn criterion	-2.656
Durbin-Watson statistic	2.210

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Kuwait

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

									Critical values					
	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	5.537	5.683	6.1633	3.784	0.617	-0.916	3.249	0.13	ADF	-1.26	0.64	-3.7	-3.0	-2.6
									PP	-0.91	0.77	-3.7	-3.0	-2.6
LNGDP	5.007	5.106	5.714	3.462	0.596	-0.675	2.759	0.32	ADF	-4.49	0.00	-3.7	-3.0	-2.6
									PP	-1.84	0.36	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 10:40

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.529	0.414	1.280	0.215
LNGDP	0.716	0.327	2.192	0.040
LNGDP(-1)	-0.541	0.262	-2.067	0.052
LOG(PR(-1))	-0.134	0.077	-1.745	0.096
LOG(PR(-2))	0.139	0.069	2.027	0.056
LNDM(-1)	0.746	0.163	4.585	0.000
DV	0.090	0.064	1.409	0.174

R-squared	0.967
Adjusted R-squared	0.957
S.E. of regression	0.106
Sum squared residual	0.223
Log likelihood	26.436
F-statistic	98.020
Prob (F-statistic)	0.000

Mean dependent variable	5.630
S.D. dependent variable	0.511
Akaike information criterion	-1.440
Schwarz criterion	-1.104
Hannan-Quinn criterion	-1.340
Durbin-Watson statistic	2.247

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Mexico

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	7.626	7.627	7.694	7.557	0.031	-0.089	2.508	0.648	ADF	-2.37	0.15	-3.5	-2.9	-2.6
									PP	-3.29	0.02	-3.5	-2.9	-2.6
LNGDP	12.426	12.481	12.723	12.044	0.204	-0.379	1.720	0.030	ADF	-1.70	0.43	-3.5	-2.9	-2.6
									PP	-1.74	0.41	-3.5	-2.9	-2.6
R	0.015	0.014	0.037	0.007	0.007	1.519	5.140	0.000	ADF	-2.63	0.09	-3.5	-2.9	-2.6
									PP	-3.39	0.01	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/05/19 Time: 11:24

Sample (adjusted): Q2 2000 - Q4 2018

Included observations: 75 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	4.532	0.889	5.101	0.000
LNGDP	0.068	0.057	1.190	0.238
LNGDP(-1)	-0.114	0.053	-2.164	0.034
LOG(PR(-1))	0.037	0.011	3.426	0.001
R	-0.584	1.373	-0.425	0.672
R(-1)	0.988	1.302	0.759	0.451
D1	-0.010	0.007	-1.374	0.174
D2	-0.004	0.007	-0.534	0.595
D3	-0.013	0.007	-1.824	0.073
DV	0.002067	0.00838	0.24657	0.806
LNDM(-1)	0.461453	0.10941	4.21758	0.000

R-squared	0.624
Adjusted R-squared	0.565
S.E. of regression	0.021
Sum squared residual	0.027
Log likelihood	190.805
F-statistic	10.625
Prob (F-statistic)	0.000

Mean dependent variable	7.625
S.D. dependent variable	0.031
Akaike information criterion	-4.795
Schwarz criterion	-4.455
Hannan-Quinn criterion	-4.659
Durbin-Watson statistic	2.144

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

New Zealand

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	5.028	5.030	5.193	4.852	0.077	-0.232	3.065	0.707	ADF	-1.42	0.57	-3.5	-2.9	-2.6
									PP	-3.63	0.01	-3.5	-2.9	-2.6
LNGDP	10.360	10.473	10.867	9.429	0.437	-0.789	2.436	0.012	ADF	-1.76	0.40	-3.5	-2.9	-2.6
									PP	-1.47	0.54	-3.5	-2.9	-2.6
R	0.011	0.009	0.019	0.004	0.005	0.256	1.543	0.023	ADF	-1.07	0.72	-3.5	-2.9	-2.6
									PP	-1.04	0.73	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/07/19 Time: 10:36

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	2.336	0.411	5.687	0.000
LNGDP	0.051	0.079	0.643	0.523
LNGDP(-1)	0.135	0.079	1.721	0.090
LOG(PR(-1))	0.007	0.027	0.265	0.792
LOG(PR(-2))	-0.067	0.028	-2.388	0.020
R	-7.296	4.342	-1.680	0.098
R(-1)	11.074	4.904	2.258	0.028
D1	0.005	0.013	0.366	0.715
D2	-0.072	0.014	-5.020	0.000
D3	-0.068436	0.01097	-6.23743	0.000
DV	-0.006231	0.01954	-0.31892	0.751
LNDM(-1)	0.198574	0.12095	1.64174	0.106

R-squared	0.833
Adjusted R-squared	0.803
S.E. of regression	0.033
Sum squared residual	0.068
Log likelihood	153.483
F-statistic	28.099
Prob (F-statistic)	0.000

Mean dependent variable	5.032
S.D. dependent variable	0.075
Akaike information criterion	-3.824
Schwarz criterion	-3.450
Hannan-Quinn criterion	-3.675
Durbin-Watson statistic	1.998

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Oman

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	4.489	4.357	5.220	3.738	0.491	0.254	1.614	0.268	ADF	-0.76	0.82	-3.7	-3.0	-2.6
									PP	-0.61	0.85	-3.7	-3.0	-2.6
LNGDP	4.549	4.467	5.289	3.696	0.470	-0.006	1.918	0.493	ADF	-1.53	0.51	-3.7	-3.0	-2.6
									PP	-1.53	0.51	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 11:04

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	-0.079	0.267	-0.297	0.770
LNGDP	-0.307	0.741	-0.414	0.683
LNGDP(-1)	0.586	0.676	0.867	0.396
LOG(PR(-1))	0.049	0.054	0.912	0.373
LOG(PR(-2))	-0.010	0.054	-0.175	0.863
LNDM(-1)	0.712	0.126	5.660	0.000
DV	0.193	0.073	2.630	0.016

R-squared	0.976
Adjusted R-squared	0.969
S.E. of regression	0.084
Sum squared residual	0.142
Log likelihood	32.517
F-statistic	138.310
Prob (F-statistic)	0.000

Mean dependent variable	4.529
S.D. dependent variable	0.482
Akaike information criterion	-1.890
Schwarz criterion	-1.554
Hannan-Quinn criterion	-1.790
Durbin-Watson statistic	1.785

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Poland

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	6.234	6.253	6.581	5.924	0.156	-0.076	2.514	0.663	ADF	-1.47	0.54	-3.5	-2.9	-2.6
									PP	-2.12	0.24	-3.5	-2.9	-2.6
LNGDP	11.458	11.670	11.925	10.669	0.405	-0.743	2.007	0.006	ADF	-1.70	0.43	-3.5	-2.9	-2.6
									PP	-1.61	0.47	-3.5	-2.9	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/05/19 Time: 16:03

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.006	0.196	0.032	0.975
LNGDP	0.089	0.040	2.232	0.029
LOG(PR(-1))	-0.031	0.025	-1.244	0.218
LOG(PR(-2))	-0.012	0.024	-0.510	0.612
D1	-0.084	0.011	-7.580	0.000
D2	0.054	0.015	3.671	0.001
D3	0.090	0.012	7.466	0.000
LNDM(-1)	0.863	0.070	12.261	0.000
DV	0.000	0.011	-0.024	0.981

R-squared	0.959
Adjusted R-squared	0.954
S.E. of regression	0.032
Sum squared residual	0.068
Log likelihood	153.449
F-statistic	189.835
Prob (F-statistic)	0.000
Mean dependent variable	6.241
S.D. dependent variable	0.151
Akaike information criterion	-3.904
Schwarz criterion	-3.624
Hannan-Quinn criterion	-3.792
Durbin-Watson statistic	2.287

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Qatar

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	4.504	4.443	5.438	3.497	0.711	-0.015	1.425	0.224	ADF	-0.75	0.82	-3.7	-3.0	-2.6
									PP	-0.81	0.80	-3.7	-3.0	-2.6
LNGDP	4.485	4.347	5.877	3.095	0.990	0.065	1.497	0.253	ADF	-0.18	0.93	-3.7	-3.0	-2.6
									PP	-0.25	0.92	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 11:14

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.897	0.278	3.230	0.004
LNGDP	0.710	0.328	2.164	0.043
LNGDP(-1)	-0.257	0.302	-0.853	0.404
LOG(PR(-1))	0.022	0.070	0.318	0.754
LOG(PR(-2))	0.092	0.065	1.415	0.173
LNDM(-1)	0.259	0.215	1.206	0.242
DV	-0.015	0.038	-0.406	0.689

R-squared	0.985
Adjusted R-squared	0.980
S.E. of regression	0.096
Sum squared residual	0.184
Log likelihood	29.040
F-statistic	214.992
Prob (F-statistic)	0.000

Mean dependent variable	4.578
S.D. dependent variable	0.681
Akaike information criterion	-1.633
Schwarz criterion	-1.297
Hannan-Quinn criterion	-1.533
Durbin-Watson statistic	1.864

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Republic of Korea

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	7.731	7.748	7.898	7.579	0.085	-0.114	2.191	0.33	ADF	-0.09	0.95	-3.5	-2.9	-2.6
									PP	-5.35	0.00	-3.5	-2.9	-2.6
LNGDP	12.442	12.513	12.928	11.788	0.341	-0.526	2.078	0.05	ADF	-1.21	0.67	-3.5	-2.9	-2.6
									PP	-4.80	0.00	-3.5	-2.9	-2.6
R	0.008	0.008	0.013	0.003	0.003	-0.041	1.707	0.07	ADF	-1.73	0.41	-3.5	-2.9	-2.6
									PP	-1.19	0.68	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/06/19 Time: 13:36

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	4.105	0.763	5.381	0.000
LNGDP	0.197	0.042	4.670	0.000
LOG(PR(-1))	-0.101	0.025	-3.993	0.000
LOG(PR(-2))	0.034	0.025	1.384	0.171
R	-4.835	6.006	-0.805	0.424
R(-1)	2.881	6.436	0.448	0.656
D1	-0.006	0.015	-0.397	0.693
D2	-0.095	0.016	-6.126	0.000
D3	-0.080	0.011	-7.456	0.000
DV	0.000805	0.00196	0.41142	0.682
LNDM(-1)	0.195116	0.11809	1.65225	0.104

R-squared	0.874
Adjusted R-squared	0.854
S.E. of regression	0.033
Sum squared residual	0.067
Log likelihood	154.393
F-statistic	43.530
Prob (F-statistic)	0.000

Mean dependent variable	7.732
S.D. dependent variable	0.085
Akaike information criterion	-3.875
Schwarz criterion	-3.533
Hannan-Quinn criterion	-3.739
Durbin-Watson statistic	1.806

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Russia

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	8.016	7.993	8.219	7.843	0.103	0.268	1.826	0.143	ADF	-0.65	0.85	-3.6	-2.9	-2.6
									PP	-1.89	0.34	-3.6	-2.9	-2.6
LNGDP	12.863	12.884	13.337	12.056	0.304	-0.605	2.818	0.174	ADF	-2.35	0.16	-3.6	-2.9	-2.6
									PP	-2.45	0.13	-3.6	-2.9	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/09/19 Time: 09:58

Sample (adjusted): Q2 2005 - Q4 2018

Included observations: 55 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.263	0.491	0.535	0.595
LNGDP	0.118	0.075	1.577	0.122
LNGDP(-1)	-0.063	0.083	-0.764	0.449
LOG(PR(-1))	-0.037	0.038	-0.987	0.329
LOG(PR(-2))	0.019	0.041	0.456	0.651
D1	0.015	0.020	0.719	0.476
D2	0.033	0.014	2.338	0.024
D3	0.106	0.014	7.731	0.000
LNDM(-1)	0.886	0.075	11.743	0.000
DV	-0.021163	0.01411	-1.49978	0.141

R-squared	0.910
Adjusted R-squared	0.892
S.E. of regression	0.034
Sum squared residual	0.052
Log likelihood	113.434
F-statistic	50.362
Prob (F-statistic)	0.000
Mean dependent variable	8.018
S.D. dependent variable	0.103
Akaike information criterion	-3.761
Schwarz criterion	-3.396
Hannan-Quinn criterion	-3.620
Durbin-Watson statistic	2.426

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Saudi Arabia

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	7.566	7.527	8.136	6.916	0.378	0.066	1.716	0.365	ADF	-1.71	0.41	-3.7	-3.0	-2.6
									PP	-1.53	0.50	-3.7	-3.0	-2.6
LNGDP	6.833	6.792	7.527	6.109	0.432	0.188	1.680	0.320	ADF	-0.50	0.88	-3.7	-3.0	-2.6
									PP	-0.50	0.88	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 12:48

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
LNGDP	0.284	0.177	1.603	0.125
LNGDP(-1)	0.033	0.205	0.163	0.873
LOG(PR(-1))	-0.008	0.019	-0.404	0.691
LOG(PR(-2))	0.012	0.022	0.539	0.596
TS_Vision 2030	-0.036	0.014	-2.557	0.019
DV	0.014	0.021	0.682	0.504
LNDM(-1)	0.638	0.154	4.138	0.001

R-squared	0.996
Adjusted R-squared	0.995
S.E. of regression	0.025
Sum squared residual	0.012
Log likelihood	66.251
F-statistic	734.174
Prob (F-statistic)	0.000
Mean dependent variable	7.612
S.D. dependent variable	0.349
Akaike information criterion	-4.315
Schwarz criterion	-3.931
Hannan-Quinn criterion	-4.201
Durbin-Watson statistic	2.381

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

South Africa

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	6.311	6.374	6.646	6.031	0.152	-0.253	1.818	0.073	ADF	-1.49	0.54	-3.5	-2.9	-2.6
									PP	-2.19	0.21	-3.5	-2.9	-2.6
LNGDP	11.113	11.237	11.605	10.130	0.396	-1.034	2.878	0.001	ADF	-1.48	0.54	-3.5	-2.9	-2.6
									PP	-1.52	0.52	-3.5	-2.9	-2.6
R	0.019	0.018	0.029	0.012	0.004	0.492	2.246	0.088	ADF	-2.43	0.14	-3.5	-2.9	-2.6
									PP	-2.03	0.27	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 13:52

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.200	0.589	2.038	0.046
LNGDP	0.214	0.065	3.317	0.002
LOG(PR(-1))	-0.104	0.063	-1.639	0.106
LOG(PR(-2))	0.080	0.055	1.452	0.151
R	14.135	7.713	1.832	0.072
R(-1)	-13.023	7.730	-1.685	0.097
D1	-0.022	0.025	-0.853	0.397
D2	-0.016	0.025	-0.639	0.525
D3	-0.026	0.025	-1.047	0.299
LNDM(-1)	0.448	0.105	4.288	0.000
DV	-0.001	0.033	-0.029	0.977

R-squared	0.779
Adjusted R-squared	0.744
S.E. of regression	0.075
Sum squared residual	0.357
Log likelihood	92.374
F-statistic	22.198
Prob (F-statistic)	0.000

Mean dependent variable	6.317
S.D. dependent variable	0.149
Akaike information criterion	-2.199
Schwarz criterion	-1.857
Hannan-Quinn criterion	-2.063
Durbin-Watson statistic	2.255

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Turkey

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	6.587	6.542	7.028	6.303	0.166	0.899	3.153	0.006	ADF	1.32	1.00	-3.5	-2.9	-2.6
									PP	-3.82	0.00	-3.5	-2.9	-2.6
LNGDP	11.888	12.110	12.443	10.774	0.502	-0.910	2.476	0.003	ADF	-3.11	0.03	-3.5	-2.9	-2.6
									PP	-2.25	0.19	-3.5	-2.9	-2.6
R	0.055	0.043	0.145	0.030	0.028	1.655	4.801	0.000	ADF	-2.45	0.13	-3.5	-2.9	-2.6
									PP	-2.47	0.13	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/06/19 Time: 09:55

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.351	0.725	0.485	0.630
LNGDP	0.140	0.075	1.850	0.069
LOG(PR(-1))	-0.126	0.053	-2.377	0.021
LOG(PR(-2))	0.036	0.052	0.703	0.485
R	-0.585	1.333	-0.439	0.662
R(-1)	0.772	1.339	0.577	0.566
D1	-0.016	0.025	-0.640	0.525
D2	0.160	0.027	5.934	0.000
D3	0.139	0.023	5.965	0.000
LNDM(-1)	0.738	0.083	8.926	0.000
DV	-0.017	0.028	-0.604	0.548

R-squared	0.857
Adjusted R-squared	0.834
S.E. of regression	0.068
Sum squared residual	0.288
Log likelihood	100.250
F-statistic	37.673
Prob (F-statistic)	0.000
Mean dependent variable	6.591
S.D. dependent variable	0.166
Akaike information criterion	-2.412
Schwarz criterion	-2.070
Hannan-Quinn criterion	-2.276
Durbin-Watson statistic	2.626

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

United Arab Emirates

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	6.278	6.194	6.823	5.768	0.301	0.414	1.884	0.312	ADF	-0.57	0.86	-3.7	-3.0	-2.6
									PP	-0.61	0.85	-3.7	-3.0	-2.6
LNGDP	5.781	5.847	6.597	4.866	0.556	-0.159	1.684	0.330	ADF	-1.01	0.74	-3.7	-3.0	-2.6
									PP	-1.02	0.73	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 11:29

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.389	0.255	1.522	0.144
LNGDP	0.556	0.230	2.418	0.025
LNGDP(-1)	-0.524	0.235	-2.234	0.037
LOG(PR(-1))	-0.008	0.023	-0.364	0.720
LOG(PR(-2))	0.060	0.022	2.750	0.012
DV	-0.018	0.029	-0.636	0.532
LNDM(-1)	0.879	0.067	13.099	0.000

R-squared	0.990
Adjusted R-squared	0.987
S.E. of regression	0.032
Sum squared residual	0.021
Log likelihood	58.527
F-statistic	342.283
Prob (F-statistic)	0.000

Mean dependent variable	6.308
S.D. dependent variable	0.287
Akaike information criterion	-3.817
Schwarz criterion	-3.481
Hannan-Quinn criterion	-3.717
Durbin-Watson statistic	2.593

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

United Kingdom

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	7.416	7.408	7.540	7.286	0.065	-0.063	1.716	0.072	ADF	-1.01	0.75	-3.5	-2.9	-2.6
									PP	-1.82	0.37	-3.5	-2.9	-2.6
LNGDP	13.333	13.386	13.598	12.894	0.196	-1.037	3.013	0.001	ADF	-2.18	0.22	-3.5	-2.9	-2.6
									PP	-1.79	0.38	-3.5	-2.9	-2.6
R	0.006	0.002	0.014	0.000	0.005	0.203	1.241	0.006	ADF	-1.63	0.46	-3.5	-2.9	-2.6
									PP	-1.15	0.69	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/05/19 Time: 14:46

Sample (adjusted): Q4 2000 - Q4 2018

Included observations: 73 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	2.238	0.688	3.254	0.002
LNGDP	-0.001	0.070	-0.020	0.984
LNGDP(-1)	0.036	0.067	0.531	0.597
LOG(PR(-1))	-0.021	0.017	-1.186	0.240
LOG(PR(-2))	0.035	0.023	1.483	0.143
LOG(PR(-3))	-0.035	0.018	-2.001	0.050
R	2.183	4.158	0.525	0.602
R(-1)	1.396	4.625	0.302	0.764
D1	0.009	0.007	1.210	0.231
D2	0.008	0.007	1.158	0.251
D3	0.006	0.007	0.878	0.383
LNDM(-1)	0.644319	0.09345	6.89514	0.000
DV	-0.007183	0.00934	-0.76896	0.4449

R-squared	0.920
Adjusted R-squared	0.904
S.E. of regression	0.020
Sum squared residual	0.024
Log likelihood	188.602
F-statistic	57.315
Prob (F-statistic)	0.000
Mean dependent variable	7.413
S.D. dependent variable	0.065
Akaike information criterion	-4.811
Schwarz criterion	-4.403
Hannan-Quinn criterion	-4.648
Durbin-Watson statistic	2.446

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

United States

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat	Prob.	1%	5%	10%	
LNDM	9.905	9.904	9.969	9.835	0.037	0.000	1.913	0.154	ADF	-1.52	0.52	-3.5	-2.9	-2.6
									PP	-1.47	0.54	-3.5	-2.9	-2.6
LNGDP	15.113	15.117	15.470	14.732	0.206	-0.181	1.998	0.166	ADF	-0.17	0.94	-3.5	-2.9	-2.6
									PP	-0.69	0.84	-3.5	-2.9	-2.6
R	0.004	0.002	0.014	0.000	0.004	1.002	2.627	0.001	ADF	-3.91	0.00	-3.5	-2.9	-2.6
									PP	-2.12	0.24	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/02/19 Time: 15:42

Sample (adjusted): Q4 2000 - Q4 2018

Included observations: 73 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.669	0.663	2.517	0.015
LNGDP	0.449	0.295	1.522	0.133
LNGDP(-1)	-0.431	0.293	-1.471	0.147
LNPR(-1)	-0.016	0.009	-1.817	0.074
LNPR(-2)	0.019	0.012	1.540	0.129
LNPR(-3)	-0.016	0.009	-1.730	0.089
R	4.715	2.109	2.235	0.029
R(-1)	-4.148	1.999	-2.075	0.042
D1	-0.005	0.004	-1.347	0.183
D2	-0.003	0.004	-0.784	0.436
D3	0.008	0.004	2.046	0.045
LNDM(-1)	0.810	0.071	11.453	0.000
DV	0.000729	0.00672	0.10847	0.914

R-squared	0.921
Adjusted R-squared	0.905
S.E. of regression	0.012
Sum squared residual	0.008
Log likelihood	227.858
F-statistic	57.910
Prob (F-statistic)	0.000

Mean dependent variable	9.905
S.D. dependent variable	0.038
Akaike information criterion	-5.887
Schwarz criterion	-5.479
Hannan-Quinn criterion	-5.724
Durbin-Watson statistic	2.604

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Venezuela

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat		Prob.	1%	5%	10%
LNDM	6.450	6.449	6.770	6.043	0.184	-0.159	2.052	0.205	ADF	-0.67	0.85	-3.5	-2.9	-2.6
									PP	-0.82	0.81	-3.5	-2.9	-2.6
LNGDP	10.662	10.674	11.336	9.894	0.455	-0.006	1.496	0.028	ADF	-0.67	0.85	-3.5	-2.9	-2.6
									PP	-0.66	0.85	-3.5	-2.9	-2.6
R	0.067	0.065	0.088	0.062	0.006	1.541	4.308	0.000	ADF	-2.69	0.08	-3.5	-2.9	-2.6
									PP	-2.65	0.09	-3.5	-2.9	-2.6

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/09/19 Time: 11:34

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.357	0.292	1.224	0.226
LNGDP	0.082	0.070	1.170	0.246
LNGDP(-1)	0.041	0.077	0.534	0.595
LOG(PR(-1))	0.026	0.037	0.716	0.477
LOG(PR(-2))	-0.055	0.037	-1.477	0.145
R	-2.641	2.014	-1.311	0.195
R(-1)	2.707	2.143	1.263	0.211
D1	0.016	0.016	0.983	0.329
D2	0.024	0.017	1.431	0.157
D3	0.014	0.015	0.923	0.360
LNDM(-1)	0.756	0.074	10.236	0.000
DV	-0.021	0.020	-1.055	0.296

R-squared	0.945
Adjusted R-squared	0.936
S.E. of regression	0.046
Sum squared residual	0.131
Log likelihood	129.387
F-statistic	97.482
Prob (F-statistic)	0.000
Mean dependent variable	6.457
S.D. dependent variable	0.181
Akaike information criterion	-3.173
Schwarz criterion	-2.799
Hannan-Quinn criterion	-3.024
Durbin-Watson statistic	1.981

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Country Groupings

Rest of Africa

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	7.477	7.449	7.964	7.034	0.297	0.231	1.767	0.351	ADF	0.19	0.97	-3.7	-3.0	-2.6
									PP	1.24	1.00	-3.7	-3.0	-2.6
LNGDP	7.617	7.601	8.444	6.840	0.536	0.048	1.547	0.278	ADF	-0.66	0.84	-3.7	-3.0	-2.6
									PP	0.27	0.97	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/09/19 Time: 09:38

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.159	0.683	1.697	0.105
LNGDP	0.032	0.338	0.095	0.925
LNGDP(-1)	0.172	0.405	0.426	0.675
LOG(PR(-1))	-0.007	0.022	-0.324	0.749
LOG(PR(-2))	0.005	0.020	0.263	0.796
DV	0.001	0.029	0.039	0.970
LNDM(-1)	0.642	0.222	2.887	0.009

R-squared	0.991
Adjusted R-squared	0.988
S.E. of regression	0.031
Sum squared residual	0.019
Log likelihood	59.881
F-statistic	367.721
Prob (F-statistic)	0.000

Mean dependent variable	7.508
S.D. dependent variable	0.283
Akaike information criterion	-3.917
Schwarz criterion	-3.581
Hannan-Quinn criterion	-3.817
Durbin-Watson statistic	2.034

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Rest of Asia

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	8.450	8.507	8.890	7.849	0.303	-0.448	2.316	0.464	ADF	-2.25	0.19	-3.7	-3.0	-2.6
									PP	-2.43	0.14	-3.7	-3.0	-2.6
LNGDP	7.969	7.965	8.927	6.948	0.594	-0.047	1.789	0.410	ADF	-1.12	0.69	-3.7	-3.0	-2.6
									PP	-1.12	0.69	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/07/19 Time: 14:23

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.749	0.353	4.952	0.000
LNGDP	0.205	0.050	4.126	0.001
LOG(PR(-1))	-0.031	0.012	-2.576	0.018
LOG(PR(-2))	0.001	0.013	0.085	0.933
LNDM(-1)	0.616	0.083	7.373	0.000
DV	-0.021	0.010	-1.984	0.060

R-squared	0.996
Adjusted R-squared	0.994
S.E. of regression	0.020
Sum squared residual	0.008
Log likelihood	71.350
F-statistic	936.959
Prob (F-statistic)	0.000

Mean dependent variable	8.494
S.D. dependent variable	0.263
Akaike information criterion	-4.841
Schwarz criterion	-4.553
Hannan-Quinn criterion	-4.755
Durbin-Watson statistic	2.288

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Rest of Eurasia

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	7.768	7.563	8.421	7.489	0.387	1.059	2.154	0.127	ADF	-1.72	0.41	-3.9	-3.0	-2.7
									PP	-1.69	0.42	-3.9	-3.0	-2.7
LNGDP	7.526	7.625	7.990	6.862	0.347	-0.568	2.083	0.430	ADF	-3.00	0.05	-3.9	-3.0	-2.7
									PP	-2.69	0.09	-3.9	-3.0	-2.7
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/09/19 Time: 10:36

Sample (adjusted): 2001 - 2018

Included observations: 18 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	-0.068	0.619	-0.110	0.915
LNGDP	0.633	0.259	2.447	0.032
LNGDP(-1)	-0.579	0.247	-2.346	0.039
LOG(PR(-1))	-0.036	0.024	-1.503	0.161
LOG(PR(-2))	-0.002	0.026	-0.086	0.933
DV	-0.905	0.031	-28.989	0.000
LNDM(-1)	0.972	0.042	22.973	0.000

R-squared	0.997
Adjusted R-squared	0.995
S.E. of regression	0.025
Sum squared residual	0.007
Log likelihood	45.429
F-statistic	625.548
Prob (F-statistic)	0.000

Mean dependent variable	7.735
S.D. dependent variable	0.369
Akaike information criterion	-4.270
Schwarz criterion	-3.924
Hannan-Quinn criterion	-4.222
Durbin-Watson statistic	2.406

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Rest of Europe

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	8.917	8.923	9.023	8.807	0.073	0.055	1.563	0.285	ADF	-1.72	0.41	-3.9	-3.0	-2.7
									PP	-1.69	0.42	-3.9	-3.0	-2.7
LNGDP	8.816	8.867	9.318	8.199	0.343	-0.355	1.831	0.323	ADF	-3.00	0.05	-3.9	-3.0	-2.7
									PP	-2.69	0.09	-3.9	-3.0	-2.7
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/06/19 Time: 10:45

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	0.423	0.428	0.989	0.335
LNGDP	0.693	0.198	3.497	0.002
LNGDP(-1)	-0.671	0.199	-3.366	0.003
LOG(PR(-1))	-0.023	0.009	-2.428	0.025
LOG(PR(-2))	0.004	0.011	0.423	0.677
DV	-0.007	0.015	-0.455	0.654
LNDM(-1)	0.935	0.047	19.728	0.000

R-squared	0.969
Adjusted R-squared	0.960
S.E. of regression	0.015
Sum squared residual	0.004
Log likelihood	79.858
F-statistic	105.696
Prob (F-statistic)	0.000

Mean dependent variable	8.922
S.D. dependent variable	0.073
Akaike information criterion	-5.397
Schwarz criterion	-5.061
Hannan-Quinn criterion	-5.297
Durbin-Watson statistic	2.196

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Rest of Latin America

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	7.511	7.500	7.716	7.318	0.118	0.105	1.742	0.076	ADF	0.16	0.97	-3.5	-2.9	-2.6
									PP	-0.32	0.92	-3.5	-2.9	-2.6
LNGDP	12.433	12.509	12.962	11.762	0.432	-0.409	1.605	0.016	ADF	-1.42	0.57	-3.5	-2.9	-2.6
									PP	-0.99	0.75	-3.5	-2.9	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/09/19 Time: 12:15

Sample (adjusted): Q3 2000 - Q4 2018

Included observations: 74 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.580	0.460	3.435	0.001
LNGDP	0.065	0.047	1.385	0.171
LNGDP(-1)	0.035	0.051	0.686	0.495
LOG(PR(-1))	-0.002	0.010	-0.189	0.851
LOG(PR(-2))	-0.011	0.009	-1.146	0.256
D1	-0.022	0.006	-3.912	0.000
D2	0.023	0.006	3.548	0.001
D3	0.015	0.004	3.587	0.001
LNDM(-1)	0.634	0.102	6.213	0.000
DV	0.000	0.001	0.609	0.545

R-squared	0.991
Adjusted R-squared	0.990
S.E. of regression	0.012
Sum squared residual	0.009
Log likelihood	228.226
F-statistic	771.237
Prob (F-statistic)	0.000
Mean dependent variable	7.515
S.D. dependent variable	0.117
Akaike information criterion	-5.898
Schwarz criterion	-5.587
Hannan-Quinn criterion	-5.774
Durbin-Watson statistic	2.022

Appendix 4. Summary statistics for daily time series, unit root test results and regression results

Rest of Middle East

Summary statistics and unit root tests

Unit root tests (Augmented Dickey-Fuller and Phillips-Perron)

Critical values

	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	JB-prob.	T-stat Prob.		1%	5%	10%	
LNDM	6.287	6.271	6.585	5.846	0.197	-0.416	2.507	0.568	ADF	-2.24	0.20	-3.7	-3.0	-2.6
									PP	-2.40	0.15	-3.7	-3.0	-2.6
LNGDP	5.337	5.456	5.931	4.501	0.363	-0.558	2.619	0.432	ADF	-2.66	0.09	-3.7	-3.0	-2.6
									PP	-2.78	0.07	-3.7	-3.0	-2.6
R	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ADF	0.00	0.00	0.0	0.0	0.0
									PP	0.00	0.00	0.0	0.0	0.0

Regression results

Dependent variable: LNDM

Method: Least squares

Date: 05/08/19 Time: 13:29

Sample (adjusted): 1992 - 2018

Included observations: 27 after adjustments

Variable	Coefficient	Std. error	t-statistic	Prob.
C	1.512	0.765	1.977	0.062
LNGDP	0.139	0.098	1.419	0.171
LNGDP(-1)	0.082	0.095	0.862	0.399
LOG(PR(-1))	0.010	0.025	0.389	0.701
LOG(PR(-2))	-0.030	0.024	-1.274	0.217
DV	-0.067	0.036	-1.873	0.076
LNDM(-1)	0.587	0.218	2.686	0.014

R-squared	0.958
Adjusted R-squared	0.946
S.E. of regression	0.039
Sum squared residual	0.031
Log likelihood	53.037
F-statistic	76.699
Prob (F-statistic)	0.000
Mean dependent variable	6.316
S.D. dependent variable	0.169
Akaike information criterion	-3.410
Schwarz criterion	-3.074
Hannan-Quinn criterion	-3.310
Durbin-Watson statistic	2.015

Note: LNDM = Logged demand; LNGDP = Logged GDP; Std. dev = standard deviation; T-stat = t-statistic; S.E. = standard error; S.D. = standard deviation; JB-prob = Jarque-Bera probability test; Prob = T-stat probability; C = Coefficient; R = ; DV = Dummy variable; D1, D2, D3 = Seasonal variables.

Appendix 5

Unit root and Jarque-Bera tests

Unit root and Jarque-Bera tests were performed on all of the variables. To summarize the results: The Jarque-Bera test confirms the null hypothesis that OECD inventories are normally distributed. The lag length for the Augmented Dickey-Fuller (ADF) tests are selected according to the Schwartz information criterion, and the results show that we can reject the null hypothesis that the variable OECD inventories have a unit root at the 10% significance level. In the case of Brent crude oil prices, the Jarque-Bera test confirms the null hypothesis that

Brent is normally distributed at the 10% level, and the ADF tests show clear evidence of a unit root at the 10% significance level. The Jarque-Bera test confirms the null hypothesis that relative inventories are normally distributed at the 10% level. The ADF suggests that we can reject the null hypothesis of a unit root at the 10% significance level, but we cannot rule out the possibility at the 5% level of significance. For IEA estimates of excess supply, the Jarque-Bera test confirms the null hypothesis that the variable is normally distributed at the 10% level. The ADF suggests that we cannot reject the null hypothesis of a unit root at the 10% significance level.

Note: It is important to test for unit roots in the data, as the presence of a unit root can have serious consequences for the regression analysis. A unit root is a stochastic trend in a time series that is often referred to as a random walk with a drift. If a time series has a unit root, there is a systematic pattern that is unpredictable, and the properties of the time series, or the shape of the distribution, will change if the time series shifts. As a result, the analysis can have some serious problems such as high R² values when the data is uncorrelated. The Jarque-Bera test tests for the normality of the underlying time series utilized in the data analysis. This test is important because most of the statistical tests for the validity of the regression assume that the underlying variables are normally distributed. If this is not the case, and the variables are not normally distributed, then the results of the analysis might be unreliable (Statistics How To 2017).

Appendix 6

Contango and convenience yield

The definitions of contango and the convenience yield are given as follows:

Contango

The crude oil market is said to be in a state of contango when the futures price of oil is higher than the spot price, indicating that the market expects the price of oil to increase steadily in the future. Backwardation is the opposite state: when the futures price of oil is lower than the spot price, the market expects the price of oil to fall in the future. This might be due to increased supply or falling demand.

Let $F(t, T)$ be the futures price at time t for delivery of crude oil at some time in the future. Let T and $P(t)$ be the spot price of crude oil at an earlier time t .

The contango is calculated as the simple return from purchasing the commodity at time t and selling it for delivery at T , $F(t, T) - P(t)$. For this analysis $P(t)$ is equal to the price of crude oil at time $t=2$, essentially the second month futures price, and T is equal to the futures price seven months later (the ninth month futures price). Note: We start at month $t=2$ instead of $t=1$ to accommodate statistical discrepancies arising on the last few days of bid week, which is the close of trading on various crude oil futures contracts. The contract for WTI crude closes on the third business day before the 25th calendar day of the month preceding the delivery month (CME Group 2019).

Convenience yield

The convenience yield is a measure of the benefit of holding a physical barrel of oil rather than the futures contract. If a consumer purchases a physical barrel of oil instead of a futures contract and there is a sudden price shock, for example due to sanctions on Iran, then the convenience yield is the difference between the original price of the barrel of oil, and the price after the imposition of Iranian sanctions.

As mentioned above, the marginal convenience yield $C(t, T)$ is a benefit (or cost) that accrues to the owner of a physical asset, such as a barrel of crude oil, but not a futures contract. If in the commodities spot and futures price the borrowing costs and time to maturity are known, the yield can be calculated as the simple difference between the interest rate (borrowing rate) and $(1/T)$ times the natural log of the futures price divided by the spot price (Smith 2019).

Y.1)

$$F(t, T) = S(t) * e^{((R(t, T) - C(t, T)) * T)}$$

So that:

Y.2)
$$C(t, T) = R(t, T) - \left(\frac{1}{T}\right) * \ln\left(\frac{F(t, T)}{S(t)}\right)$$

Appendix 7. Delphi model questionnaire sample

What are the chances of a trade war between China and the United States?						
OPTION	H1 2019	H2 2019	H1 2020	H2 2020	H1 2021	H2 2021
Certain	☐	☐	☐	☐	☐	☐
Almost certain	☐	☐	☐	☐	☐	☐
Probable	☐	☐	☐	☐	☐	☐
Even chance	☐	☐	☐	☐	☐	☐
Unlikely	☐	☐	☐	☐	☐	☐
Remote	☐	☐	☐	☐	☐	☐
Impossible	☐	☐	☐	☐	☐	☐

Will it impact?	
Demand	Supply
☐	☐

If supply, will it impact its	
Exports	Total production
☐	☐

Will the impact be (may choose more than one)	
If supply:	If Demand:
Strong ☐	≥ 1 MMb/d ☐
Medium ☐	≥ 500 Kb/d ☐
low ☐	≥ 200 Kb/d ☐
	≥ 100 Kb/d ☐
Stagnate ☐	≥ 50 Kb/d ☐
Gradually declining ☐	≥ 10 Kb/d ☐
Gradually increasing ☐	

What are the chances of a recession/financial crisis in the coming years?						
OPTION	H1 2019	H2 2019	H1 2020	H2 2020	H1 2021	H2 2021
Certain	☐	☐	☐	☐	☐	☐
Almost certain	☐	☐	☐	☐	☐	☐
Probable	☐	☐	☐	☐	☐	☐
Even chance	☐	☐	☐	☐	☐	☐
Unlikely	☐	☐	☐	☐	☐	☐
Remote	☐	☐	☐	☐	☐	☐
Impossible	☐	☐	☐	☐	☐	☐

Will it impact?	
Demand	Supply
☐	☐

If supply, will it impact its	
Exports	Total production
☐	☐

Will the impact be (may choose more than one)	
If supply:	If Demand:
Strong ☐	≥ 1.5 MMb/d ☐
Medium ☐	≥ 500 Kb/d ☐
low ☐	≥ 200 Kb/d ☐
	≥ 100 Kb/d ☐
Stagnate ☐	≥ 50 Kb/d ☐
Gradually declining ☐	≥ 10 Kb/d ☐
Gradually increasing ☐	

Note: The survey's platform may change to an online version, such as Google Surveys or Survey Monkey. However, the methodology would remain the same.

About the Authors

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Hamid is a research associate in the Markets and Industrial Development program with a particular interest in climate change and oil demand. Previously, he worked as an oil demand analyst at Saudi Aramco with a focus on long-term forecasting and short-term oil pricing. Hamid was also a negotiator for the Saudi Climate Change team at different United Nations bodies between 2012-2016.

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About the Project

The KAPSARC Oil Market Outlook (KOMO) provides a comprehensive overview of the world oil markets, including supply and demand balances, crude oil inventories, and Brent crude oil prices. The goal of this paper is to provide readers with an understanding of the tools and methods used to estimate KAPSARC's world oil markets, including the key factors affecting world oil prices.

Using publicly available data on 195 countries and regions, we developed detailed country and region specific statistical models of oil demand, supply, inventories and oil prices. KOMO takes a critical look at all of the major factors affecting world oil markets, including:

- financial variables such as interest rates and gross domestic product (GDP);
- seasonal variables, such as regional temperatures;
- physical production considerations, such as reservoir characteristics for conventional and unconventional oil;
- investment decisions and timelines;
- the influence of trading and speculation;
- geopolitical factors such as trade wars, sanctions, and complex international relations.

All of the above are built into a dynamic model with the objective of keeping the variables sensitive to price changes and one another.

This paper provides analysts with a perspective on KAPSARC's own methodology while providing readymade elasticities and tool descriptions for modelers to recreate this model, or build their own with elements of it.

Note: This publication is dedicated to the initial model that estimates the short-term and is constantly updated and evolving when improvements are possible.

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