The (time-varying) Importance of Oil Prices to U.S. Stock Returns: A Tale of Two Beauty-Contests

David C. Broadstock[a] and George Filis[b]

a) The motivations underlying the research

There is a rich evidence base on the impact of oil prices, their changes, or some transformation/decomposition to obtain a measure of `oil price shocks', to stock market returns. Despite this, most prior research focuses either on aggregate stock market indices or selected industrial sectors.

The existing literature has paid relatively little attention to examining the relationships using frm- level data. Moreover, among the existing studies using frm-level data, only limited consideration has been given to the time-varying patterns of association between oil prices and stock markets.

b) A short account of the research performed;

Two widely used oil price measures are considered, one based on raw oil price changes and another based on disentangling the source of oil price changes due to supply-side or demand-side effects. As far as we know our dataset, which comprises 10,118 stock price series with up to 25,372,588 observations between 1995-2018, is the most comprehensive used for this purpose. We develop two 'beauty-contests' in which we estimate multi-factor models separately for individual stocks, for each of the two oil price measures.

Against this backdrop we contribute to the literature by:

(i) implementing a `beauty contest' of sorts, sequentially analyzing a large sample of individual stocks; and more importantly
(ii) placing special emphasis in testing for time-varying effects and relationships, placing our work in a unique position relative to the existing literature.

For this purpose we employ a multi-factor empirical asset pricing framework in which the excess returns of a given stock i.e. the returns over and above the risk-free rate of return, are regressed against a number of price determining factors, including different measures of oil price change/uncertainty (i.e. to capture for example asymmetric or symmetric responses to oil price changes).

Estimation is done using the dynamic model averaging (DMA) framework which allows us to obtain time varying probabilities that oil price changes are among the set of indicators that govern excess stock return movements in any given period, as well as time-varying coefficients. In this paper, we place special emphasis on the interpretation of these probabilities.

c) The main conclusions

Our findings offer convincing evidence that US stocks generally do not contain a systematic premium due to oil price changes (symmetric, asymmetric) or shocks (demand or supply

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The Energy Journal, Vol. 41, No. 5

driven). We therefore lay challenge to the prevailing wisdom that oil-prices/shocks are important in determining the excess returns of listed firms in the US stock markets. We offer a generally more humbling appraisal of the topic, which supports the view that oil price fluctuations are not a `frequent' determinant of excess returns. This result is strongest when using daily frequency data, where, on average, stocks tend to price oil related information for around 2-3% of the sample period. For the monthly frequency data there is stronger evidence of the importance of oil price shocks, yet still the average stock is only significantly affected for 33% of the sample period, according to the results of our analyses.

Reconciling our conclusions against the current consensus (that oil prices have wide reaching impacts over stock prices) we note that around 50-100% of stocks, depending on the use of daily or monthly frequency data, show a significant reaction to oil-price related information, at least once over the sample period. Regarding the hypothesized asymmetries, the evidence suggests for the daily data, the responses of excess stock returns to asymmetric oil price changes are more frequent compared to the symmetric changes.

The picture is less clear for the monthly data, where excess stock returns seem to respond more frequently to different oil price shocks, depending on the time period. We should note, though, that this response is also at a fraction of the time over the sample period. Thus, in summary the primary conclusion is that oil price shocks, though not negligible, are not a core determinant of excess stock returns.

d) Potential benefits, applications and policy implications of the work.

This topic is important for at least four reasons. First, given the recent shifts in international oil prices during 2014-2015, the sustained stagnancy at below-expected price levels through to the early part of 2016 and continuing into 2017, as well as, the upward movements since then, there is a valid question as to whether the role of oil prices to stock market performance has been altered.

Second, it would be valuable to gauge how financial markets might react to the oil price recovery, which appears to be emerging towards the end of 2018 and generally continuing into the early part of 2019.

Third, the majority of previous studies focus on aggregate or industrial indices and/or low frequency data, whereas in this study daily firm-level data are used, which provide richer information, in the sense that heterogeneous effects are not masked by the very nature of the indices construction.

Fourth, the majority of the studies concentrate on static econometric frameworks rather than time- varying frameworks. Hence, despite the wealth of literature, the question on how and whether oil prices impact stock market returns still remains open.

Growth Sources of Green Economy and Energy consumption in China: New Evidence Accounting for Heterogeneous Regimes

Guanchun Liu,[a] Yuanyuan Liu,[b] and Chien-Chiang Lee[c]

Since the reform and opening up in 1978, China has experienced rapid growth for nearly three decades with an average rate 10%, and especially the amount of energy consumption has been rising dramatically. However, China has entered a 'new normal' stage since 2012, at which the growth rate continuously drops and the relative importance of the tertiary industry keeps increasing. Under this new background, it is essential to reestimate the growth sources of green economy in China, and especially investigate whether the importance of energy consumption varies across industries and years.

In this paper, we propose an extended Solow growth model accounting for regime heterogeneity, which is incorporated via a finite mixture model that permits multiple growth regimes and regime switch over time. The framework decomposes growth into two components, namely, green total factor productivity and factor endowment. In particular, we classify Chinese provinces on the basis of the similarity of the conditional distribution of real GDP. More importantly, the number of multiple green growth regimes is endogenously determined and regime-specific output elasticities for production factors are estimated.

Based on a panel data of three industries for 29 Chinese provinces over 2000–2015, our empirical analysis proceeds with four main questions: (i) investigating whether the same industry across provinces follows a universal green growth path; (ii) estimating the green growth sources of different industries; (iii) assessing the importance of energy consumption across industries, and (iv) exploring the decomposition bias in traditional methods that do not account for regime heterogeneity.

The empirical results show that a finite mixture model with three regimes is best to describe the green production technology of each industry for Chinese provinces. Specifically, some provinces switch their regimes over time, while the others maintain the same regime. Furthermore, when accounting for regime heterogeneity in the Solow decomposition framework, we observe that the contribution rate of factor endowment (green total factor productivity) is overestimated (underestimated) in traditional methods. With respect to the role of energy consumption, it is overestimated in traditional methods for the primary and tertiary industries, but underestimated for the secondary industry. More importantly, the reliance of China's over economy as well as the secondary and tertiary industries on energy consumption tends to decline during the period 2000–2015.

Our work is related to a number of different literatures. First, this paper contributes to the researches on the growth sources of China's green economy. We extend the data sample to 2015 that includes the 'new normal' stage after 2012, whereas most similar studies generally examine the question before 2000 and especially ignore energy consumption in the production function. Second, this paper connects to the studies on accounting for regime heterogeneity. Differing from traditional works, we overcome the issue using a finite mixture model based on the similarity of the conditional distribution of real GDP. Third, this paper relates to the empirical literature that applies the latent

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class models or finite mixture models. We permit Chinese provinces to switch regime over time, while most previous researches assume a constant growth regime for each economy.

Fuel Demand across UK Industrial Subsectors

Paolo Agnolucci[a] and Vincenzo De Lipsis[b]

The industrial sector contributes significantly to the world energy consumption and emissions of greenhouse gases. Pursuing actions to keep a global temperature rise this century within 1.5 degrees Celsius, as part of the Paris agreement, will require drastic action from all sectors of the national economies, including the industrial sector. In this context, econometric studies are useful to help explore the pathways of energy and fuel consumption which can be expected if historical drivers continue to unfold in the way they did in the recent past.

Econometric studies of industrial energy demand are however surprisingly scarce. Studies for industrial subsectors are even more so, with evidence starting to be built recently and for a very limited number of countries. On the other hand, the topic of heterogeneity has gained more and more importance in energy economics, as testified by contributions taking into account the impact of this factor topics such as energy efficiency and the rebound effect. In fact, heterogeneity in the industrial subsector fuel demand is key to understand fuel substitution, its impact on business-as-usual scenarios used as a starting point for climate mitigation, as well as the strength of the levers available to policy maker to help the industrial sector in the decarbonizing transition. As future climate commitments become more stringent, the importance of understanding subsectorial of fuel substitution becomes more valuable. At the same time, as longer time series become available, econometric studies assessing heterogeneity in the industrial subsectors become more and more viable.

This paper show that useful empirical evidence on this subject can be obtained by applying a parsimonious multivariate cointegration analysis that makes use of the readily available time series data on fuel demand and its determinants. We estimate fuel demand by incorporating dynamic specifications typical of cointegration studies and the system approach typical of translog studies. We model fuel demand as shares in a cointegrating VAR system with as many cointegrating vectors as the number of modelled fuels, each representing the long-run demand for a specific fuel.

Our approach presents a number of important advantages. Firstly, we are able to model the simultaneous determination of demand for different fossil fuels within a consistent framework. Secondly, we can exploit the cross-equation restrictions implied by the long-run representation, which offer a useful means to reduce the number of parameters to estimate. Finally, additional gain in terms of degrees of freedom is ensured by the fact that we model shares rather than fuel intensities.

Our main result, the emergence of substantial differences in the systematic behavior of firms across subsectors, provides a note of caution to authors imposing homogeneity in the fuel demands across subsectors, estimating fuel share elasticities for the industrial sector as a whole or focusing on energy consumption rather than fuel consumption. In addition, we find that price elasticities in the UK industrial sector are larger than many previous estimates available in the literature, and we confirm that gas consumption is more sensitive to price variations than electricity consumption. These conclusions are important not only from a modelling perspective, in a way which we would expect to be replicated for other countries, but also for policy-making

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Unveiling the Time-dependent Dynamics between Oil Prices and Exchange Rates: A Wavelet-based Panel Analysis

Hyunjoo Kim Karlsson,[a] Kristofer Månsson, and Pär Sjölander**

The objective of this paper is to re-examine the relationship between real oil prices and real effective exchange rates (REER) for major oil-exporting countries with floating exchange rates. A new panel wavelet method, suggested by Gallegati et al. (2016), is utilized since it is a powerful alternative estimator for analyzing economic relationships at different time-horizons in the situation of integrated, but not cointegrated, sets of data. Based on monthly time-series data from 1996 to 2015, we apply the wavelet-based principles of Gallegati et al. (2016) both for the individual time series and for a panel of real oil prices and REER. In contrast to many previous studies, our results support the theoretically expected positive nexus between the real oil prices and REER for our dataset. As is illustrated by the coefficient estimates, this (theoretically expected) positive relationship is stronger at the larger time scales (that is, at the 4–8 and 8–16 month wavelet scales) compared to the smaller time scales (that is, at the 1–2 and 2–4 month wavelet scales). The findings of this study therefore add to the existing literature, since they disentangle the specific relationship between oil prices and exchange rates at different time scales, which has important policy implications.

Why the Effects of Oil Price Shocks on China's Economy are Changing

Shouyang Wang,[b] Xun Zhang,[c] and Lin Zhao[d]

In recent years, some studies reveal that the effects of oil price shocks on the macro economy have decreased in some developed countries, while studies about China are still not clear enough. A TVP-VAR model is established to investigate how the effects of oil price shocks on China's economy are changing. Results show that both responses of output and inflation to the oil price shock are decreasing but fluctuating over the whole period (January 1997 to December 2018), and responses on real output are much greater and last longer than those on inflation.

Reasons for effects changing in China may be different from those of some developed oil importing countries. First, China is a net crude oil importing country and its dependency on imported crude oil has gradually increased over the last twenty years. This is different from some developed countries for which oil import dependency has decreased (United States1) or remained relatively stable (Japan and most countries in the European Union) over the same period. Second, China has undergone a series of economic reforms and structural changes (Huang et al., 2019) and is

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a typical transition economy since the 1970s (Campos and Coricelli, 2002). Stylized facts and many deep parameters in the structural model of China have changed over time. That is very different from some developed countries which have relatively stable parameters (such as the U.S.).

Based on these facts, a DSGE model is used to explore which factors play important roles in determining these changes. The model accurately summarizes the features of the economic structure and oil consumption in China. The two critical features of this model are the inclusion of oil inputs in the production function and the inclusion of transportation sector. These features provide important channels by which oil price shocks can affect the dynamics of the Chinese economy. Results indicate that, among all the factors, decreasing oil intensity and monopoly power reduce the effects of oil price shocks, while increasing capital intensity in production amplifies them. Other factors, such as changing price stickiness, deregulations of refined oil prices, and shifts in monetary policy targets, have limited effects on the relationship between oil price shocks and China's macroeconomy.

Energy R&D Investments and Emissions Abatement Policy

Di Yin[a] *and Youngho Chang*[b]

Economic models of climate change have attempted to evaluate the benefits and costs of slowing down climate change. Considering the long-term effects of greenhouse gases on climate change, policymakers must take into account the interaction between energy technological progress and emissions abatement policies. This study aims to analyze whether and how energy R&D investments shape energy technological changes. The study considers R&D investments in energy efficiency and in backstop technologies. The former is expected to enhance the level of efficiency in energy supply chains and convey the same energy with fewer carbon emissions. The latter is supposed to expand the system scales of backstop technologies, to speed up energy transitions from fossil fuels to backstop technologies endogenously, and to reduce the amount of carbon emissions in the long-term.

This study develops a new model incorporating energy R&D investments and endogenous energy substitution. The model is built upon two sectors, the capital-goods production sector and the consumption-goods production sector, and four energy resources, three fossil fuels and a backstop technology. The new model has two distinct innovations. First, it adopts a two-factor learning curve to capture the effect of the two R&D investments on energy technological progress. Second, the model develops a two-sector and multi-energy production function with detailed energy representation, which emphasizes the micro-foundation of the energy transition. The study simulates four R&D cases, i.e., without energy R&D investments, only with R&D investments in energy efficiency, only with R&D investments in backstop technologies, and with both R&D investments. Each case considers four CO_2 abatement policies, i.e., business as usual (BAU), an optimal policy, a 2 °C policy, and a 1.5 °C policy.

The simulations show that R&D investments in backstop technologies appear to account for 80% share in the total energy R&D investments. Considering the interactions within the two types of energy R&D investments, R&D investments in backstop technologies crowd out more

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R&D investments in energy efficiency under the case with a more stringent abatement policy. A more restrictive abatement policy appears to boost the R&D investments in the early period from 2015 to 2050.

The simulations present energy transition progress in the economy. The sequence of the energy transition in the capital goods-production sector is from oil products to coal products, and to a backstop technology while one in the consumption goods-production sector is from natural gas to oil products, to coal products, and to a backstop technology under the BAU policy, the optimal policy, and the 2 °C policy. However, under the 1.5 °C policy the energy transition appears to occur from oil products/natural gas directly to a backstop technology in the capital/consumption goods-production sector. The energy transition to backstop technologies occurs in 2090 under the optimal policy, in 2070 under the 2 °C policy, and in 2050 under the 1.5 °C policy provided two types of energy R&D investments. The R&D investments in backstop technologies appear to accelerate the energy transition to the backstop technology by five years.

A more restrictive abatement policy appears to hurt the economic welfare more in the short-term, while it appears to enhance the economic welfare more in the long-term. The abatement costs under the optimal policy are one-tenth of those under the 2 °C policy and one-fifteenth of those under the 1.5 °C policy. R&D investments in the backstop technology lead to about 10% gains in GDP under the three abatement policies and reduce the abatement costs by 5% under the 2 °C policy and by 4% under the 1.5 °C policy. The highest temperature is expected to reach 2.65 in 2105 under the optimal policy, which is 0.42 °C lower than one under the BAU scenario.

The study runs the robustness check regarding the learning rate and the time horizon. A high learning rate brings an early energy transition to the backstop technology and results in high economic gains through the R&D investments in the backstop technology. Two time-horizons, i.e., a 100-year horizon and a 300-year horizon, are adopted and examined. The differences between the results of the two time-horizons are small for the relative changes in energy R&D investments, economic gains, abatement costs, and the timeframe of energy transition from 2015 to 2100.

Are Energy Executives Rewarded for Luck?

Lucas W. Davis[a] *and Catherine Hausman*[b]

From January 2014 to January 2016, oil prices fell from nearly $100 per barrel to just over $30 per barrel. In those same two years, the CEOs of 30 large U.S. oil and gas exploration companies lost an average of over half a million dollars each in annual compensation. Perhaps in no other industry are the fortunes of so many executives so dependent on a single global commodity price.

In this paper, we analyze executive compensation data from 78 U.S. oil and gas companies over a 24-year period. We document a strong correlation between crude oil prices, company value, and executive compensation. In our primary specification, a 10% increase in company value driven by oil prices leads to a 2% increase in executive compensation. Across specifications, we cannot rule out that executive compensation responds just as much to changes in firm value driven by oil prices as it does to generic changes in firm value.

We then perform a series of additional analyses to better understand the mechanisms. First, we show that this oil-price effect is robust to including time-varying controls for capital

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expenditures and labor. Second, we show that the oil price effect holds for both CEOs and non-CEOs. Third, we show that the oil price effect is widespread across the different individual components of executive compensation, including not only total compensation, but also bonuses and long-term cash incentives. Fourth, we show that the oil price effect is larger at companies with more insiders on the board. Finally, we show that the oil price effect is asymmetric, with executive compensation increasing more with rising oil prices than it decreases with falling oil prices.

We then discuss potential interpretations, drawing from the existing literature on executive compensation. An influential analysis by Bertrand and Mullainathan (2001) interprets regression results similar to ours as evidence of rent extraction, in which executives are able to co-opt the pay-setting process. Indeed, it is difficult to reconcile this oil price effect with the predictions of standard contracting models in which companies should "filter out" oil prices and other forms of observable luck (Holmstrom, 1979). Still, there are ways to reconcile the oil price effect with models in which firms are maximizing returns to shareholders. For example, one could imagine that when oil prices are high, additional executive effort is needed, and so compensation rises to induce that effort. As in much of the rest of the literature, we are unable to sharply distinguish shareholder value and rent extraction interpretations. Part of the challenge, as explained by Murphy (2013), is that these two views are not mutually exclusive, with both forces impacting compensation to varying degrees across firms and over time.

Our results provide a window into executive compensation in a dynamic, multi-billion dollar sector. The United States is the world's largest producer of oil and natural gas. The annual value of U.S. oil and natural gas production exceeds $200 billion, and the firms in our sample have a total market value of almost half a trillion dollars. Reflecting the size of this industry, the dollar value at stake in executive pay is substantial: total compensation of oil and gas executives in the latter part of our sample is almost $1 billion per year.

Behavioral Anomalies and Energy-related Individual Choices: The Role of Status-quo Bias

Julia Blasch[a] and Claudio Daminato[b]

The gap between the actual and optimal rate of adoption of energy efficient appliances is usually referred to as the energy efficiency gap. The economic literature on the energy efficiency gap provides several explanations for the persistence of the gap in the residential sector, which are usually categorized into market failures and behavioral failures or behavioral anomalies. One such behavioral anomaly is the status-quo bias, that is an individual's tendency to do nothing or to maintain one's current or previous decisions. The theoretical literature suggest that status-quo biased individuals potentially refrain from replacing their old household appliances by newer and more efficient ones. Furthermore, theory suggests that the status-quo bias could make households use their appliances more intensely, due to a desire to justify the initial investment cost. While the relation between the status-quo bias and energy-related decisions of households has been discussed theoretically, no empirical testing of the relation has been performed so far.

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This study is the first to empirically explore the role of status-quo bias for the replacement and use of household appliances. We conduct a multivariate regression analysis using data from a household survey among customers of European energy utilities. The results show that our measure of status-quo bias is an important predictor of both the age of home appliances and the level of consumption of energy services of a household. If an individual is status-quo biased the probability that the individual's household owns at least one appliance that is more than 10 years old increases by 4 percentage points. Also, we find that the consumption of energy services of a household increases by 5.4 percent when the household head is status-quo biased. The tendency of status-quo biased individuals to own older (less efficient) appliances and to use their appliances more is also reflected in the total electricity consumption of their households, which is found to be around 6% higher than the one of households with non-biased household heads.

Our results suggest that the status-quo bias is an important determinant of the level of energy consumption of European households. They inform behavioral models of consumer behavior about the channels through which the status-quo bias operates and have important policy implications. Given that the status-quo bias expresses a preference to stay with the current situation, rather than a lack-of knowledge or cognitive ability, it is more difficult to address with policy measures than other behavioral anomalies. It may then constitute a severe limit to policy-makers' opportunities to narrow the energy efficiency gap. Yet, our findings offer guidance to policy makers about what range of policy measures might be more effective in overcoming the consequences of the status-quo bias and prompt to the importance of tailoring alternative policies for individuals with different characteristics.

Impact of Permit Allocation on Cap-and-trade System Performance under Market Power

Mei Wang[a] *and Peng Zhou*[b]

Carbon market is established to achieve CO_2 emission reduction targets cost efficiently. However, the existence of market power usually has negative impacts on the cost-effectiveness of the carbon market. As market power-induced efficiency loss depends on permit allocation, the choice of permit allocation methods is likely to affect the cost-effectiveness of the carbon market. This paper theoretically examines the effect which yields some policy recommendations on how to choose a CO_2 emission permit allocation method for different industries.

We first construct theoretical leader-follower model in the carbon market to show how the choice of emission permit allocation method affects the cost-effectiveness of an ETS when market power exists. Meanwhile, we analyze the effect of emission permit allocation method on CO_2 cost pass-through for fairness consideration.

The model results show that proper choice of emission permit allocation method can help reduce the efficiency loss. Under grandfathering and benchmarking rules, the carbon market would be more efficient if the permits initially allocated to the dominant firm were closer to its CO_2 emissions. Under the auctioning rule, the dominant firm tends to lower the CO_2 price, which may result

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in e f ciency loss. We also f nd that the CO_2 emission permit allocation method a f ects the CO_2 cost pass-through and the fairness of ETS. Although receiving free allocation of CO_2 emission permits under the grandfathering rule, f rms still pass all the CO_2 cost through to downstream consumers, resulting in windfall pro f ts. Under the benchmarking rule, f rms just pass a small portion of the CO_2 cost. Under the auctioning rule, f rms buy the CO_2 emission permits themselves and pass on all the CO_2 cost.

Based on these f ndings, we suggest that di f erent emission permit allocation methods may be used in di f erent industries. Firms in the power sector are likely to have the market power to determine the CO_2 price in the carbon market and the CO_2 cost pass-through potential in the product market. Thus, the benchmarking rule may be used for the power sector. Firms in energy-intensive industry have high CO_2 costs and would pass most CO_2 costs through to downstream consumers. Therefore, benchmarking is recommended for energy-intensive industry in a new carbon market and auctioning is suggested in a mature carbon market. As f rms in the domestic sector have diverse products in the product market, auctioning is the best choice for the domestic sector. Since CO_2 costs in the domestic sector are relatively low, grandfathering could be the second choice for the sector.

Transient and Persistent Energy Efficiency in the Wastewater Sector based on Economic Foundations

Stefano Longo,[a,b,c,d] Mona Chitnis,[b] Miguel Mauricio-Iglesias,[a] and Almudena Hospido[a]

As the number of wastewater treatment plants (WWTPs) increases worldwide and the ef- f uent quality requirements become more demanding, the issue of energy e f ciency has been attracting increasing attention from an environmental and economic point of view. Recent approaches to estimating WWTP energy e f ciency, based on e.g. Data Envelopment Analysis (DEA), have focused on controlling for exogenous variables (e.g. temperature, in f uent dilution, etc.) ignoring the possible presence of omitted (unobserved) variables. In e f ect, WWTPs may be characterized by operating under particularly heterogeneous environment, due to e.g. di f erent topography of the service area which has a direct e f ect on the number of lift pumps and therefore on electric energy consumption. Variation in operating environment that manifests as variation in energy use, if not controlled for, may be misinterpreted as e f ciency di f erences and can lead to poor root-cause diagnosis. Furthermore, since the level of e f ciency can be decomposed in two parts, one persistent and one transient, for a correct low-e f ciency diagnosis, distinguish between the two component seems important. Otherwise, water utilities may wrongly decide to invest in new equipment and infrastructure, while ine f ciency arises from some application of wrong operational strategies due to e.g. error in management of sludge age and return sludge, too infrequent sampling or inadequate evaluation of monitoring data, or vice versa.

Using data from 183 Swiss WWTPs over the period 2001 to 2015, this research applies a novel approach of Stochastic Frontier Analysis (SFA) for energy demand modelling to estimate the comparative energy e f ciency of a comprehensive set of WWTPs, as far as in known, for the f rst time. The objective of this paper is to investigate how overall ine f ciency of WWTPs is decomposed into persistent and transient ine f ciency and the importance of each of these components in

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the sector. Energy e f ciency estimates obtained from three panel data models are compared in order to f nd out whether accounting for unobserved heterogeneity in the model signi f cantly in f uences the results.

The proposed electricity demand speci f cation controls for the price of energy, volume of wastewater treated, plant capacity, concentration of main pollutants removed from wastewater (e.g. COD, NH4 and NO3), temperature, type of secondary treatment and the presence of sludge dewatering in order to obtain a measure of energy e f ciency. Overall, a fair degree of variation among plants is established in energy e f ciency estimates, indicating that there is considerable room for improvement. The results illustrate that the e f ciency scores are, as expected, sensitive to model speci f cations. Depending on the model employed, considering overall e f ciency estimates, WWTPs could save on average as much as 20–60% of their electricity usage, being persistent energy ine f ciency more severe than transient energy ine f ciency. Consequently, the majority of ine f ciency is not caused by operational technical problems but instead to recurring (over the years) identical problems. Thus, unless there is a structural change in the operation of individual plants such as a change in mechanical equipment, it is very unlikely that ine f ciency will change. However, by employing a model able to decompose the time-persistent component of ine f ciency into a time-invariant heterogeneity e f ect and a persistent ine f ciency e f ect, we show that a large part of the persistent ine f ciency is due to time-invariant unobserved heterogeneity suggesting that di f erences in topography may a f ect signi f cantly e f ciency at WWTP, hence its e f ect should be controlled for in order to obtain meaningful e f ciency estimates.

Furthermore, it is shown that the level of energy e f ciency of equipment in f uences the demand for energy. Consequently, technological innovation can induce a reduction of energy consumption provided that the equipment is used in an e f cient way. Finally, the estimation of economies of output density and scale suggests that large energy savings can be achieved by directing higher volume of wastewater to the plant. On the one hand, it is con f rmed that it would be convenient for WWTPs to operate at the maximum possible scale due to the presence of economy of scale. On the other hand, it is shown that economy of output density is even a bigger driver to reduce the unit consumption. Even if in general, design guidelines propose over-dimensioned WWTP designs in order to avoid malfunctions and non-compliance with e f uent requirements, our results suggest that special attention should be given during WWTP designing phase in order reduce energy demand by avoiding extra and unnecessary reaction volumes.

Concluding, it is seen that, thanks to the possibility to take into account the presence of unobserved heterogeneity, to distinguish persistent from transient ine f ciency and to take into account the statistical noise of data errors, the proposed approach, compared to previous research, is superior to deduce appropriate energy diagnosis in order to make ine f cient WWTPs e f cient. In light of the above f ndings, the methodology and results of this study can be of great interest for researchers, policy makers and plant operators in designing new WWTPs, developing optimal energy saving operational strategies and make informed decisions for improving energy e f ciency of WWTPs.

International Oil Market Risk Anticipations and the Cushing Bottleneck: Option-implied Evidence

Marie-Hélène Gagnon[a] and Gabriel J. Power[b]

A. The motivations underlying the research:

WTI (US) and Brent (Europe) are the world's two most important crude oil indexes. Prior research has found they have not achieved complete integration due to macroeconomic, production, and transportation infrastructure frictions. From a practitioner's point of view, it matters to what extent the two indexes are substitutes for one another, whether risk anticipations are similar in the two markets and how they are transmitted, or whether managers can hedge or diversify extreme risks--such as those linked to supply disruptions or economic slowdowns. This paper's objective is to contribute to a better understanding of how Brent and WTI risk expectations are related, how they co-move, in which market they are formed (discovered) and transmitted, and how risk equilibria can become weakened or fragmented during crisis periods. The results should deepen our knowledge of international oil market integration and have clear practical implications for portfolio diversi f ca-tion, cross-hedging, forecasting, and risk management. The paper also pays special attention to the impacts of the Cushing bottleneck on market risk expectations.

B. Short account of the research performed:

This paper investigates the equilibrium dynamics in prices and risk anticipations in crude oil markets between WTI and Brent over the period 2006-2019. We compute daily time series observations of option-implied WTI and Brent volatility, skewness, and kurtosis, thereby obtaining new risk metrics to capture market expectations of evolving risks. We analyze these variables pairwise using a bivariate time series system highlighting the channels of international linkages and risk spillovers. The framework we use is the fractionally cointegrated VAR (FCVAR), which generalizes classic cointegration to allow for variables that are stationary but display long memory. We interpret the estimates and the hypothesis tests to assess the degree of oil market integration. This framework allows us to measure long- and short-run adjustments to and analyze them using formal hypothesis tests, documenting comovement and spillovers between WTI and Brent. First, we test whether there is an international equilibrium (a cointegration relation) in investor anticipations of volatility, asymmetric risks, and tail risks. Second, we investigate whether signi f cant WTI-Brent spreads in prices and risk metrics are supported in the long run. Third, we perform weak exogeneity tests to assess speeds of adjustment in the model. These tests have practical relevance because they highlight the adjustment process following disequilibrium between the two markets. Finally, we measure Brent and WTI discovery (information) shares for prices and risk expectations. The results describe whether news about prices and risk expectations tend to originate more in a speci f c market, or whether both markets contribute information equally.

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C. Conclusions

This study provides four important conclusions:

i) Persistence (long memory) matters for crude oil markets. This paper documents 'limits to arbitrage', as we find that market disruptions can have a lasting effect on oil prices. We also document that risk anticipations are persistent in crude oil markets and that accounting for persistence is required in order to effectively model risk dynamics.
ii) International oil markets are partially integrated in risk expectations, as they share a common equilibrium ex ante. Brent-WTI risk expectations are integrated over the full sample period, but they diverge during the Cushing bottleneck sub-period.
iii) Fragmentation of the common oil market equilibria, associated to the Cushing bottleneck. We document a volatility differential during this period. The joint market dynamics for extreme risks appears to matter less than regional constraints.
iv) The Brent-WTI relationship in risk expectations holds across investment horizons, but it is more fragile for extreme risks valued at longer horizons.

D. Potential benefits and applications:

These conclusions lead to several practical implications:

a) Despite partial integration, WTI and Brent are not substitutes for one another to cross-hedge volatility or extreme risks. However, there is a silver lining. Diversification across indexes for extreme risks may be possible during periods of disruption, as the joint dynamics breaks and investor risk anticipations regarding oil indexes are more locally driven.
b) Oil market risk forecasts could be improved using the combined information from both indexes rather than from only one market and by using the forward-looking information provided in the option markets. Indeed, using option data is advantageous because it is challenging to measure higher moments accurately using historical price data.
c) Brent plays an increasing international role, but the discovery of extreme risk anticipations still occurs mostly on the WTI index. These findings underscore for crude oil markets the importance of accounting for higher-order moments, which behave differently than expected in a traditional risk-return asset allocation strategy.
d) Understanding the joint dynamics of crude oil higher moments is valuable for modeling and forecasting purposes, even though the relationship is harder to capture at longer horizons.

Locational Investment Signals: How to Steer the Siting of New Generation Capacity in Power Systems?

Anselm Eicke,[a] Tarun Khanna,[b] and Lion Hirth[c]

The location of new power plants signi f cantly determines the need for investment in transmission infrastructure. In addition, new generators that are located far from consumption centers increase network losses and, potentially, grid congestion. In this paper, we study how market signals resulting from the electricity market design and from additional regulatory instruments may a f ect the location of new investment in power generation.

A variety of instruments provide locational incentives that can steer generation investments within a power system. We introduce a conceptual framework for categorizing and analyzing these instruments and cluster them into the f ve groups locational electricity markets, deep grid connection charges, grid usage charges, capacity mechanisms, and renewable energy support schemes. We use our framework to review and discuss the locational signals provided by such instruments in twelve major power systems. We also provide quantitative estimates of their importance as locational instruments.

We f nd that all twelve reviewed power systems employ at least one locational instrument. Most systems, including power systems that implemented a locational electricity market such as nodal pricing, use multiple instruments in parallel. None of the identi f ed instruments prevails. Quantitative estimates suggest that the signals' magnitude di f ers signi f cantly across systems. While the di f erence between locations where the signal is strongest and weakest is small for some instruments, for others it is around 20 EUR per MWh. Such a di f erence is signi f cant when compared to the levelized costs of combined cycle plants of 64-72 EUR per MWh in Europe.

The impact of locational signals on investment decisions is however limited by some design elements. Many of the instruments reviewed are not easily predictable, also due to a lack of transparency, which strongly reduces their impact on investment decisions. Some of the reviewed instruments also have low spatial granularity and therefore do not su f ciently re f ect bottlenecks in the network infrastructure. None of the instruments, except for locational electricity markets, re f ects the temporal dimension. This may lead to undesired dispatch incentives.

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