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A Regionalized or Unified Oil Market: The Price Spread Between Brent and WTI

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Motivations underlying the research

Over the last several years, I have published papers that show arbitrage opportunities largely unify the world oil market and that they can account for much of the price differences among crude oils. Exceptions include crude oils that are especially heavy or originate in nations with poor governance.

But my confidence in these results was limited by the sudden appearance of a large spread in the prices for Brent and WTI, which are two of the world's most important benchmark crude oils. As stated by the Morpheus character in the film The Matrix, "You don't know what it is, but it's there, like a splinter in your mind, driving you mad." My splinter, I had to understand why to crude oils from nations with relatively transparent governments and similar physical characteristics (both light and sweet), suddenly seemed to be priced by regionalized markets.

This sudden separation in price also perplexed other researchers. They posited several possible explanations; the shale oil boom, imports from Canada, building inventories, the lifting of the US ban on crude oil exports, changes in transportation infrastructure, declining production of crude oils that make-up Brent, the collapse of Libyan production, and even exchange rates.

But these efforts did not satisfy my curiosity. Often, authors examined only a subset of possible explanations, which raised the specter of omitted variable bias. In others, authors ignored the nonstationary nature of the data, which raised the possibility that the statistical results were spurious. Finally, many analyses implicitly assumed that the spread was caused by a sudden change in an explanatory variable and so looked for a change-point in the price spread, rather than focusing on the factors that influenced the price of Brent and WTI.

Research performed

Here, I try to solve these shorting-coming by estimating two cointegrating vector autoregression (CVAR) models for the price of Brent and WTI and analyzing their residuals to identify periods when the model fails in a statistically significant manner. A univariate model specifies only the price of Brent and WTI. This model likely suffers from omitted variable bias and so its residual should identify periods when the long- and short-term relations between the two prices change in a statistically significant fashion. The second CVAR model contains all possible explanary variables. If this expanded CVAR model includes the relevant variables, the residuals should not contain any structural changes and the long-and short-run relations should quantify the factors that open and close the price spread.

After an initial period (1987-2010) when the price spread between Brent and WTI remains relatively constant, their prices move separately during three periods. Starting in 2011, the price spread expands suddenly. This spread narrows starting in 2014. But in 2017, the price spread widens again. The CVAR models identify the likely causes for the two later periods. In 2014, the price spread shrinks because investments in transportation infrastructure increase the flow of crude oil from the mid-continent to Texas. Expanding the market for WTI raises its price. The price spread expands when the US lifts the ban on exporting crude oil. The price of WTI falls because the existing infrastructure forces exporters to load their cargos onto smaller, higher cost vessels and introducing new customers to the physical characteristics of WTI forces exporters to offer price discounts.

Conversely, the CVAR models do not clearly identify the causes for and the timing of the increase in the price spread between Brent and WTI that starts in 2011. Results suggest that increasing imports

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of crude oil from Canada, rising production of crude oil from hydraulic fracturing, expanding inventories, and declining production of crude oil from the North Sea raise the price of Brent relative to WTI. But their effects are small and gradual compared to the sharp and large increase in the price of Brent relative to WTI. And so a small splinter remains for further investigation.

Finally, the CVAR models are consistent with a speculative bubble in the world oil market between 2007 and 2009. During this period, the residuals for price of WTI and Brent fail in a statistically significant fashion in both the univariable and expanded CVAR model. Failures in both models suggest that market fundamentals do not account for prices, which is the definition of a speculative bubble.

Main conclusions

Taken together, the results presented here add nuance to the debate about whether the world oil market is unified or regionalized. Rather than an either or, I argue that a feedback loop moves the world oil market between phases when it is unified or regionalized. Innovations, such as hydraulic fracturing change the local balance between supply and demand. If these changes are sufficiently large, they can regionalize local prices, which can enlarge price spreads. These larger spreads create opportunities for arbitrage. Sometimes these opportunities are limited by bottlenecks, such as transportation infrastructure. Over time, these bottlenecks spur new investments. And once the opportunities for arbitrage are realized, price differences are reduced, and world oil market moves towards unification.

But the return towards a unified market does not imply a return to the status quo ante. Technical changes that tend to regionalize the market and the new investments that are used to arbitrage the resultant price differences change the point of reference used to arbitrage the price spread. These changes likely create a new equilibrium as represented by a new set of price spreads.

The Ephemeral Brent Geopolitical Risk Premium

Hany Abdel-Latif,[a] Mahmoud El-Gamal,[b] and Amy Myers Jaffe[c]

Motivations underlying the research

In our previous research, we have highlighted a self-perpetuating tri-variate cycle in oil prices, financial market conditions, and geopolitical risk, which dates back at least to the early 1970s and has continued to this day. Low oil prices lead to heightened geopolitical risk in the Middle East and more broadly, and the latter eventually leads to higher oil prices, which leads to increased global financial liquidity due in part to recycling of petrodollars. Petrodollar recycling, in turn, plays a critical role in raising the prices of various financial assets, including commodity and oil prices, and also contributes to arms deals that can fuel later geopolitical strife. Upswings of the secular business cycle are thus amplified through oil and financial markets, until asset overvaluation and high energy prices precipitate a downturn in the business cycle, which is likewise amplified by withdrawal of petrodollars from the global financial system. Although we do not know of other authors who have connected all three components of this global self-perpetuating cycle, our analysis for each of the three pairwise combinations of variables agree with other research in the literature.

In recent years, we have noticed that correlation structures between oil prices, geopolitical risk, and global financial liquidity have exhibited changes in magnitude and structure, and we wanted to investigate those changes in some detail. In this paper, we have focused on one particular pair of variables: oil prices and geopolitical risk. We study the changing correlation structure at different times and time horizons between Brent prices and a geopolitical risk index, conditioning on variables that measure the

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level of aggregate economic activity and oil inventories, as proxies for physical oil market supply-and-demand conditions.

Research performed

We conducted three sets of statistical analyses to investigate the changing correlation structure between Brent prices and the geopolitical risk index compiled by Caldara and Iacoviello, based on major newspaper reports. All three sets of analysis were conducted conditional on Kilian's index of global economic activity, constructed from shipping data, and global oil inventory data from Energy Intelligence Group, publisher of Petroleum Intelligence Weekly. The first analysis, which spans partial correlation structures for various time horizons from two months to several years, used Continuous Wavelet Transform (CWT) analysis. This analysis showed somewhat stable trends over the past decade at the medium term of one to three years, and to a lesser extent at the shorter term of six to twelve months. The primary result from this analysis was to show that oil prices followed geopolitical events during the Arab spring period in 2011–12 but have led those changes by about two months since the end of the Arab Spring in 2013.

Unfortunately, CWT results showed too much variation at the shorter time horizon of two to three months. Therefore, we used a second methodology, Vector Autoregression (VAR), at the monthly frequency, allowing for two different regimes in the periods 1993–2004 and 2005–2018. The results of this analysis reconfirmed our earlier results using CWT—that after the end of the Arab Spring in 2013, oil prices have moved ahead and in the same direction of geopolitical events by approximately two months. Finally, we conducted GARCH-MIDAS analysis of oil price volatility for the shortest possible time horizon allowed in our data, which is daily, and found that dynamic oil price volatility structures at this time horizon suggest that speculative traders with this time horizon were reacting to geopolitical events.

Main conclusions

Our main result from the two sets of analyses using CWT and VAR methodologies—that oil price movements have led same-direction geopolitical risk movements by approximately two months since the end of the Arab Spring in 2013—is consistent with the hypothesis that some financial market speculators, such as macro hedge funds and algorithmic traders, may amass long positions in Brent in anticipation of geopolitical threats that might potentially lead to oil disruptions. Under the hypothesis, such traders would build long positions based on initial news reports regarding a possible geopolitical event, thus contributing to the advance rise in oil futures prices, and would take profits once the events materialize. While we do not have direct evidence on this trading strategy presented in this paper, anecdotal examination of the periods preceding several geopolitical events lend further credibility to this interpretation.

Price movements at the daily frequency are driven by different types of financial traders, and we find in our third analysis that geopolitical risk has had a positive effect on oil price volatility in later days during the second half of the sample from 2005 to 2018. We conclude that while purely financial speculative traders may base their trading reactions on geopolitical events, more sophisticated investors with longer time horizons anticipate geopolitical events successfully, and trade two months in advance of those events—resulting in higher prices two months prior to heightened geopolitical risk, and vice versa.

OPEC's Pursuit of Market Stability

Axel Pierru,[a] James L. Smith,[b] and Hossa Almutairi[c]

Motivations underlying the research

Maintaining stability in the world oil market is a prominent component of OPEC's self-stated mission. OPEC's modus operandi is to tap spare production capacity to offset shocks to demand and supply. The attempt to stabilize the world oil market is not a small or easy task, disruptions to demand and supply are both large and frequent. Indeed, it is entirely possible that, despite best efforts, the attempt might fail.

We therefore examine the extent to which OPEC has succeeded in this mission. We assess how effective has been OPEC's management of its spare capacity to reduce the volatility of the price of oil. We also estimate the value of OPEC's spare capacity buffer to the global economy and investigate how the benefits of OPEC's effort to reduce price volatility have been distributed geographically.

Research performed

Using annual data starting in 1971, we provide a novel decomposition of shifts in global oil demand and non-OPEC supply that forms the backdrop for OPEC's attempts to stabilize the market. From this decomposition we derive an estimate of the call on OPEC's oil that would have assured the oil price remained constant throughout time, and we compare this inferred call to OPEC's historical production. The following factors can, however, complicate the analysis: (i) the level around which OPEC has attempted to stabilize the price has most likely varied throughout time; (ii) OPEC may not have been able to accurately anticipate or respond to each of the shifts.

Using more detailed monthly data available only since 2001, we turn to Pierru, Smith and Zamrik's (*Energy Journal*, 2018) analytical approach that incorporates these complicating factors. We extend their analysis by including the tumultuous years 2015-2019 and updating the counterfactual exercise (assuming there had been no attempt to stabilize the price of oil) that measures the success of OPEC's attempt to offset perceived shocks to demand and supply.

By elaborating on Pierru et al.'s analytics, we derive the formula giving the value of OPEC's spare capacity buffer to the global economy. Using parameters estimated with our data, we calculate the value of the buffer as the expected increment to global GDP that is generated by OPEC's attempt to counter supply shortfalls. We also provide estimates of the buffer value for some of the world's large economies.

Main conclusions

Our decomposition of shifts in global demand and non-OPEC supply provides a fresh perspective on the debate over the relative importance of demand versus supply factors as determinants of previous price movements. When factoring in OPEC's production, the analysis provides support to the hypothesis that, to a certain extent, OPEC has adjusted its production in response to changes in the call on its oil. It therefore suggests long-term market stabilization efforts by OPEC during the past fifty years.

Our counterfactual analysis based on monthly data indicates that OPEC in general, and Saudi Arabia in particular, has succeeded to a limited but important degree in its attempt to employ spare capacity to offset shocks and stabilize the price of oil. Although the size of each monthly offset may have been subject to significant error (of estimation as well as execution), the magnitude of those errors has nevertheless been contained within the bounds necessary for stabilization to succeed.

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We conclude that from September 2001 to October 2014 OPEC's management of spare capacity decreased price volatility substantially, by at least 25% relative to what it otherwise would have been. During OPEC's market share campaign (November 2014–December 2016) the use of spare capacity did not reduce price volatility, but this was a purposeful departure from previous attempts to stabilize the market. Finally, our counterfactual analysis shows that during the agreement between the OPEC+ nations (2017–2019) the management of OPEC's spare capacity reduced monthly oil price volatility considerably, from 19.3% to 7%.

The value of OPEC's spare capacity buffer to the global economy increases with the magnitude and persistence of the shocks to offset, and the GDP losses incurred when there are production shortfalls. However, the value is diminished by the error that OPEC makes when estimating the size of the shocks to offset and executing production decisions. We find that OPEC's attempt to stabilize the oil price produces an expected annual increment to global GDP equivalent to some $175 billion in 2015 prices, around 0.2% of the world's GDP. For the USA, China and the European Union, the annual value of OPEC's buffer amounts to $39.4 billion, $30.9 billion and $59.4 billion, respectively. These results conform to the intuition that the value of OPEC's spare capacity would be highest for economies that are oil-intensive and that import a large share of their total oil consumption.

Shale oil has a limited impact on the elasticity of the demand for OPEC's oil since it comprises only a small fraction of non-OPEC supply. Therefore, the development of shale oil has not significantly reduced the value of OPEC's buffer. Our results show that OPEC's spare capacity, as an institutional mechanism, plays a critical role in the well-functioning of the oil market, for the benefit of the global economy.

Resource Adequacy with Increasing Shares of Wind and Solar Power: A Comparison of European and U.S. Electricity Market Designs

Audun Botterud,[a] Hans Auer[b]

1. Motivations underlying the research

The installed capacity of renewable electricity generation technologies, in particular wind and solar, has increased rapidly in Europe and the United States in the last decade. At the end of 2016, Europe was generating 29.6% of its electricity from renewables, about twice as much as in the United States. Since 2005, most of the growth in renewables in both regions came from increased wind and solar energy, with hydropower generation remaining roughly constant.

Several factors have led to the rapid development of these variable renewable technologies. In Europe, the main support mechanism has been feed-in-tariffs, which provides a fixed payment per kWh of generation from selected technologies. However, there has been a recent trend towards governments conducting auctions to achieve renewable generation targets in a more cost-effective manner. In the U.S., the main policy instruments have been federal tax credits and state-level renewable portfolio standards. In both the U.S. and Europe, tariff structures such as net metering, where customers with local generation are compensated at the full retail rate, provide indirect support for renewables. Finally, a focus on distributed generation, microgrid solutions, and a growing interest in purchasing wind and solar

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from different consumer groups (households, local energy communities, corporations) that are willing to pay a premium for green products all have contributed to the demand for wind and solar power.

The rapid growth in variable renewable electricity generation is starting to make an impact on the prices in the electricity markets. Wind and solar energy have very low operating costs, which may even be negative when policy support schemes are considered. Hence, these resources displace generation from technologies with higher operating costs. This merit order effect tends to reduce electricity market prices, as observed particularly in some European markets. In addition, constraints on the system combined with occurrences of excess wind and solar generation has led to a significant increase in the frequency of negative prices in electricity markets on both continents. Of course, other factors also influence prices in the electricity market. In the U.S., several studies show that reductions in the cost of natural gas is the primary reason for the low electricity prices in recent years.

In principle, the revenues from the markets for energy and operating reserves should be sufficient to provide incentives for adequate investments in generation capacity. This is the premise for the so-called energy-only market design. However, the reductions in electricity market prices are making it harder for existing generators to make a profit. This has led to renewed discussions about the need for capacity mechanisms, which are additional compensation schemes designed to provide incentives for generation investments and system reliability. Several capacity mechanisms have been implemented in Europe, where some countries have relied on capacity payments or strategic reserves for a long time, and other countries recently have introduced capacity markets or obligations. However, many countries in Europe still rely on the energy-only market design. In the U.S., four electricity markets rely on centralized capacity markets, two on capacity obligations, whereas the market in Texas (ERCOT) is the only energy-only market. The current status clearly illustrates that no consensus exists on the best approach to incentivize capacity investments and maintain system reliability.

2. A short account of the research performed

Against the background compiled above, we raise the question if improvements to current energy-only markets in Europe and the U.S. could be sufficient to maintain resource adequacy in electricity markets or whether the rapid increase in wind and solar generation gives stronger arguments for additional capacity mechanisms. In detail, a comparative analysis of the European and the U.S. electricity market design is conducted in terms of both short-term electricity market operation and long-term resource adequacy. This comparative study reveals some fundamental differences, but also many similarities in electricity market design on the two continents. We highlight good-practice market design elements in each case and provide a list of general and specific recommendations for improved electricity markets in Europe and the United States.

3. Main conclusions and policy implications of the work

As a general recommendation, we argue that the most important challenge in electricity market design is to achieve good incentives for operations and investment in the short-term markets. A sharper price formation will provide better incentives for system flexibility from supply, demand, and energy storage resources. This can be obtained through increased demand response to market prices so that they better reflect consumers' preferences and willingness to pay for electricity. A particularly important issue is what happens to prices when supplies are short, as scarcity rents are critical for capital cost recovery. Ideally, improved scarcity pricing in short-term markets should follow from increase in the demand participation. However, administrative mechanisms, such as using demand curves for operating reserves rather than fixed reserves requirements will provide prices of energy and reserves that better reflect the value of reliability in situations with supply shortages. It would also be beneficial to move from technology specific incentive schemes for renewable technologies towards adequate pricing of carbon emissions, as it would have the effect of increasing the cost of emitting technologies rather than depressing wholesale electricity prices. We argue that these general recommendations, which apply to Europe as well as

the United States, would foster a more market-compatible integration of wind and solar energy, better functioning energy only markets, and less reliance on (or, ideally, no need of) capacity mechanisms.

We also find that certain market design challenges differ in Europe and the U.S. For instance, a specific recommendation for Europe is to improve the representations of the transmission network in market clearing algorithms to obtain locational prices that better reflect congestion patterns. In addition, substantial benefits would be achieved from moving towards shorter time intervals in real-time balancing markets and from introducing integrated markets for energy and operating reserves, as is already done in some U.S. markets. In the United States, electricity markets should follow the European approach of using intraday markets to enable a more market-based balancing of system deviations that arise, in part, from variable renewable electricity. Overall, as electricity markets continue the transition towards a low-carbon future on both continents, lessons can and should be learned in both directions.

The Impact of Intermittent Power Generation on the Wholesale Electricity Prices of the MIBEL Iberian Market

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1. Motivations underlying the research

Intermittent renewable energy sources, such as wind, solar photovoltaic, or wave energy, are becoming a mainstream electricity generation option. If current targets of international agreements on climate change are met, many countries in the world will achieve high penetration of these power sources in the coming decades. In fact, several countries are trying to accelerate this shift towards generation of intermittent renewable energy, giving further importance to the question of how these changes will weigh on the costs of the electricity system.

Intermittent renewable energy sources (*iRES*) demonstrate the ability to generate significant quantities of electricity at low marginal costs. Their reduced marginal costs are expected to have a short-term negative impact on wholesale electricity prices, owing to their capacity to displace other technologies featuring higher marginal costs. Our research deals with this aspect by evaluating the sensitivity of wholesale electricity prices to the supply of *iRES*. Moreover, this research also ascertains whether (and why) this sensitivity varies significantly within the set of available *iRES* technologies.

Another common feature of these power sources is the fact that they generate variable and unpredictable quantities of electricity over time. Consequently, greater penetration could increase price volatility and cause the frequent occurrence of extremely low prices, thereby hampering profit margins of conventional power plants that operate at low variable costs and that cannot be switched on and off. Moreover, further back-up capacity could be required to cope with the variability and unpredictability of production to ensure the stability of the power grid.

By impacting the generation mix of the power grid towards flexible (and more expensive) conventional power sources, the impact of *iRES* on electricity prices is more uncertain in the long-term than in the short term. In addition, increasing investment in installed capacity may result in diminishing marginal returns as the share of renewables rises above a certain threshold. This study advances current knowledge on this issue by investigating the long-term dynamics of the sensitivity of prices to the output generated by , which is relevant for evaluating the point at which net gains turn negative.

Finally, this research also explores the potential benefits arising from market coupling. It adds to the debate on this issue by empirically assessing the impact of coupling on the sensitivity of prices to

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the output generated by *iRES*. Coupling with adjacent markets may help reduce price volatility stemming from variable and unpredictable weather conditions that affect the supply of *iRES*. As electricity storage faces technical restrictions and high costs, inter-temporal arbitrage is not feasible. However, coupling with adjacent markets permits carrying out spatial arbitrage in different zones and promotes risk sharing. By addressing this topic, this study contributes towards a better understanding of the impact of integration on energy markets.

2. A short account of the research performed

This study addresses the effect of *iRES* on the dynamics of electricity prices using empirical data from the Iberian (Portugal and Spain) market for the period 2010-2015. The first research question explores the presence of the merit-order effect in the Iberian market, i.e. a negative sensitivity of wholesale electricity prices to the output generated by *iRES*. By means of regression analysis, the (semi-)elasticity of prices to (the penetration ratio of) *iRES* supply is estimated. The findings confirm the presence of a merit-order effect in that *iRES* generation brings prices downward (on average, +1% increase in supply cuts the price by roughly -0.5%). This result is consistent with the notion that by displacing more expensive non-renewable technologies from the wholesale market, *iRES* supply cuts electricity prices.

Using a similar econometric setting, it is also examined whether wind and solar photovoltaic power technologies produce effects of different magnitudes on prices. Notably, wind power produces a greater impact on price vis-à-vis solar photovoltaic. Wind power supply benefits from greater correlation effects with the demand than solar photovoltaic power supply. Consequently, wind supply could be used more effectively as a hedging tool for demand variation, thereby bringing about greater gains.

The second research question asks whether the sensitivity of prices to *iRES* supply has fallen over time. The long time span available from our sample enables the examination of the pattern of the (semi-)elasticity of prices to *iRES* supply (penetration ratio) over time in a period marked by a sharp increase in installed capacity (in Spain, between 2010 and 2013, the installed capacity of wind and solar photovoltaic sources augmented 17% and 21%, respectively). Our findings show that the (semi-)elasticity varied considerably during the six-year span. However, the path of that measure is not signaling a declining sensitivity of prices to *iRES* supply. Since the supply of these sources is positively correlated with demand, there are hedge effects that constitute a positive externality from the expansion of installed capacity. Together, these results reveal that potential downside effects of the expansion of *iRES* are still contained, at least when considering an average penetration ratio close to 30%.

Finally, an evaluation was made of the effects of a coupling agreement with France (applicable after May 14, 2014) on the semi-elasticity of prices to the penetration ratio of *iRES*. The results demonstrate that from that date forward, semi-elasticity dropped considerably. By reducing the sensitivity of prices to changing weather conditions, market coupling added efficiency to the allocation of resources and improved risk sharing.

3. Main conclusions and policy implications of the work

This study addresses the effect of *iRES* generation on the dynamics of electricity prices in the Iberian market during the period 2010-2015. The findings indicate that *iRES* output has a material negative effect on electricity price. Still, that effect varies with the technology employed: wind power produces a greater impact on price vis-à-vis solar photovoltaic energy. In view of this result, policy makers and the industry could consider the correlation of each technology with the demand when deciding new investments in installed capacity and defining the target for the generation mix of the power grid.

Notably, there is no evidence that the impact of these sources on price has been declining over time. In other words, no evidence was found to indicate that *iRES* penetration reached a saturation point where benefits are surpassed by costs. This could be a relevant indicator for energy producers to (still) consider the expansion of *iRES* in the near future.

Finally, market coupling weighs (negatively) on the elasticity of price to *iRES* supply. This result is consistent with the notion that further market integration improves risk sharing and resource

allocation, so that policy makers could encourage integration of regional electricity markets in order to maximize benefits from further penetration of *iRES*.

Shale Gas and Oil Development: A Review of the Local Environmental, Fiscal, and Social Impacts

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1. Motivations underlying the research

Hydraulic fracturing and horizontal drilling technology became commercially viable in the early 2000s, leading to a veritable boom in the development of natural gas and oil from shale plays. In 2018, about 63 percent of natural gas and 61 percent of crude oil production in the US was from shale resources. The effects of this rapid expansion of shale oil and natural gas extraction may include lease and royalty payments to land and mineral rights owners; increased demand for labor, land, housing, and infrastructure; increased truck traffic, air pollution, surface-level ecological disturbances; and the risk of soil or water contamination. Development is also associated with new sources of tax revenue for States and local governments, as well as strains on government resources to improve and maintain public infrastructure and services.

In this article, we review the literature on the environmental, social, and fiscal implications of shale development for residents and the environment in shale areas. To our knowledge, this is the first article that combines a review of the social, environmental, and government finance impacts of shale development with a discussion of the local, state, and federal regulatory framework in which this development is occurring.

2. A short account of the topics reviewed

Regulatory context. The shale gas and oil boom is occurring within a framework of local, state, and federal regulations. While local governance can influence the effect of this energy transition on local communities, local policies and fiscal choices are often bounded by state and federal regulations. Impacts at the local level will be shaped concurrently by the local, state, and federal regulatory framework.

Environmental impacts. Direct environmental effects encompass the potential for groundwater contamination as well as surface-level ecological disturbances, both terrestrial and riparian. In addition, fugitive methane from operations, as well as the accumulation of volatile organic compounds (VOCs) and ozone, can affect air quality. Induced seismicity and methane leakages are the two main pathways that shale gas and oil production in one location affects larger regions.

Effects on income and employment. Landowners with mineral rights can receive lease and royalty payments. Severance taxes paid on extracted natural gas can contribute to higher revenues for state and local governments. Spending on goods and services by local residents and governments from these additional sources of income, as well as by workers involved in construction or operations activities, can further affect local economies. Some studies have found positive benefits to total local employment,

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wages, and population growth, while others found much more modest impacts on local employment and wages.

Local resident participation in energy-development benefits. Unconventional methods of gas extraction may have dissimilar impacts on community residents, with some residents receiving significant benefits while others experience mostly the inconveniences or costs of development. We review studies that find that local ownership of mineral rights varies substantially across shale plays, from an average low of 12 percent in the Permian in Texas to a high of 55 percent in the Marcellus in Ohio and Pennsylvania, while a study of farmer ownership of mineral rights found that in oil- and gas-producing counties 11 percent of farm operators own oil and gas rights.

Zoning and other local regulation. Setback provisions regulate how far away oil and gas wells must be from a person's residence or any other commercial structure. While these laws are passed at the State level, the local city or county government often handles zoning and other land-use issues. As a result, there is considerable variation in the types of laws and degrees of regulation placed on oil and gas development across the United States. How much control local governments should have to regulate gas or oil development activities has been a source of major contention in some States, with States providing varying local authority (and experiencing court cases).

Local fiscal issues. The impact of energy development on state and local governments depends upon the structure of taxation and expenditures in affected jurisdictions, in addition to the level, pace, and duration of the development activity. In most States, State governments set and modify the fiscal codes. Consequently, local governments typically are only able to choose from the tax options granted to them by their State government. Thus, policy decisions at the State level have a significant effect on both state-level and local fiscal outcomes.

3. Main conclusions and policy implications of the work

In this review article, we discuss the local, state, and federal regulatory context in which shale gas and oil production occurs and review how it affects local communities, the environment, and government income and spending. As production of oil and gas from shale plays is projected to increase, shale development will occur in more areas and increase in existing ones. As such, this review can serve both as an interim assessment of how shale development has affected local communities and the environment and as a compilation of various lessons learned and different regulatory approaches for regions where shale development is only beginning.

The Synergies between EU Climate and Renewable Energy Policies–Evidence from Portugal Using Integrated Modelling

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In the fight against climate change and following the need to reduce significantly greenhouse gas (GHG) emissions over the coming decades, the European Union (EU) has defined new mitigation and renewable energy targets for the post-2020 period. The agreement on the 2030 climate and energy framework has defined the EU-wide commitment of an at least 40% reduction in GHG emissions compared to 1990 levels and at least 27% of total energy consumption from renewable energy sources (RES).

The European climate-energy policy has been based on an economy-wide cap-and-trade system (the EU ETS) for energy-intensive sectors, national emissions reduction targets for the sectors outside the ETS, and ambitious renewable energy targets. Nevertheless, there is no consensus about the cost-ef-

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fectiveness of this policy configuration. The coexistence of GHG emissions reduction and renewable energy targets, as well as the EU Emissions Trading Scheme, have been subject to some criticism.

In this paper we explore the interactions between the multiple EU climate and renewable energy policy instruments and its economic implications. It assesses the synergies and trade-offs between alternative policy designs and the implementation of alternative mechanisms to cope with the EU GHG emissions reduction and renewable energy deployment targets for 2030. The analysis is carried out by using the Hybrid Bottom-up General Equilibrium Model (HyBGEM), a comparative-static hybrid computable general equilibrium model, and taking Portugal as a case study. Although Portugal has a high RES share in electricity generation it is still very dependent of fossil fuels, which results in a large carbon intensity. Thus, there is a significant potential to decarbonize the economy, making the country a relevant case study. Four alternative policy scenarios were studied, including the current EU policy configuration and alternative cap-and-trade system, wherein all sectors have access to the carbon market.

Results show that the current segmentation of the EU emissions market (between ETS and non-ETS sectors) leads to a costly emissions mitigation. This is reflected in higher welfare losses, reduction in GDP and higher unemployment rates. Moreover, imposing a renewable energy target on top of the emissions constraints may attenuate the GHG abatement costs from second-best induced gains in efficiency. Renewable energy subsidies act as a correction of pre-existing taxation on the Portuguese economy, countervailing excess burden on abating carbon emissions. The sensitivity analysis corroborates these insights, indicating that, for the case study, a uniform CO_2 price without emissions market segmentation together with a RES-E target implemented via feed-in tariffs is the most cost-effective option (i.e., lower economic impacts to achieve the GHG emissions reduction and RES targets).

This study, and its comparison with existent literature, demonstrates that setting a common climate mitigation policy for all the EU Member States may require additional precautions as many factors can affect the cost-effectiveness of such policy, namely the level of economic growth, pre-existing tax distortions, GHG emissions and the energy consumption profile. The most cost-effective mitigation policy may differ between Member States with distinct conditions and dissimilar financial instruments. Therefore, the individual evaluation of the cost-effectiveness of alternative climate policy designs, as the one performed in this paper, is a valuable and essential tool in policy support.

Beyond the Inverted U-shape: Challenging the Long-term Relationship of the Environmental Kuznets Curve Hypothesis

Lars Sorge[a] and Anne Neumann[b]

1. Motivations underlying the research

A substantial amount of greenhouse gas emissions results from the increased use of energy, primarily fossil fuels, as the main driver for production processes and economic growth. Continued emissions of carbon dioxide (CO2) will lead to further surface warming and likely cause irreversible damage to the ecosystem. Following the Environmental Kuznets Curve (EKC) hypothesis, global economic prosperity may reduce CO2 emissions in the long-term: after a certain threshold income level is reached, environmental quality improves over the course of further economic development (Grossman and Krueger, 1991).

The EKC hypothesis however crucially relies on the assumption that initial increases in emissions are only temporary, whereas the subsequent decrease in emissions are considered to be permanent

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(Dinda, 2004). Consensus regarding the existence or shape of an EKC particularly for pollutants having long-term effects on a global scale such as CO2 emissions have not been reached, although the literature has grown rapidly (Dinda, 2004; Shahbaz and Sinha, 2018).

The estimation of an EKC with a quadratic specification however produces highly biased results in favour of an inverted U-shaped pattern (Lieb, 2003). Ignoring what could happen after the first turning point wrongly leads to the impression that patterns of economic growth are ecologically sustainable (Shahbaz and Sinha, 2019). We thus use a cubic formulation to allow the relationship between income and CO2 emissions to follow other forms than the rather optimistic inverted U-shaped pattern to identify other impacts of income on CO2 emissions by extending the analysis beyond the inverted U.

Against this background, we challenge the long-term relationship of the EKC: our hypothesis is that the improvement in the relationship between income and CO2 emissions is - if at all - only a transitory phenomenon which is unlikely to hold in the long-term. We thus contribute to the relatively scarce cubic EKC literature for CO2 emissions, by analyzing whether the Environmental Kuznets Curve does hold in the long-term, or if the improvements are only a transitory phenomenon.

2. A short account of the research performed

We empirically question the long-term relationship of the EKC hypothesis for CO2 emissions using nonstationary panel time series data methods applied to a panel of 69 countries from 1971 to 2014, altogether as well as clustered into high-, middle-, and lower-income groups. To empirically analyze our hypothesis, we utilize a cubic regression specification and account for other relevant CO2 emissions factors than income such as per capita energy consumption and trade-openness. As the EKC hypothesis represents a long-term relationship between environmental impacts and economic growth and to tackle spurious regressions issues, we test for cointegration among the variables. The results of the error correction-based panel cointegration test proposed by Westerlund (2007) supported the existence of a long-term equilibrium relationship in any panel. Within the panel time series framework, we utilize the Pedroni (2001) dynamic group-mean panel DOLS estimation technique to addresses the issue of slope parameter heterogeneity.

We cannot establish an inverted U-shaped relationship but rather find a N-shaped relationship for the global panel which indicates that patterns of economic growth on average are ecologically not sustainable. For our high-income panel our results indicate a N-shaped pattern which strongly suggests that the EKC is not sustainable in the long-term for high-income countries: scale effects tend to exceed composition and technological effects after the second-turning point is reached. Over time, CO2 emissions per capita may decline due to technological and structural changes. However, technological improvements to increase energy and material efficiency may reach an upper limit at which without breakthroughs in research and development further efficiency improvements are exhausted or become economically too expensive and further income growth then leads CO2 emissions per capita to increase again. As a result, the growth component again becomes more pronounced and CO2 emissions will be re-linked as it becomes increasingly difficult to keep up innovation with continuing growth of production (de Bruyn et al., 1998; de Bruyn and Opschoor, 1997). The absence of an EKC for the pollution and income relationship in our lower- and middle-income panel suggests that these countries are still likely to be on the upward sloping section of a possible EKC. Economic growth has not reached income levels high enough at which CO2 emissions per capita decline as economic growth still tends to outweigh environmental concerns (Dinda, 2004).

3. Main conclusions and policy implications of the work

Our empirical results rather support a N-shaped than an inverted U-shaped pattern for the pollution income relationship particularly in the all-income panel. We find no evidence of an inverted U-shaped pattern associated with the EKC hypothesis in any panel. The implementation of stronger and international development cooperation could help to prevent that future economic growth is inevitable accompanied by environmental degradation in early stages of economic development. Thus, countries

need to substitute fossil fuels by cleaner inputs as an important measure to reduce carbon dioxide emissions from energy consumption as early as possible. Moreover, as improvements in energy efficiency are often the most readily available means to reduce emissions, all countries should implement policies which support improvements in energy efficiency within any economic sector. In conclusion, our analysis indicates that simply promoting economic growth is not a panacea to just grow out of pollution related problems in the long-term as hypothesized by the EKC but rather results in a catastrophic roller coaster ride.

Measuring Energy Efficiency: Accounting for the Hidden Costs of Product Failure

Art Fraas[a] and Sofie E. Miller[b]

1. Motivation underlying research

DOE sets energy efficiency standards for a wide variety of consumer appliances to achieve a "significant conservation of energy." Advocates for these standards claim that households have realized substantial cost savings with the existing standards. There is a substantial literature—although no consensus—on the effects of energy efficiency regulation, however.

While an increasing emphasis has been placed on the potential reduction in greenhouse gas emissions, the relative benefits of these emissions reductions are generally small. Instead, the basis for energy efficiency regulation rests on the claim of an "energy paradox"—that the private benefits of energy efficiency measures substantially exceed the marginal costs, and that households and firms fail to adopt them because of market or behavioral imperfections.

As further support for an energy paradox effect, ex ante engineering analyses by regulatory agencies typically estimate substantial net private benefits for energy efficiency rules. In the case of the 2001 energy efficiency standards for clothes washers and the 1997 standards for refrigerators, DOE estimated between $16.97 billion and $26.5 billion in cumulative net benefits through 2030. However, both rules resulted in unanticipated burdens for consumers in the form of diminished product reliability, increased repair costs, and decreased product lifetime. To date, existing retrospective analyses have considered consumers' energy savings without considering these substantial added burdens, which captures only half of the picture.

2. A short account of the research performed

In 1997 and 2001, DOE established statutorily-mandated minimum efficiency standards for refrigerators and clothes washers, respectively. These two standards—especially the clothes washer standard—have received special attention in other recent studies of the DOE standards. While these studies have considered the effect of the two standards on price and some aspects of product quality, these studies largely neglect some important factors related to in-use performance that affect consumer welfare.

This paper examines the experience with these two energy efficiency standards over the 2001 to 2011 period and finds that design changes occasioned by energy efficiency standards resulted in problems with product quality. Specifically, three issues plagued these appliances and yielded lower cost savings than projected in DOE's ex ante analyses: (1) product life and reliability; (2) greater energy usage than anticipated; and (3) additional operation and maintenance (O&M) costs. As a result, households would have benefited from these standards far less than ex ante estimates predicted, and in some cases, they would have had net costs.

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We use information from class action lawsuits in our case studies to develop a link between DOE energy efficiency standards and product defects. The product defects that attract class action lawsuits tend to be attention-getting issues such as moldy washers and defects requiring immediate repair, while longer-term repair or replacement issues that affect product life generate less attention. As a result, we have also obtained information on product life expectancy for our case studies from Consumer Reports articles on reliability and product repair or replacement decisions, product life data from the housing industry, and internet postings.

We used this information to develop a revised analysis illustrating the sensitivity of DOE's life-cycle analysis to different energy usage and product life assumptions. As a result, we estimate that only 24% - 49% of consumers actually benefitted from DOE's standards for clothes washers (in comparison to the 81% estimated by DOE). With higher energy usage than projected and reduced product lifetime, our analysis suggests that many consumers did not save money as a result of DOE's standards for refrigerators.

3. Main conclusions and policy implications of the work

For both clothes washers and refrigerators, consumers bore significantly more costs than accounted for in DOE's ex ante analyses and other retrospective analyses. In the case of clothes washers only a minority of households would realize net energy savings based on ex post estimates of usage and product life; in the case of refrigerators, breakeven analysis suggests that, accounting for reduced product life, a modest increase in energy usage relative to DOE projections would offset the expected savings for many consumers.

In the cases of clothes washers and refrigerators, actual product lifetime and product usage differed significantly from DOE's ex ante estimates, which negatively affected consumer net benefits. DOE could have improved its analyses by developing distributions for these key analytical components. To the extent that it is not possible to do so, sensitivity analysis could help identify the effect of alternative values for the key variables that affect life-cycle analysis.

Our research points to a potential information problem in these durable goods–appliance markets. These markets are characterized by a rapid turnover in a large number of models. As a result, there is only limited information available to consumers on repair and replacement rates at the time of purchase. Our analysis suggests that many consumers experienced a much shorter product life over 2000–2011 than DOE projected in its ex ante analyses for these two rules, which dramatically reduces the benefits to consumers.

In addition, current standards only require the certification of appliances prior to distribution and fail to consider potential reductions in product reliability and product life. While manufacturers claim a 10-year or longer product life, current standard manufacturer warranties typically only provide 1 year of protection—a significant decrease from the 1990s. This suggests that energy efficiency standards should consider potential effects on product reliability, and that the appliance market could be enhanced with information disclosure on product life and reliability, and full warranty for repair over an extended period.

The Economics of Sustainability: Causes and Consequences of Energy Market Transformation

Rabah Arezki[a]

The collapse in oil prices that started in 2014 and subsequent 2020 plunge have put diversification at the forefront of the policy debate in many nations that have been dependent on fossil fuel produc-

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tion. Many oil rich countries have indeed either announced or already put in place policies to help transform their economies and move away from the dependence on oil. Diversification strategies have been pursued in the past and historically those managed by the state have not worked. That is because top-down management almost inevitably obstructs the economic diversification process because it does not empower managers of the companies (and their teams) who are best able to guide the process and adapt to new circumstances. In other words, countries should not concentrate on the end goal—namely diversification—and focus instead on what is required to get there, no matter how disruptive that transformation process might be to traditional production.

The present paper deals with the economics of sustainability associated with the transformation of energy markets. It emphasizes the interrelations between technical changes and energy markets and how in turn the resulting transformations alter the sustainability of economic systems that are dependent on these markets. It also explores how innovation (or the lack thereof) is intimately linked to the ability of energy rich economies to adapt and transform.

The agenda is especially relevant for oil rich countries that have announced or already put in place policies to help transform their economies and move away from dependence on oil. The agenda is also relevant for the global community, as it relates to the economic consequences of the needed transformation of energy markets to support the goal of limiting global warming by reducing greenhouse gas emissions.

Indeed, energy markets are subject to changes in technologies that affect producers and consumers alike. These changes—such as certain innovations in oil drilling techniques or in battery technology for automobiles—can be risky for oil companies and national economies that depend on fossil fuel production. But technological change can also offer new opportunities for growth.

The biggest risk for oil producers and oil-dependent economies comes from changes that cause oil price collapses followed by a protracted period of low prices, as is occurring now. What is more is that low prices could strand oil reserves—which will be left in the ground because they are no longer economical to extract—a sharp blow to economies whose national wealth is heavily bound up with fossil fuel reserves.

The opportunities associated with technological change include potential improvements in extraction efficiency that permit profitable production of oil at lower prices. Other changes not directly associated with oil, such as the development of technologies around renewable energies, can allow economies that have say a high potential for solar irradiation to limit the risks of trying to develop non-fossil fuel industries and better align with the goals set by the 2015 Paris Climate Accord. The accord, if adhered to, will reduce the burning of oil, natural gas and coal and further depress their prices (if global production does not decline).

Policies geared toward "behavioral change," such as changes in attitude toward innovation and risk-taking by managers and employees—especially as they relate to how firms govern themselves, can complement policies that have so far focused almost exclusively on improving the business environment outside the firm. Specifically, to induce behavioral change, policies should aim at turning state owned enterprises (SOEs) in the oil sector into publicly listed corporations. That would enhance their transparency and efficiency and make them more accountable to investors. The result should be that instead of timidly approaching diversification, SOEs would be sitting at the technological frontier in the energy sector and exert positive spillovers to the rest of the economy that would drive overall development. That is, of course, a tall order but a goal worth pursuing for its long-term socioeconomic gains.

The focus on transformation—rather than on the objective of diversification—also has important policy implications for the energy (-producing and -using) industry and the ever-growing number of countries that are dependent on the exploitation of energy resources. This new focus has also broader relevance for the global community as it relates to the economic consequences of the needed transformation of energy markets to support the goal of limiting global warming by reducing greenhouse gas emissions.

The paper mobilizes relevant strand of literature from economics and finance, as well as data to address the following elements. First, it explores the role of technological change in shaping energy markets. Second, it lays out the nature of the risks and opportunities associated with the changes occurring in energy markets. Third, argues for the need for economic transformation of oil dependent economies and SOEs. Fourth, it concludes on the modalities for the shifting landscape for "big state oil."