How Valuable is the Reliability of Residential Electricity Supply in Low-Income Countries? Evidence from Nepal

Anna Alberini,[a] Jevgenijs Steinbuks,[b] and Govinda Timilsina[c]

Access to reliable electricity services is essential for poverty reduction and economic growth (World Bank, 2017). However, many developing countries face severe electricity shortages, leading to frequent power outages. The causes of such shortages are numerous, and include high technical and commercial losses, insufficient revenues to finance investment in infrastructure, and many others.

Valid estimates of the willingness to pay (WTP) for reliable power supply are thus critical for both power system planning decisions and regulatory policies aimed at improving the quality of the electricity services. This is especially important for the residential sector, where low energy consumption makes electricity cost recovery a challenging problem.

This paper estimates the value of lost residential electricity service in Nepal, a low-income country that has experienced chronic load shedding in the last decade. The load-shedding crisis over the period 2007-2016 has imposed high economic costs on Nepal's economy. Recent estimates suggest that load shedding may have cost the country up to 7% of its GDP annually. At the end of 2016, however, the daily load shedding of residential customers ended due to improved electricity dispatch, increased electricity production, and imports from India, though households may still experience unscheduled outages (World Bank, 2019).

We use contingent valuation to elicit the willingness to pay of residential customers in Nepal for improved power supply. We rely on a nationally representative survey of Nepali households. Our study design exploits the fact that the survey was done shortly (i.e., less than a year) after the residential load shedding had been eliminated. The respondents were asked to indicate their willingness to pay to avoid the number of days with outages they had experienced before the termination of the load shedding schedule of October 2016. This takes advantage of the respondents' *actual experience* with improved reliability of power supply. Using supplemental data on *actual outages* at the transformer substation level, we can validate the quality of respondents' recall.

Our analysis starts with calculating the WTP per kWh lost (i.e., the Value of Lost Load, VoLL) given assumptions about the load or exact information about the kWh used in a typical day. We then calculate the WTP per outage-day avoided and analyze its key drivers. Finally, we assess the internal validity of our estimates by regressing the WTP on the number of outage-days reported by the respondents, controlling for a variety of household characteristics. To our knowledge, our study is the first contingent valuation study to address measurement error in the good to be valued by instrumenting for it, which should avoid biased inference. We instrument for the number of outage-days using the frequency of all types of outages at the substation level.

We find that households, on average, attach economically significant value to a reliable power supply. The average WTP is about 123 NR ($1.11) per month, or 65% of the actual average monthly bill at the time of the survey, even though about 26% of the households are not willing to pay anything at all.

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When we convert the WTP to a VoLL (i.e., the WTP per kWh lost), our preferred estimates are in the range of 5 to 15 NR/kWh (¢4.7 to ¢14/kWh), and thus bracket the average price per kWh from the grid paid by the respondents at the time of the survey. Surprisingly, our average VoLL estimates are no larger than those from a survey conducted more than a decade ago, when the load-shedding crisis started (Karki et al., 2010), even though the country's GDP per capita has grown by 42% since.

For the sample as a whole, the VoLL is higher for service lost in unscheduled outages than for service lost during scheduled load shedding. This finding is consistent with expectations, as households presumably can make arrangements to limit the damages and the inconvenience from the outages themselves. But when we restrict the analysis to the "attentive" respondents—namely those who appear to have recollected exactly the number of outages in the month a year before the time of the survey—the VoLL is identical for unscheduled and scheduled lost electricity consumption.

Households that use rechargeable batteries (i.e., inverters) or solar equipment as backup equipment report systematically *lower* WTP. This result is in sharp contrast with earlier studies in developing counties (e.g., Oseni, 2017), where households that own diesel generators with high running costs reported a higher WTP for reliable power supply. However, when we adjust the VoLL of those with rechargeable batteries and solar equipment to the VoLL implicit in the purchase of such equipment, we obtain higher estimates ranging from 9 to 22 NR/kWh. These results indicate that, in the absence of effective public policies, households internalize their WTP for reliable power supply by investing in power backup equipment.

Finally, although most households have an economically meaningful willingness to pay for a reliable power supply, our VoLL figures appear to be below the marginal cost of avoided load shedding (i.e., utilizing high-cost operating reserves or importing electricity at times of high demand). These findings suggest that if the government's goal is to improve the quality of residential electricity consumption, it must either lower the cost of generation, transmission, and distribution or resort to demand response—if technologically feasible and acceptable to the public.

Distinguishing the Complex Effects of Foreign Direct Investment on Environmental Pollution: Evidence from China

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Attracting foreign direct investment (FDI) to boost local economy is a priority for most developing countries. However, FDI can also bring in pollution-intensive industries as well as environmental-friendly technologies. Whether FDI can increase or reduce environmental pollution in host countries is a controversial question. Given the theoretical debate and mixed findings regarding this subject, this study analyzes mechanisms and pollutant types to investigate the effects of FDI on different types of environmental pollution.

We select China, one of the top recipients of FDI in recent years, as our research context. Owning to economic reform and the opening-up policy, as well as large market potential and human capital endowment, China has been the preferred investment location for foreign firms. At the same time, as a result of rapid industrialization, energy consumption and environmental pollution have

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also become a serious problem in China. We use China's provincial panel data from 1995 to 2015 as our samples to examine the effects of FDI on different types of environmental pollution.

We find that FDI mitigates air pollution, suggesting the pollution halo effect. However, it has insignificant effect on water and solid pollution. We also reveal that technology effect is most dominant, followed by scale effect and structure effect. In addition, by taking into account of time effect to reflect environmental policy change, we suggest that pollution halo effect mainly occurs after air pollution policy revision. Our finding provides insight on the complex effect and mechanisms of FDI on different types of environmental pollution, thereby helping to reconcile the mixed findings in the literature.

Our findings also have policy implications. Our study suggests that local governments in developing countries should not adopt a universal policy for controlling pollution. Instead, they should have more authority to form specific environmental policies to regulate different pollutants. In addition, local governments should take measures to create fair and open institutional environments for developing local firms' innovation abilities. Such effort can enhance local firms' absorptive capacity on clean technology.

Risk-adjusted Social Discount Rates

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The choice of the discount rate is a key determinant of most long-term investment projects. There is no consensus among economists about which discount rate should be used, whether it should be common to all projects and to all sectors, or whether it should be adjusted for the riskiness of the project under scrutiny. In this paper, we claim that the answer to this last question should be positive, as recommended by all classical theories of asset pricing. We refine the methodology to estimate the corresponding risk premia and show that the adjustment of project-specific discount rates to projects' risk can significantly improve public investment decisions. According to our results, this is particularly true regarding investments in core infrastructure carrying goods or services, such as such as energy transmission and distribution assets. All this matters a lot for the energy sector, confronted today to an immense transitional challenge with the necessity to decarbonize our economies.

We take a normative approach to this question by examining the investment decision rules that are compatible with the intertemporal social welfare. Because our society is averse to risk, one should penalize projects that contribute the most to the collective risk. This can be done by adjusting the project-specific discount rate positively for the macro-risk contribution of the project. As shown for example in the Consumption-based Capital Asset Pricing Model (CCAPM), the risk-adjustment of the discount rate should be proportional of the "beta" of the project, which is a measure of the statistical relation between the net benefit of the project and aggregate consumption. For example, most macro-prevention projects have a negative beta, since their benefit materialize in recession, i.e., when aggregate consumption is low. This justifies using a discount rate lower than the risk-free discount rate.

Among the various applications of our methodological analysis, we consider a class of investments in transportation infrastructures, such as a railway infrastructure or an electricity network. We show that their social betas vary greatly, exhibiting a decreasing term structure starting from a

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surprisingly large value at short maturities, when capacity is under-utilized. In the electricity sector, we show that projects of cross-border connection have a negative beta from the viewpoint of the country that predominantly uses the infrastructure to export electricity. This is due to the fact that in a recession, the demand for electricity will be reduced, thereby rendering the connection more useful to export its excess electricity. Thus, the net benefit of this cross-border high voltage line will be larger when aggregate consumption will be smaller. Given the long lifetime of these infrastructures, this provides a strong argument to raise electricity interconnections for countries with a comparative advantage to produce electricity.

Although the applications of our model are mostly devoted to the electricity sector, our aim is to address the general question of the determinants of the risk-adjustment of discount rates. Contrary to financial assets for which purely financial betas can easily be estimated by regressing the asset return on the market return, it is often the case that no data is available to estimate the social beta of specific public investment projects. Estimating project-specific social betas therefore remains a challenge, especially as the literature is scarce on these issues. We link the risk-adjustment coefficient beta of a project to the price and income elasticities of supply and demand. As an illustration, we provide a rough estimate of the social beta of a generic investment in the electricity sector in France and discuss its relationship with the market beta of companies listed in the sector.

This work is part of the attempts to convince public decision-makers to adopt more efficient discounting rules. This is all the more important for investments in core infrastructures with capacity constraints. Institutions in charge must constantly anticipate the growth in demand and allocate investments accordingly between maintenance, renewal and extension of their networks. The decreasing term structure highlighted in our work can play a crucial role in determining the optimal timing of such investments. The estimation carried on the electric cross-border link provides, to our knowledge, the first real-case based example of a negative beta and illustrates how adjusting social betas to risk can drastically change the discounted net present value of public investment projects.

Electricity Tariff Rebalancing in Emerging Countries: The Efficiency-equity Tradeoff and Its Impact on Photovoltaic Distributed Generation

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A recurrent problem in many economies is that residential electricity tariffs fail to achieve economic efficiency. This simple diagnosis imply that the true marginal cost of energy is not reflected into the service rates afforded by households in their electric bills. As a result, these users end up consuming above or below the efficient level. In several developing countries, this problem can be exacerbated when other objectives, different from economic efficiency, are pursued by means of complex tariff designs. Among the additional goals, income redistribution goals and conservation goals are likely the most popular. However, the use of a single instrument –i.e., existing tariffs– neither produce a fair distributional outcome nor provides the right incentives for optimal consumption decisions. In some cases, highly disbalanced tariffs discourage the investment in energy efficiency improvements and deter the adoption of renewable sources of energy supply such as solar PV sys-

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tems. In addition, when subsidies to energy consumption are sizeable, distorted tariffs generate unsustainable fiscal positions for government with critical financial constraints.

In this paper we illustrate the points mentioned above using household-level and hourly-industry data for the Mexican residential electricity sector, where 98% of residential users are highly subsidized and the fiscal cost associated is sizeable. In an arbitrary scenario with a 30-percent subsidy reduction, we exemplify how a more efficient pricing mechanism consisting of a two-part tariff, a well-targeted transfer program, and a tailored environmental regulation can simultaneously improve economic, social, and environmental outcomes. The proposed variable (volumetric) charge in each locality is composed of the externality cost of pollution plus the corresponding nodal price, which incorporates the energy cost, the transmission cost due to congestion, and energy losses (technical and non-technical). The fixed charge –i.e., the second component of the two-part tariff– plays the essential role of recovering fixed costs related to financing, installation, maintenance, management, operation, and expansion of the infrastructure necessary to provide the electricity service. In this paper, we propose a particular set of non-uniform fixed charges that are reflective of households' total income –i.e., a valid proxy variable for the true willingness-to-pay. Since the proposed fixed charges do not depend upon observed consumption, and because the marginal prices are set equal to the social marginal costs, the differences across users do not distort the electricity consumption choices but ameliorate the distributional impact of the proposed subsidy reduction.

Finally, we present a concrete example that shows the undesired effects of electricity price distortions on investment decisions in the medium and long term: solar photovoltaic systems. With the simulated tariff schemes and customized PV system characteristics and prices, we simulate different adoption scenarios using a household optimization model. The simulated outcomes are also used to quantify the subsidy changes and the environmental impacts of the proposed policy reforms.

Most relevant findings are summarized as follows. The average deadweight loss per residential consumer is between 0.79 and 0.99 US dollars per month, depending on the demand specification used, which represent, on average, 6.5% and 8.2% of the monthly average electricity expenditure, respectively. With the proposed tariff schemes we correct the allocative distortions and reduce the subsidy burden. By avoiding the negative distributional consequences that a typical two-part tariff has, our proposed tariff scheme applies discounts to the fixed charges with the help of a means tested mechanism. Even with the 30% reduction in the electricity subsidy, the final electric bill afforded by household located in the first three income deciles are practically unaffected. The bill increments are progressively passed to more advantageous households located in upper income deciles. Going to the medium- to long term impacts of the tariff rebalancing application, we identified the set of potential PV system adopters, which roughly amounts to 49% of Mexican households, and then simulate the optimal adoption choice. We find that under the current (inefficient) increasing block tariff, the predicted PV penetration would reach 12% of residential users at most, whereas under the two-part tariff scheme with subsidized fixed charges, it could reach between 16% and 39% of users, depending on whether cross-subsidies are allowed, and on what fraction of network costs are recovered from the net-metering bills.

Regarding air pollution abatement, the proposed alternative tariff scheme could reduce between 4 to 16 million tons of equivalent carbon dioxide emissions per year. These numbers would critically help Mexico to accomplish with the emissions reduction goals set under the Paris Agreement (UNFCCC) in 2015, and also represent considerable resources in monetary terms (between 135 and 551 million of USD dollars per year). The savings could be even more significant if the tariff rebalancing policy comes along with a DPV adoption subsidy program. For instance, any sort of financial aid program that transfers money from the current electricity consumption subsidy to a

technology adoption subsidy, like price discounts or tax rebates. Finally, the overall subsidy reduction –i.e., incorporating rebalanced tariffs and simulated solar panels adoption– could reach a total of 345 million USD per year. As the main conclusion, we show that a complete tariff rebalancing towards a social efficient scheme would have very positive outcomes. It would enhance economic efficiency, improve air quality, and reduce the fiscal resources needed for the electricity subsidy. The latter resources, in turn, could be used for a long list of better social welfare enhancing purposes in a country with severe poverty, education and health issues.

Distortions of National Policies to Renewable Energy Cooperation Mechanisms

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The EU endeavors to stimulate the use of renewable energy cooperation mechanisms. These cooperation mechanisms can significantly reduce the policy cost for meeting renewable targets. Several authors, however, have raised concerns that such cooperation mechanisms can be subject to efficiency losses due to different national regulatory conditions, and due to an ill-advised selection of cross-border support instruments. Renewable cooperation mechanisms can, for instance, bias renewable capacity towards Member States with the more favorable regulatory conditions.

In this contribution, we first develop a unifying analytical framework to show how optimal cross-border renewable energy trade should be organized and how these mechanisms could be distorted. We furthermore aim to quantitatively evaluate the importance of these distortions. To this end, we develop a partial equilibrium model, formulated as a large-scale mathematical program with equilibrium constraints, to assess the impact of (i) different national grid cost allocation regimes and (ii) different cross-border feed-in premium implementations: the fixed- and the sliding feed-in premium. The model is then applied to a case study that examines cooperation in onshore wind energy among France, Germany, the Netherlands and Belgium.

Our results indicate that one needs to pay attention when organizing cross-border auctions for renewable electricity. These should ideally not be based on sliding feed-in premiums since renewable capacity will then be biased towards high potential Member States, even if their electricity market value is low. In our case study, cross-border auctions based on the sliding feed-in premium perform even worse than no renewable cooperation at all. In addition, granting uniform subsidies to renewable installations can be sub-optimal even if the system is based on the fixed feed-in premium. Various non-harmonized national policies will decrease the efficiency of cross-border auctions if these are non-discriminatory. One should opt for an auction system that ensures the convergence of marginal support costs, instead of one that ensures the convergence of support levels.

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The Role of Uncertainty in Shaping Individual Preferences for Residential Energy Renovation Decision

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This article examines a crucial question that has been raised in recent years in both policy and economic literature: the role of uncertainty as a barrier to energy retrofit decisions. We develop a discrete choice experiment to elicit preferences for energy renovation measures. This methodologically innovative experiment design includes two insurance schemes covering potential sources of uncertainty as attributes of the energy retrofit alternatives. We use a mixed logit model to investigate the nature of systematic heterogeneity in household preferences for attributes of energy retrofit solutions. Our results indicate some potential avenues for action to increase energy efficiency investment. First, they suggest that uncertainty about energy prices and energy retrofit quality negatively affect the energy-retrofit decision-making process. Indeed, we provide evidence that French homeowners value greater certainty about future trends in energy pricing and quality of the renovation when making decisions (i.e., greater certainty has a positive impact on utility). Consistent with theory, the impact on the utility of reduced uncertainty is higher for risk-averse individuals. Furthermore, willingness to pay (WTP) for insurance with regard to energy retrofit quality and a fixed energy price contract is positive and heterogeneous among respondents: A larger share of homeowners preferred quality insurance to the fixed energy price contract. Finally, we use our results to simulate the impact of specific initiatives and show how they could substantially increase the energy retrofit rate of French homeowners. We found that introducing insurance for retrofit quality over 10 years increases the energy renovation rate by 10%–15% compared with the reference scenario. This result paves the way for new strategies that policymakers should consider to increase energy retrofit rates.

Assessing the Impact of Exceptional Drought on Emissions and ElectricityGeneration:The Case ofTexas

Jamal Mamkhezri[c] and Gregory L. Torell[d]

Electricity sales in Texas spiked during a prolonged heat wave and subsequent severe drought in the summer of 2011, and electricity prices increased across the state. The highest system-wide hourly peak demand to that point occurred in August of 2011, reaching 68,305 MW. During this time, at least one plant curtailed night-time operations, several plants switched from their normal sources of water to alternate sources or added new pumps to reach existing sources, and operators prepared emergency plans to enact demand management and bring mothballed plants online. Though the increase in electricity prices was caused in part by increased demand for air conditioning, some of the increase in prices could also be explained by drought-induced shifts in plant availability or increased costs of obtaining sufficient cooling water supplies. The simultaneous supply

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and demand shocks led to extremely high prices, increased electricity demands, and increased water demands.

Drought frequency and severity is forecasted to increase in the coming decades. While projections of precipitation show little change most of the world, projections of atmospheric demand for moisture show an increase in land surface in drought from 5-45%. Prolonged periods of drought are particularly threatening to the thermoelectric power sector, which is reliant on large water withdrawals for cooling. Texas provides an ideal setting to investigate how the electricity market responds to exceptional drought conditions. The state of Texas has a single, rather isolated, and integrated electricity market which reports generator-level offer prices and quantities at a sub-hourly frequency. The Texas electricity sector is water-intensive, accounting for nearly half of all water withdrawals in Texas. Importantly, the state has a variety of climatic regions. From 2010 through 2017, all but two counties experienced exceptional drought conditions and all counties experienced some level of non-exceptional drought conditions. This variation in exceptional drought conditions is essential to identifying the effect of water scarcity on the electricity supply and, subsequently, on emissions, making Texas an ideal case study.

The effects of water scarcity on power plant cooling and emissions are widely addressed in the engineering and climate science literature, as well as in the energy economics literature. The consensus of these literatures is that during drought episodes, electricity demand (especially in the residential sector), transmission losses, and congestion increase, leading to a need for a greatergeneration. The fuel portfolio that provides electricity to meet the excess demand, which varies region to region, impacts the electricity price and quantity, and subsequently, the emitted emissions. Previous studies find that drought increases net emissions during drought periods, while few researchers find the opposing effect can hold for certain regions. We build on this literature and add to this body of ongoing research by empirically assessing the effect of exceptional drought‡ on electricity grid outcomes in the Electricity Reliability Council of Texas (ERCOT) region.

The objective of this paper is to test whether exceptional drought conditions have a significant effect on electricity price and quantity offerings of electricity plants for the years 2010–2017 using intra-hourly ERCOT data. We further estimate the effect of exceptional drought[a] on emissions intensity of electricity production during that period. We find that the effect of exceptional drought on electricity supply varies with the generator's cooling technology type. Generators with water-intensive cooling technologies respond to exceptional drought conditions by raising their average offer prices. However, generators that use dry cooling technologies do not raise offer prices but increase the total quantity offer during exceptional drought periods. These offer price changes lead to lower emissions plants being dispatched during exceptional droughts in ERCOT, resulting in an overall reduction of emissions during our study period. We contribute to this literature by utilizing more granular level and updated data, intra-hourly price and quantity data, and estimate the impact of exceptional drought on the electricity market and emissions in Texas interconnection from 2010–2017 and find results that contradict existing understandings. Another contribution of this paper is that we focus on individual supply curves in the form of generation unit offers to avoid the potential endogeneity problems associated with the joint determination of market quantities and prices.

These results have important implications for state-level electricity regulators. Increasingly frequent and severe droughts could reduce output and raise prices offered by generators using water-intensive cooling technologies. Regulators charged with promoting market stability should

a Our exceptional drought measure is a measure of the percent of each county experiencing exceptional drought, where zero indicates no exceptional drought in a county, and 100% indicates the entire county experiencing exceptional drought.

take into account climate change projections regarding drought when formulating rules for cooling technology.Both water-intensive and dry cooling technologies are needed to efficiently supply the market during normal periods and prolonged, exceptional droughts. Our results add understanding to the impacts of exceptional drought on the electricity sector; if exceptional drought has significant effects on electricity prices and electricity grid outcomes, public policy towards electricity markets and drought management will need to be aware of these effects as it can have an impact on the risk of grid failure (brownouts or blackouts) and private and social welfare. Understanding the effect of drought on electric generation, and the resilience of the electric sector to water scarcity, will be important in a variety of policy contexts.

How Far is Gas from becoming a Global Commodity?

Luís Aguiar-Conraria,[a] Gilmar Conceição,[b] and Maria Joana Soares[c]

For decades, energy professionals have predicted that regional gas markets will become tighter and, eventually, will behave like a single, global market. We take the oil market as a benchmark and assess how far gas is from becoming a global commodity. We conclude that not much progress has been made. Gas markets are still quite regional.

Our definition of market integration relies on price behavior. We say that two markets are integrated and behave like one if prices in both markets are very well synchronized.

To define a benchmark, we first look at oil prices of three different markers: WTI, Brent, and Dubai. We confirm what other authors have already concluded. At least since 1990, the oil markets behave like a single market. This synchronism occurs both at high and business cycle frequencies.

We then study gas price synchronization in Europe, Japan, and North America. We study synchronization between each pair of gas markets and between each gas region and the oil market (we consider Brent as the benchmark). Interestingly, each gas market is closer to the oil market than to any other gas market. It is also worth noting that the North American gas market seems independent of the others. Although European and Japanese markets form a cluster, we cannot talk about a single market for these regions. The desynchronization between the European and the Japanese markets is much more significant than between the oil markets.

We also argue that oil is the primary synchronization mechanism between the European and Japanese gas markets. It is not that Europe and Japan are connected; it is that the gas prices in those regions are associated with oil. And, therefore, are correlated with each other. Once one removes the arbitraging effect of the oil price, synchronization basically disappears.

What explains the apparent detachment of the North American gas market? Probably the extensive pipeline network present in the United States, with roughly equivalent gas specifications, with many buyers and many sellers, facilitates an independent market. In North America, gas prices result from local supply and demand, where gas competes with other gas (gas-on-gas pricing). In the different regions of the world, it is common to have gas prices directly linked to oil prices. To be more precise, in Europe, gas prices are a function of energy substitutes, which naturally include

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oil products. It is common to have pure oil-linked pricing in North Asia, especially in Japan, Korea, and Taiwan. This contract structure may explain several of our results.

In conclusion, it is still not the time for industry strategists to think of regional gas markets as one market. That means that geographical diversification reduces obvious local risks, like political risks, and reduces exposure to price shocks. The fact that our analysis is frequency varying allows for portfolio managers to adjust their choices to their clients' time horizons.

Our results reinforce the need to decouple gas pricing from oil prices in Europe and Japan (especially in the latter case) for policymakers. Given the typical contract structure of gas transactions, an increase in oil prices will increase gas prices, possibly leading to overpriced gas, which will hurt consumers. Moreover, a policymaker may prefer that gas consumption share increases because of environmental concerns while oil decreases. Such substitution is difficult if the prices of both energy sources are tied together. Policymakers may wish to create incentives to redesign gas contract structures.

Oil Price Shocks in Major Emerging Economies

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As a gradual shift occurs in terms of economic power from the advanced G7 countries—Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States—to the emerging E7 countries—Brazil, China, India, Indonesia, Mexico, Russia, and Turkey—understanding the vulnerability of these economies to exogenous shocks becomes of growing importance.

Previous studies that investigated the impact of oil price uncertainty on the real economy were limited to the advanced economies and were also limited in terms of the econometric approach. This paper aims to fill the gap in the literature by investigating the impact of oil price uncertainty on the industrial production of seven of the largest emerging markets in the world today. Previous analyses that investigated this question for advanced economies using a bivariate analysis made a limiting assumption that the price of oil was exogenous to the real economy, without addressing demand side and supply side effects that drive both oil prices and macroeconomic variations such as industrial production. We extend the Elder and Serletis (2010) bivariate GARCH-In-Mean VAR model to a multivariate framework addressing concerns raised by Kilian (2009) and Kilian and Park (2009).

We find that oil price uncertainty has a negative and statistically significant effect on real economic activity in India, Indonesia, Mexico, Russia, and Turkey, but has a positive and statistically significant effect on real economic activity in China and Brazil. On first glance, the results for China and Brazil might seem puzzling, but having a closer look at the literature, we find that Brazil is the second largest producer of ethanol in the world, a substitute for crude oil. A rise in the price of the substitute will increase the demand for the good, hence explaining why uncertainty about crude oil prices has a positive effect on economic activity of Brazil. Chinese data on the other hand has been criticized in the literature for lack of reliability, as in Cheng et al. (2019). We also find uncertainty about the impending realization of oil prices has a negative effect on world oil production and that the relationship between oil prices and economic activity is in general symmetric.

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Adaptation Funding and Greenhouse Gas Emissions: Halo Effect or Complacency?

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The debate surrounding climate change on the choice of appropriate policy tools to address the impacts of greenhouse gases (GHGs) is ongoing. The two main tools are abatement of emissions and adaptation to climate change. In this context, the option to adapt raises the potential for complacency with regards to emission abatement efforts by countries that might adapt or over-adapt. This concern is widely discussed by both policy makers and the nascent theoretical literature on the adaptation-abatement nexus. As it stands, there is no clear consensus about the impact of adaptation efforts on emission abatement. While some papers find that adaptation and emission abatement are substitutes, others imply that they are complements.

Using data from the World Development Indicators and various adaptation funds under the UNFCCC framework, this paper provides an empirical analysis of the relation between adaptation and emissions. We specifically test whether adaptation measures to climate change affect emissions of GHGs in a world where adaptation funds are available using a difference-in-differences approach. We consider several measures of emissions such as CO_2 emissions, per capita CO_2 emissions, dollar CO_2 emissions, CO_2 intensity, as well as methane, nitrous oxide and other greenhouse gases.

Specifically, we apply a difference-in-differences analysis where we compare the emissions of non-Annex I countries that received adaptation funding relative to non-Annex countries that did not receive such funding before and after the fund approval. We find that receiving adaptation funding significantly and negatively affects all measures of CO_2 emissions except CO_2 intensity, providing preliminary evidence of the presence of a halo effect of adaptation funding. We do not find evidence of a significant change in the emissions of methane, nitrous dioxide and other greenhouse gases. Our results are supported by an event study analysis. For robustness, we also provide a falsification test by randomly assigning a fund approval date and find no significant effects on emissions.

The Integration of Variable Generation and Storage into Electricity Capacity Markets

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Many electricity systems throughout the world now operate capacity markets. While such markets have been largely designed with conventional generation in mind, it is increasingly necessary to incorporate both variable generation and storage within them.

The present paper shows how to value both variable generation and storage so as to enable them to be optimally integrated into such markets. We develop a theory based on balancing expected energy unserved against costs of capacity procurement, and in which the optimal procurement may

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be expressed as that necessary to meet an appropriate reliability standard. In the absence of variable generation and storage the theory reduces to that already in common use, both in the definition of a standard and in its economic justification. Further the valuation of both variable generation and storage in the proposed approach coincides with the traditional risk-based approach leading to the concept of an equivalent firm capacity.

We show that the contribution of any given amount of variable generation or storage is crucially dependent on the characteristics of the remainder of the system to which it is being added. The determination of the contribution of storage requires particular care. This is partly due to the time-limited nature of storage and the flexibility with which its addition to an existing system may be scheduled, and partly due to the fact that, when *any* capacity-providing resource is added to an existing system, storage *already within that system* may be flexibly rescheduled. This leads ultimately to substantial *subadditivity* of the equivalent firm capacities of storage resources.

A further conclusion of our analysis is that the contribution of storage to capacity adequacy is not well measured by the reduction it achieves in the traditional *loss-of-load* risk metric employed in GB and in many other countries. Rather it is necessary to consider directly the contribution of storage to reduction in *expected energy unserved*, something which has now been accepted in the design and running of the GB capacity market.

Finally, we study also the operation of a capacity market in an example system which closely mimics that of GB, except only that substantially more storage than at present participates within the capacity market.

The results of the paper should enable also the correct evaluation of the contributions of variable generation and storage resources elsewhere, together with the correct design of the markets required to optimally utilise these resources.

Extending the Macroeconomic Impacts Forecasting Capabilities of the National Energy Modeling System

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Decision makers involved in energy policy are facing unprecedented challenges arising from globalization, decarbonization, and the advent of new energy technologies. Energy-economy forecasting models are often used to help inform their decisions regarding the development of critical energy infrastructure development and implementation of new energy technologies. Forecasts

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generated by these models, however, rarely include detailed estimates of the macroeconomic impacts associated with policy changes. And those that do, lack the transparency required for large scale utilization.

Recognizing the need for a transparent model that was capable of producing comprehensive estimates of the macroeconomic impacts of changes in long-term forecasts the energy-economy, the United States Department of Energy's National Energy Technology Laboratory (NETL) worked with researchers at West Virginia University (WVU)'s Regional Research Institute (RRI) to develop the WVU/NETL econometric input output (ECIO) model. The ECIO model is capable of estimating industry-specific changes to employment, labor income, and gross domestic product associated with departures from a reference forecast of the U.S. energy-economy over a long-term time horizon. This manuscript provides an overview of the methodological foundations of the NETL/WVU ECIO model, its functionality as an extension of integrated energy-economic modeling frameworks, and its role in providing a consistent method for assessing the economic impacts associated with long-term energy forecasts.