Proposed plan of research: Economics of a greener, more connected electric grid

Financial pre-commitments alter payoff streams and consequently, physical production and consumption decisions of market participants. In imperfect markets, a market regulator may impose regulation on the design and accessibility of financial products with the aim to improve market efficiency. For example, fixed price forward contracts have been introduced and regulated in many commodity markets to reduce participant risk exposure and improve liquidity. However, regulatory designs that do not account for the production incentives tied to financial assets can result in poor market efficiency. This dissertation proposal, a study of transmission revenue rights in electricity markets, addresses the moral hazard that can arise when auctioning such rights. It has been theoretically shown that firms with the ability to perform damage to market efficiency are the ones who will value transmission revenue rights the highest. Therefore, effective design of these financial products requires a complete picture of firm payoff streams. This dissertation will describe these payoff streams and quantitatively assess the merits of different regulations on these financial products in Australia's National Electricity Market.

This dissertation proposal relates to my portfolio of empirical analyses describing how imperfect electricity markets can respond to environmental policy and market design. This document describes the dissertation proposal, related work-in-progress and deliverables from the proposal.

Transmission revenue rights and moral hazard in electricity markets

Transmission revenues exist when electricity is passed between two neighboring regions that have unequal regional prices. Bushnell (1999) notes that an auction-based distribution of the rights to these revenues will result in the rights *"flowing to those that can abuse them most."*[1] Moral hazard arises because the parties that can perform the most damage to market efficiency value the rights higher than those that cannot, and consequently pay less at auction than the revenues they will accrue from the rights. Australia's zonal National Electricity Market (NEM) allocates transmission revenue rights via auctions over three-month windows. The transmission revenues for the NEM's Victoria into South Australia interconnector from 2009-2014 were AU$226 million, delivering large returns over the auction proceeds of $158 million.[2] Using NEM data, I will investigate the extent to which generator owners acquire transmission revenue rights and respond to their new incentive structure by distorting market outcomes toward a less efficient production allocation.

To illustrate the ability for generators to perform damage when possessing transmission revenue rights, consider a modified example from Bushnell (1999) (numeric example illustrated in figure 1). The relevant feature of wholesale electricity markets are that customers (loads) and generators pay and are paid the market clearing prices in their respective geographic regions. Consequently, if electricity exchange is equal to the capacity of the interconnector (T) and prices between regions (P_1 and P_2) uncouple, there are surplus transmission revenues equal to ($T[P_1 - P_2]$). If the rights to these revenues are owned by a generator in region 1, their incentive to raise their region's price P_1 is enhanced as the transmission revenues are increasing in P_1.[3] Therefore, transmission revenues are higher and the rights more valuable when owned by a generator than a third party. However,

[1] Joskow and Tirole (2000) extend this statement and solve for rights price equilibria under a variety of settings, showing that the firms that can use the transmission rights as an instrument for market power will value the rights higher than those that cannot. In addition, auction revenues may go to transmission owners, which may create investment incentive distortions which are not the focus of this proposal, see Leautier (2001).

[2] Source: Constructed from Australian Energy Market Operator (2009) and subsequent quarterly issues

[3] Further, if transmission is not constrained in a base scenario, a transmission rights holder may have the incentive to alter their supply strategies to induce congestion.

allocation of the rights to generators translates to greater market power, less generation, higher prices and lower welfare for consumers (see figure 1).[4]

My dissertation approach will construct a model of generator expected profit maximization to estimate transmission rights holdings and compare the value of these holdings to generators and third parties under different demand levels. I hypothesize that rights-owning generators will alter their behavior most when they have greatest market power - in high-demand situations and low regional wind and solar generation. With this model I will provide a quantitative assessment of efficiency gains and the profitability of intermittent and dispatchable generators under different market design regimes, such as excluding generator participation in transmission rights auctions or proportional transmission revenue sharing rules.[5]

Work-in-progress: Transitioning to a greener grid

1. Carbon taxation and market power in wholesale electricity markets:

In two recent NBER working papers, researchers have investigated how lowering relative gas to coal prices has affected carbon emissions from electricity generation. Cullen and Mansur (2014) use the price variation provided by the shale gas boom in the USA to forecast the impact various carbon taxes would have on carbon emissions from electricity generation, holding demand and generating technologies fixed. Knittel, Metaxoglou, and Trindade (2015) examine the heterogeneity in the carbon emissions from electricity generation over the shale gas boom. Respectively, the authors of the two papers find that the emissions reductions from a carbon tax are likely to be small in the short run, and that generation in restructured electricity markets were less responsive to the shale boom than traditionally structured markets. I provide a plausible economic explanation for these findings by analyzing the immediate, short-run impact an actual carbon tax had on market power and carbon emissions in the Western Australian wholesale electricity market. I document that when controlling for demand and generator outages, carbon emissions from electricity generation were higher when a carbon tax was imposed. Under a baseline of cheap coal-fueled and expensive gas-fueled generation, the dominant generator owner supplied less of their coal fired generation to have prices clear at higher marginal gas generator prices. However, the introduction of a small carbon tax that reduced, without eliminating, the coal cost advantage removed this incentive to exercise market power, resulting in more coal use and higher emissions. This result emphasizes that while the cost-ordering of generators might change with a tax or the shale boom, imperfect markets may alter their production mix in a different manner to state-owned or regulated monopolies. Further, the majority of gains from carbon taxation are likely to come in the long-run from investment responses, rather than short run fuel substitution.

2. Assessing the merits of subsidizing renewable energy installations: The case of USA wind farms (with John Anderson and Frank Wolak):

A common argument for subsidizing the construction of wind farms is that the process of building a wind farm can result in learning and technological advancement that will provide a public good.

[4] It is a precondition that a generator must have some form of market power for transmission rights it to perform damage in the market. If markets were perfectly competitive, such a strategy would not be profitable.

[5] Given the complexity of electricity markets, solving for counterfactual equilibrium strategies is likely infeasible. However, Joskow and Tirole (2000) show that there is a mixed-strategy equilibrium in the auction for transmission revenue rights, therefore I may be able to compare the differences in outcomes across different rights ownership allocations observed in the sample window (2009-present) to infer which ownership restrictions would work best.

Previous studies have shown that wind farm installation costs have been falling, however, it is unclear how cost functions are changing, be it economies of scale, input costs, Hicks neutral technical change, learning by doing and/or knowledge spillovers. We collect project cost data for 379 projects to estimate a richly specified cost function for wind developers to examine the existence and relative sizes of private and public learning from wind farm developers. Our preliminary results indicate that while firms do learn from their experience in installing wind turbines, resulting in lower costs, there is no evidence to support the hypothesis that they learn from the completion of projects by other firms.

3. Retail electricity pricing tariff salience in developing economies (with Ognen Stojanovski, Mark Thurber and Frank Wolak):

In the developing country context, where the cost of energy may represent a high percentage of household income and electricity supplies may be inadequate, policies that encourage the efficient use of electricity could help boost household wealth while reducing the strain on overtaxed grids. Tiered electricity pricing is one such policy, but a growing body of research shows that many end-users may not understand tiered electricity pricing, potentially limiting its ability to achieve these benefits. I have been awarded a PhD I-award grant from the Stanford Institute for Innovation in Developing Economies to extend a pilot price information workshop we performed in July 2015. In 2016, we will to roll out a larger randomized control trial that will measure the effectiveness of both a self-administered online information workshop and a simple information handout in reducing household electricity consumption. The trial aims to provide information to utilities in developing countries about whether such cheap and straightforward informational treatments about electricity pricing can reduce electricity consumption.

Deliverables by May 2017

Project/Paper	Deliverable
Tax Induced Emissions? Evidence of Unintended Consequences from Carbon Taxation in Wholesale Electricity Markets	Paper presented at seminars/conferences and submitted for peer-review
Assessing the merits of subsidizing renewable energy installations: The case of USA wind farms	Working paper released, possibly submitted
Mexico field experiment: Household informedness about electricity tariff structure	Intervention performed, draft with preliminary results
Transmission revenue rights and moral hazard in electricity markets	Draft with preliminary results

References

Australian Energy Market Operator (2009): "Auction Report 2009-01 prepared by Settlement Residue Committee," Discussion paper.

Bushnell, J. (1999): "Transmission rights and market power," *The Electricity Journal*, 12(8), 77–85.

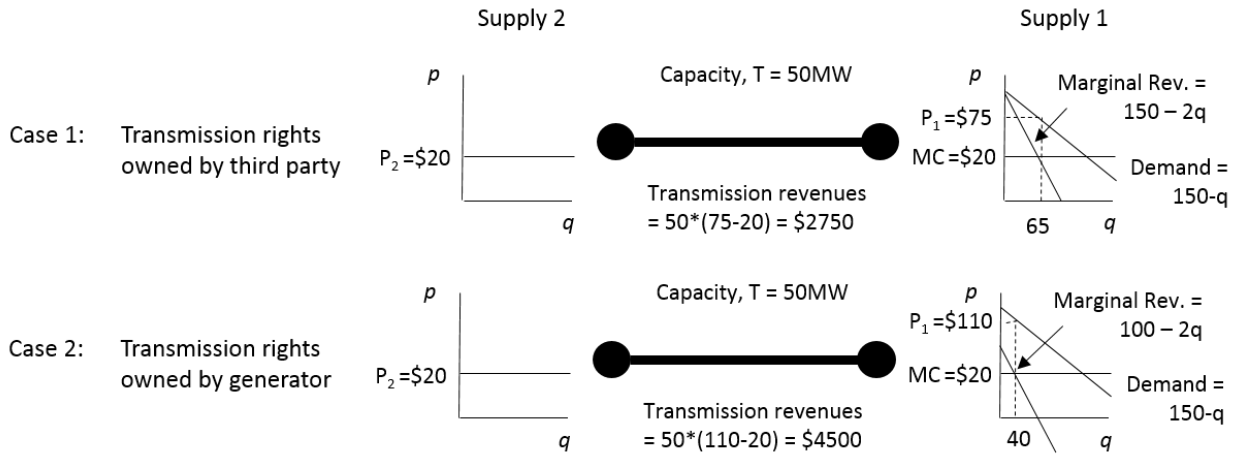
Cullen, J. A., and E. T. Mansur (2014): "Inferring Carbon Abatement Costs in Electricity Markets: A Revealed Preference Approach using the Shale Revolution," National Bureau of Economic Research Working Paper.

Joskow, P. L., and J. Tirole (2000): "Transmission rights and market power on electric power networks," *The Rand Journal of Economics*, pp. 450–487.

Knittel, C. R., K. Metaxoglou, and A. Trindade (2015): "Natural Gas Prices and Coal Displacement: Evidence from Electricity Markets," National Bureau of Economic Research Working Paper.

Leautier, T.-O. (2001): "Transmission constraints and imperfect markets for power," *Journal of Regulatory Economics*, 19(1), 27–54.

Figure 1: Transmission rights and market power



Here, a home region contains one generator and can import up to $T = 50MW$ of electricity from a neighboring region which has an unlimited, perfectly competitive generating capacity at $P_2 =$\$20/MWh. Transmission revenues equal $T[P_1 - P_2]$. Region 1's sole generator also has costs of \$20/MWh, can choose any generation quantity q and faces a demand curve of $P_1 = 200 - T - q$, and resulting marginal revenue curve of $MR = 150 - 2q$ in case 1. In case 2, for every dollar P_1 falls, the generator's transmission revenues decrease by $T = 50$, so its marginal revenue curve shifts down to $100 - 2q$, resulting in higher prices and transmission revenues with lower output.

Gordon William Leslie

Landau Economics Building
579 Serra Mall
Stanford, CA 94305, USA
Phone: +1 (650) 996 9492
Email: gwleslie@stanford.edu

Citizenship: Australian

Education

Ph.D Economics, Stanford University, commenced 2013.

B.Com (Hons) Economics, University of Melbourne, 2012.

B.Sc Mathematics (Operations Research), University of Melbourne, 2005-2009.

B.Com Economics & Finance, University of Melbourne, 2005-2009.

Fields of Research Interest

Energy and Environmental Economics, Industrial Organization

Research

Publications

How do Consumers Respond to Gasoline Price Cycles?
w/ David Byrne and Roger Ware, *Energy Journal*, 36(1), 115-147, 2015.

The Dynamics of Satisfaction with Working Hours in Australia: The Usefulness of Panel Data in Evaluating the Case for Policy Intervention
w/ Robert Breunig and Xiaodong Gong, 2015, *Asia and the Pacific Policy Studies*, 2(1), 130154, 2015.

Working Papers

Tax Induced Emissions? Evidence of Unintended Consequences from Carbon Taxation in Wholesale Electricity Markets
October 2015

Honours, Awards, Grants & Scholarships

Stanford University

Stanford Economics Graduate Research Fellowship, 2013

I-Award grant winner. Project: Does Information Provision Encourage Energy Efficiency in Mexican Households? Source: Stanford Institute for Innovation in Developing Economies (USD$7,500)

University of Melbourne

Economics Honours Prize, 2012

Subject prize winner in Advanced Macroeconomics, Econometric Techniques and Labour Economics, 2012

Dean's Honours List in the Faculty of Economics and Commerce, 2008 and 2009

The Treasury (Australia)

Post-Graduate Study Award, 2012 (Scholarship to undertake Economics Honours)

Selected Employment History

Program on Energy and Sustainable Development, Stanford University, June 2014-present

Positions: Research Assistant for Professor Frank Wolak (2014-). Teaching Assistant for Social Science Field Research Methods and Applications (Spring 2015). Field supervisor for International Field Research Training: Energy Reform in Mexico (Summer 2015).

The Treasury (Australia), 2010 - 2013

Role: Economic policy modelling in the Modelling and Behavioural Analysis Unit

Responsibilities: Tax/transfer, retirement and dynamic microsimulation modelling. Research on the working hour preferences of Australians.

Department of Economics, University of Melbourne, March 2008 - November 2009, March 2012 - July 2013

Positions: Teaching Assistant in Quantitative Methods 1 (2008, Sem1&2), Introductory Microeconomics (2009 Sem1, 2012 Sem1), Introductory Macroeconomics (2009 Sem2) and Advanced Macroeconomics (2013 Sem1). Student Reviewer for the Australian Economic Review, *For the Student* submissions (2012). Research assistant to David Byrne and Michael Coelli (2013).

Goldman Sachs JBWere, December 2008 - February 2009

Position: Quantitative Research Analyst (Intership program).

Referees

Professor Frank Wolak
Email: wolak@stanford.edu
Work: +1 (650) 724-1712

Professor Mar Reguant
Email: mar.reguant@northwestern.edu
Work: +1 (847) 491-8221

Professor Charles Kolstad
Email: ckolstad@stanford.edu
Work: +1 (650) 721-1663

Last updated: December 18, 2015

STANFORD UNIVERSITY
PROGRAM ON ENERGY AND SUSTAINABLE DEVELOPMENT

Freeman Spogli Institute for International Studies • Encina Hall E416 • 616 Serra Street • Stanford, CA 94305-6055
Telephone: (650) 724-1712 *Facsimile:* (650) 724-1717 *E-mail:* wolak@zia.stanford.edu
Website: http://www.stanford.edu/~wolak

FRANK A. WOLAK
HOLBROOK WORKING PROFESSOR OF COMMODITY PRICE STUDIES
DIRECTOR, PROGRAM ON ENERGY AND SUSTAINABLE DEVELOPMENT

December 18, 2015

Confidential Letter of Recommendation for Gordon Leslie

This letter supports the application of **Gordon Leslie** for an NBER Pre-Doctoral Fellowship on Energy Economics, I have known Gordon since the winter quarter of the 2013-2014 academic year when he took Economics 271, the second course in the first-year graduate econometrics sequence from me. Since the summer of 2014, he has worked for me as a research assistant. During the spring of 2015, as he served as a teaching assistant for Economics 121, Social Science Field Research Methods and Applications, an undergraduate course on the design and analysis of field research experiments. As part of this course, I took a group of Stanford undergraduates from the course to Puebla, Mexico to undertake a field experiment during June of 2015 and Gordon was a graduate student supervisor for that project. My assessment of Gordon is based on these interactions.

Gordon is a very productive and hard-working scholar with significant upside potential. I consistently find Gordon at work in his office when I arrive early in the morning and when I leave in the evening, as well as on most Saturdays. His work ethic has not gone unrewarded. Gordon already has one published paper on retail gasoline markets out of his undergraduate studies at the University of Melbourne and he has several papers currently in progress. By the time he is on the job market next year, Gordon will have a strong portfolio of papers that should make him a very attractive job market candidate.

His paper, "Tax Induced Emissions? Evidence of the Unintended Consequences from Carbon Taxation in Wholesale Electricity Markets," is most far along. This paper provides convincing empirical evidence that that carbon pricing can lead to increased greenhouse (GHG) emissions from an industry. One of the necessary conditions for a positive price of carbon to reduce GHG emissions is that no firm has the ability to exercise significant market power. Gordon considers the introduction of a 23 Australian Dollar per metric tonne (AUD/tonne) carbon price in Australia and its impact of the wholesale electricity market in Western Australia. This market is dominated by one large player, Synergy, which controls more than 50 percent of the installed capacity. Gordon compares total GHG emissions in the Western Australia electricity market with and without a positive price of carbon and finds that, after controlling for

all observable differences in half-hourly market conditions, total GHG emissions in the Western Australia electricity market were higher with the tax relative to the case of no carbon tax.

Economic theory allows this outcome to occur if the dominant firm finds that it faces greater competition with the carbon tax relative to the case of no carbon tax. Using information on generation unit capacities, heat rates, and natural gas and coal prices, Gordon is able to construct the aggregate marginal cost curve for both Synergy and each of the remaining firms in the market. The 23 AUD/tonne tax was set at a level that made coal units slightly cheaper than natural gas-fired units, so the imposition of the tax flattens out the aggregate marginal cost curve of the firms competing against Synergy. Because Synergy owns a mix of coal and natural gas generation units, this tax also flattens out its marginal cost curve, albeit at higher AUD/MWh values. Gordon then uses the half-hourly aggregate offer curves submitted by Synergy and its competitors to demonstrate that these offer curves become flatter with a positive price of carbon, which is consistent with Synergy facing greater competition with a positive price of carbon. Therefore, Synergy finds it unilaterally profit-maximizing to produce more output from its coal units with a positive price of carbon relative to the case of a zero price of carbon, which implies more GHG emissions from the Western Australia electricity supply industry with a positive price of carbon.

Gordon's paper is a well-executed piece of empirical Energy/IO research that demonstrates that during the initial stages of carbon pricing, GHG emissions may increase in markets where some suppliers have a substantial ability to exercise unilateral market power. As Gordon notes, new entrants into the industry have a strong incentive to build generation units that produce fewer GHG emissions per MWh and these units should displace the more GHG emissions-intensive units and thereby reduce industry-wide GHG emissions.

For his job market paper, Gordon is taking on an increasingly important issue in wholesale electricity markets: How to distribute the merchandising surplus that results from congestion management under zonal or nodal pricing. Because locational prices tend to be higher closer to major load centers, market operators typically collect more revenue from loads than they pay to generation unit owners each hour. The difference between the amount loads pay and the amount generation unit owners receive is called the merchandising surplus. Market operators often create financial instruments such as financial transmission rights (FTRs) or congestion revenue rights (CRRs) that provide hedges against locational price differences backed by this merchandising surplus. However, as I and my colleagues on the California Independent System Operator (CAISO) Market Surveillance Committee (MSC) noted, ownership of a FTR and CRR can create an incentive for a market participant to cause congestion in order to receive more revenues from this financial instrument. More important, if these FTRs or CRRs are auctioned off to market participants, it is very likely that the entity willing to pay the most in the auction for the financial instrument is the one able to derive the greatest revenue from owning it by causing congestion. This argument was made by the CAISO MSC in its argument to allocate to loads rather than auction the CCRs issued by the CAISO.

Using the Australian Settlement Residual Auction (SRA) process, Gordon proposes to the test the empirical relevance of the two incentives described above. The first hypothesis is that an increase in the share of the merchandising surplus that a market participant is allocated increases

the incentive it has to take actions to cause congestion and thereby obtain more revenues from owning these financial instruments. The second hypothesis is that the market participant that is willing to pay the most in the auction for these financial instruments is the one able earn the most revenues from owning it, and a significant portion of those revenues are due to congestion-causing actions taken by that market participant after owning the financial transmission right. The second hypothesis implies that magnitude of the realized merchandising surplus depends on which market participants win these financial instruments in the auction.

Gordon has compiled a time series of SRA outcomes and subsequent energy market outcomes over the period that these financial instruments make payments to the owner. By matching the identities of the winners in the SRA auctions to generation units and loads that they serve, Gordon can look at how generation unit owner offer behavior has changed and market outcomes have changed as result of which firms win and how much they win in the SRA process. Gordon can also compare the amount the market participants paid for each financial instrument in the auction and compare that to the revenues they subsequently received from owning it.

The results of this research should provide valuable input into the design of mechanisms for refunding the merchandising surplus and financial instruments to hedge locational price risk. Beyond its interest to energy economists, Gordon's paper provides a clean test for the existence of moral hazard in the market for financial transmission rights. Specifically, owning an FTR or CRR that hedges a locational price difference, causes a market participant want to create additional congestion.

I expect Gordon to have this paper ready in time for the 2016-2017 job market. He should also have the other joint papers with me and other scholars at the Program on Energy and Sustainable Development (PESD) completed by then. I expect him to have a very good job market.

For all of the above reasons, I think that Gordon is an outstanding candidate for the NBER Pre-Doctoral Fellowship on Energy Economics. I enthusiastically recommend him without any reservations. If you have any questions about his application, please feel free to contact me.

Sincerely,



Frank A. Wolak