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Carbon: Put a Price on It?

An investigation on the impacts of carbon taxes

CHRISTOPHER ROUND AND DARRIN FOLTZ

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Abstract

Global warming has become one of the largest environmental issues of our generation. As scientists have come to a general conclusion on the causes and potential damages of greenhouse gas emissions, nations are still struggling with developing sound policy to lower emissions. The two most prominent strategies to combat GHG emissions are carbon taxes and cap & trade systems. A cap and trade system places a quota on the amount of emissions allowed per year in the form of tradable permits. Carbon taxes place a price on carbon emissions to effectively make pollution abatement or renewables a more attractive choice, all in an attempt to reach a desired level of emissions. In 2014, Australia was the first country to repeal its carbon tax, citing it as a threat to the Australian job growth. American politicians are making similar claims that tackling climate change would gravely threaten the US economy. As American citizens, we were interested investigating these claims so as to provide input for the American climate policy discussion. To do this we investigated various carbon dioxide reduction policies, and in turn investigating the claim by the Australian government that its tax could threaten the economy. In our investigation, we demonstrated using multivariate regression analysis that the existence of the policy did not have an impact on unemployment or GDP per capita. The next step in the study is to use a general equilibrium model, to have a more realistic simulation of the Australian economy.

Introduction

Climate Change is a global environmental problem that resulted from the use of fossil fuel intensive energy production from the start of the industrial revolution. (IPCC, 2013) Greenhouse gases such as carbon dioxide are released from the combustion of fossil fuels. Once in the atmosphere, greenhouse gases trap thermal radiation from the sun. (IPCC, 2013) While these gases ensured that Earth would be warm enough to support life as we know it, the increased concentration since the dawn of the industrial revolution has is threatening to cause a bifurcation in the climate system. (IPCC, 2013) To curtail greenhouse gas pollution, around 40 national and over 20 sub-national jurisdictions are putting a price on carbon. (World Bank Climate Change Group, 2014)

Status of Climate Policy in United States

Climate change policy in the United States has been the subject of controversy for thirty years. While a carbon tax has been suggested to be the most economically efficient policy measure, it has been met with stiff opposition by special interests and the American electorate. Opposition to a carbon tax has made it politically unfavorable despite fervent support from environmental groups. Special interests have played a powerful in the formation of American climate change policy. Industrial funding of public relations campaigns to convince the public that climate change is not happening or human caused have retarded the growth of political capital for action by policymakers at the state and federal level. Thus attempts to curtail greenhouse gas emissions have focused on cap and trade and command and control models of regulation.

No binding climate change specific federal legislation has been passed to address climate change. In 2009 a cap and trade bill passed the federal House of

Representatives, but failed to garner enough support in the Senate. In the past two years the Obama administration, free of the need to seek reelection, has begun implementing a regulatory regime aimed specifically at reducing greenhouse gas emissions from power plants. The regulatory regime proposed by the Obama Administration and administered by the US Environmental Protection Agency uses the power of the Clean Air Act in accordance with the 2007 Massachusetts vs. EPA US Supreme Court decision to establish command and control mechanisms. Many of the regulatory decisions for how power generators will reduce emissions have been left to individual states.

Typical opposition to the taxation of carbon is the claim that it will negatively impact the economy in a large scale way. This was the reasoning for why Australia repealed its carbon tax. It is hoped that by analyzing the impacts of the Australian carbon tax, we can ascertain what such a policy could look like in the United States should enough support ever appear.

Australian Climate Change Policy

On July 17th, 2014, the Australian senate repealed the federal carbon tax. (Taylor, 2014) This tax was put into place by the Gillard government, and was part of a broad energy reform packaged called the Clean Energy Plan. The Clean Energy Plan had the stated objective of bring greenhouse gas emissions down 80% from levels at the year 2000 by 2050. The policy was the subject of intense political debate in Australia, which provided substantial political capital for the politically conservative Tony Abbott to ascend to the role of prime minister. Abbott repeatedly claimed that the Australian carbon tax was toxic to the economy and job growth. (Hernandez, 2012) During the

2013 election, his party placed the removal of the carbon tax as part of their national platform.

Proposed policy instruments

Before we delve into the specifics of Australia's carbon policy, it is important to understand the carbon policies that deal both directly and indirectly with greenhouse gas emissions. Two of the most commonly proposed policies that directly target greenhouse gas emissions are carbon taxes and a cap & trade system. Cap & Trade is a policy that uses tools that effect quantity produced directly. The cap is the amount of emissions that are allowed annually by an industry or by the entire economic sector as a whole. This hard cap is enforced through the use of penalties if any company produces more than its share of allowed emissions. These allowed emission materialize in the form of permits. (Kolstad, 2011)

Permits can be given away for free to companies or they can be sold. Selling permits through an auction allows for the government to gain revenue. This process has an added effect of understanding the marginal costs of abatement for all the firms based on their bidding price. If a company can abate a unit of pollution for cheaper than they can purchase a permit, they theoretically will reduce their level of emissions. If the same company finds it cheaper to purchase a permit through this process, than the marginal cost of abatement is higher than other companies. (Kolstad, 2011)

The trading aspect follows the same logic related to marginal cost of abatement. While the initial prices dictate where each company is in terms of costs of emission reductions, the trading of permits between companies tracks the marginal cost

of abatement over time. As companies reduce pollution to meet the cap, prices of permits fluctuate based on the marginal costs of abatement for all the firms. This market flexibility is one of the major benefits of the Cap and Trade policy. Aside from penalties for emitting more than permitted, the policy ultimately reaches its goals of emissions reduction as long as the goals are reasonable. (Kolstad, 2011)

Another factor that increases market flexibility is the ability for permit banking. Companies can engage in the trading of permits across multiple years. This allows for companies to plan on future prices of permits related to future costs of abatement. If a company currently has the ability to make the necessary emission reductions at a very low cost, they will trade permits for this year to companies for extra permits in other years. The opposite scenario also helps those that have incredibly high marginal costs of abatement but plan on developing or implementing a newer cheaper emission reduction technology in the future. This market flexibility allows for the emissions reduction goals to be reach via the lowest hanging fruit. (Kolstad, 2011)

The cap and trade policy incentivizes innovation while allowing for companies to take a wide variety of opportunities to reach their permitted emission levels. Depending on the yearly permitting process, the government can find an annual stream of revenue. In order to continue a cap and trade policy, there needs to be a gradual reduction in the amount of permits allocated in order to reach future emission goals. (Kolstad, 2011) The most popular cap and trade program in the world, the European Union Emissions Trading Scheme (EU ETS) has failed to do this permit reduction quickly enough and consequently has seen the price of permits plummet, essentially making them useless.

While a cap and trade system effectively places a price on carbon emissions, it is much more variable and indirect due to fluctuations in permit prices and allowances. A carbon tax on the other hand sets a price directly tied to carbon emissions. The price is formulated from analysis of the affected industries and what their marginal costs of abatement will be. If the price is set correctly, then the emission reduction goals will be reached, just like with cap and trade. The price is also reflective of the social costs of CO2 emissions. A carbon tax is a pigovian tax, as it works to correct a negative market externality. (Kolstad, 2011) The tax amount should theoretically be the difference between the market marginal cost function and the social cost function. (Kolstad, 2011) As a tax, the policy raises government revenues which can be used to promote equality among affected consumers or be used in other ways to help the efficiency of the program. The carbon tax can be regressive in the sense that it affects lower income households more than others.

The two major indirect policies that reduce carbon and other greenhouse gas emissions are CAFE standards and renewable portfolio standards. CAFE stands for Corporate Average Fuel Economy standards. This policy sets an average fuel economy that each automotive manufacturers must meet across the entire line of vehicles produced that year. By improving fuel economy of all new vehicles on the road, the amount of gasoline consumed will decrease. This effectively decreases the carbon output of all vehicles on the road. Criticisms of this policy include the rebound effect, which says that as fuel economy increases, people will drive more. Studies have shown that gasoline has a very low elasticity and that changes in price or fuel economy do not have significant impacts on demand (eia.gov).

Companies have a few different strategies to meet this fuel economy standards. The ideal response would be for companies to innovate and develop efficiency improvements across the entire line of vehicles. However the most effective means of reaching a targeted fuel economy is to introduce a new fuel efficient model. This especially incentivizes electric vehicles as their mile per gallon equivalents are almost double the mileage of a traditional motor. Another strategy that companies have taken is to segment their production. For example Chrysler and Dodge have separated their truck division, RAM, from the rest of their production line. Because RAM is composed of only large industrial trucks, they have different standards to meet than a normal automotive manufacturer. These policies all affect different industries and have a unique impacts on the market as a whole.

There are a multitude of factors that need to take into account in order to determine the effects of a proposed carbon policy. To begin, one must understand what industries are affected by the policy. Is the tax, standard or quota only applied to electricity generation or does it include other industries as well? Are any of the affected industries producing goods that are priced on the international market? If goods are price on the international market, a carbon tax can raise the price of domestically produced goods and force an increase in cheaper imports and/or less exports. Another major factor is the energy portfolio of the region involved. As we examine the Australian carbon tax policy in this research, it follows that the energy portfolio of Australia be analyzed.

Climate Change Policies Worldwide

Carbon taxes in use

Carbon taxes emerged as a policy instrument for curbing CO2 emissions in the 1990's where it was first adopted by Finland and quickly spread to the rest of Scandinavia. The policy in Finland was initially directed at the industries and goods related to "gasoline, diesel, light fuel and heavy fuel oil, jet fuel, aviation gasoline, coal and natural gas." (Lin & Li, 2011) In 1994, the policy was reformulated into a general energy tax. The current reformulated policy covers heat and electricity production as well as transportation fuels. The tax on CO2e in Finland has varying prices dependent upon the type of fuel used. According to an NREL report, Finland places a price of $73.97 (US) per metric ton on coal, while natural gas is taxed $3.02 (US) per MWh. This lower cost on natural gas is an attempt to further natural gas production in Finland while phasing out coal. Estimated revenue from Finland's carbon policy equates to $750 million dollars per year which is not earmarked for specific budget use. (Sumner, Bird, & Dobos, 2011) Finland has reported that between the years 1990 to 1998 there was a 4 million metric ton reduction in CO2 emissions. (Sumner et al., 2011) To put that number in perspective, Finland's annual emissions ranged from 10.38 metric tonnes in 1990 to 11 metric tonnes in 1998. (World Bank Climate Change Group, 2014) According to the estimates, Finland's CO2 emissions were reduced about 4% with the implementation of the carbon tax.

Norway and Sweden were the next countries to adopt forms of carbon tax policy in 1991. Norway covered approximately 55% of their emissions with the carbon tax policy, the rest of the emissions were covered under the European emissions trading

scheme. The price per tonne of CO2e varies from $4.00 to $69 depending on the fuel type and usage. (Bruvoll, Larsen, & Norway, n.d.) Norway gave more favorable rates to the "pulp and paper industry, fishmeal industry, domestic aviation, domestic shipping of goods, and the continental shelf (supply fleet). Foreign shipping, fishing in Norway, fishing in distant waters, and external aviation are all exempt from the tax." (Sumner et al., 2011) Much like Finland, the tax revenue generated goes directly to the large government fund. According to NREL, much of this revenue has been invested in a public pension fund for citizens. The carbon tax in Norway was implemented during a period of large scale economic growth, which saw the GDP of Norway to increase by 70% from 1990 to 2008. This growth has led to an increase of around 15% in GHG emissions from Norway. It is hard to say whether the carbon tax policy was successful during this large scale economic development in Norway. As we have seen with many developing countries, it is incredibly hard to have large economic growth without increasing carbon emissions.

Sweden has an incredibly high carbon tax rate compared to the other rates. The price per tonne CO2e in Sweden is $168. Like Norway, Sweden covers the majority of its carbon intensive industry under the tax with much of the remaining group under the European emissions trading scheme. Specific industries in Sweden pay a lower rate similar to how the other Scandinavian countries structured their carbon tax. The Swedish Ministry of the Environment claims that the carbon tax has significantly reduced CO2 emission in Sweden by 9% from 1991 to 2006. Lin et al, who studied the Scandinavian carbon tax structure, came to the conclusion that while a carbon tax would reduce energy use, improve energy efficiency, and simultaneously promote the development of renewable energy, it would also slow down economic growth, decrease

social welfare, and damage the competitiveness of related industries, and ultimately lead to carbon leakage. As our policy was only in place for two years, we cannot conclusively agree or disagree whether the claim made by Lin et al would pertain to Australia.

Since then more than 10 other countries have implemented carbon taxes most notably Japan, the United Kingdom and Australia. Japan has developed a carbon dioxide factor for each fossil fuel type and which allows for different rates for different amounts of output while maintaining an even tax burden of $2 per tonne CO2e. The United Kingdom's carbon tax policy covers all forms of fossil fuel used to generate electricity. The rate used in the United Kingdom is $15.75. It is clear that these policies are all reformulations of each other. All take into account the industries that need to bear the burden of the tax while other important industries pay lower rates or are completely excluded from the tax. There is no silver bullet carbon policy as all of these different formulations of a carbon tax have been effective in reducing emissions in these countries. Our overall analysis of carbon policy focuses on Australia. The specifics of the Australian carbon policy are given a means of comparison to these policies that were just discussed.

The EU Cap and Trade System

The EU ETS is comprised of 28 countries and affects more than 11,000 electricity generation stations across the European continent. While this cap and trade system does not cover all industries related to greenhouse gas production, it does cover approximately 45% of the total greenhouse gas emissions. As with many other carbon policies, the inclusion of other greenhouse gases becomes equally important. CO2 has become the default metric for measuring the global warming potential of all greenhouse

gas emissions. This metric is knows as a CO_2 equivalent which converts all other GHG covered under carbon policies into the amount of carbon dioxide that would result in the same global warming potential. The EU ETS has included both nitrous oxide (NO_2) as well as perfluorocarbons.

As mentioned before, the price of permits in the EU ETS has plummeted due to economic factors. The global recession has led to many industries decreasing their production. As companies reduce their carbon intensive production, they reduce their emissions. In this case, the emissions reduced so much that some companies only needed very few permits to maintain compliance and did not need to abate any emissions through innovative technologies or efficiency improvements. The European commission recognizes this problem as it is currently working on revisions to the amount of permits to be allocated. It is important to note that evolving policies such as the reworking of the timeline are often heavily opposed by industry. Please refer to Appendix 3 for a more detailed explanation of other carbon taxation policies.

Carbon Tax Impacts

Potential impacts from carbon taxes

The effect on the whole market can be different for every country or region that imposes the tax. There are a multitude of factors that need to take into account in order to determine the market effects of such a policy. To begin, one must understand what industries are affected by the policy. Is the tax only applied to electricity generation or does it include other industries as well? Are any of the affected industries producing goods that are priced on the international market? If goods are price on the international market, a carbon tax can raise the price of domestically produced goods and force an increase in cheaper imports and/or less exports. Another major factor is the energy portfolio of the region involved. As we examine the Australian carbon tax policy in this research, it follows that the energy portfolio of Australia be analyzed.

The Australian Carbon Tax

Australia's brief carbon tax policy had a rate around $23 per tonne[1] CO_2e from July 2012 to July 2013, and $24.50 until its removal in July 2014. (Australian Government Clean Energy Regulator, 2015) The policy was directly aimed to curb the emissions of the largest CO_2 producers. Any company that produced over 25000 tonnes of CO_2 was directly responsible to pay the carbon tax and report their emissions to the clean energy regulator. Industries and companies that did not meet that threshold were still affected by the carbon tax policy through fuel taxes and other similar policies. Of the estimated 75000 businesses affected by the carbon tax, only 370 were over the limit of 25000 tonnes. Another 1000 businesses paid for carbon equivalents through the

[1] All values in Australian dollars.

synthetic greenhouse gas levies leaving the remaining businesses to be pay through the fuel tax.

The equivalent carbon tax was aimed on reducing greenhouse gas emissions in aviation, shipping and railroads. These three sectors were only affected for domestic travel. It is quite clear that there is no international shipping happening in Australia via rail. Aside from rail, international shipping and aviation were excluded from the tax to maintain global competitiveness in those markets. (Australian Government Clean Energy Regulator, 2015)

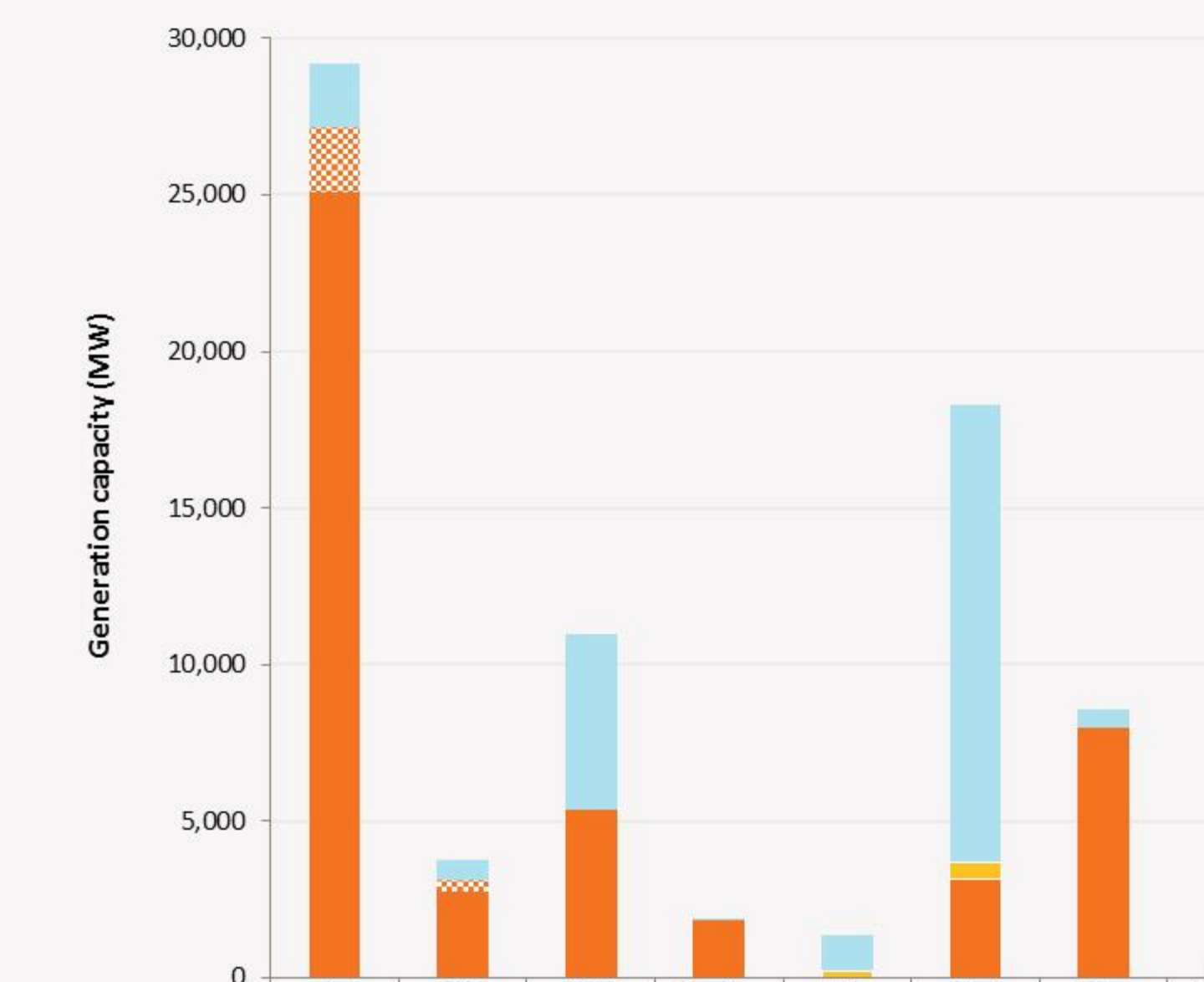
One of the many factors considered when implementing a federal policy is the affect it has on goods priced on the world market. Carbon taxation is especially influential in domestic prices of carbon intensive production. The increase in prices causes certain goods to become less competitive on a global scale. When formulating their policy, Australia planned to counter this externality by allowing certain industries that have goods traded on the global market to receive "free credits". These credits were implemented to cushion the effect carbon tax would have on price.

According to the Australian government, the carbon tax plan was estimated to generate approximately 15.4 billion dollars in revenue (Australian Government Clean Energy Regulator, 2015). Some of this revenue was to be used as a subsidy for low-income households. This part of the policy was titled the Clean Energy Advance. The Clean Energy Advance was the type of policy tool that helped make the policy more equitable to customers. As we have noted following our data collection and analysis, the price of electricity more than doubled during the first month of carbon tax implementation in Australia. Households that spend a small percentage of their monthly income on electricity would not be terribly affected by

this price jump. However, lower income households that spend a larger share of their income on electricity would be greatly affected by this price jump without some sort of assistance.

The Australian Energy Landscape

Australia's energy needs are met by a mixture of coal, natural gas and renewables. Coal is the main component of their energy sector, as coal deposits are prevalent in many regions of the country. This is commonplace for any country with large coal deposits. Coal is often the cheapest and most abundant resource available for electricity generation. Unfortunately, it is also the most carbon intensive out of the major fuel choices. Coal is useful for serving base load power needs. Base load is the amount of electricity that is needed constantly throughout a daily period. The other two parts of the load curve are intermediate and peak. As the day progresses and people wake up, use electricity for basic functions and industries begin to work, electricity demand goes up. Even when the majority of people are asleep, there is still a base load need for energy. Coal power plants are able to provide this base load source as the resource is abundant and the facilities have longer windows of time for shutting down and starting up.



	Coal	CCGT	OCGT	Gas other	Solar	Wind	Water
Proposed	2,000	650	5,635	15	1,152	14,589	599
Committed	-	-	-	-	219	539	1
Existing (Withdrawn)	2,113	385	-	-	-	-	-
Existing	25,062	2,731	5,351	1,851	2	3,143	7,986

Figure 1: Shows the August 2014 capacities of electricity generating technologies in Australia. (Australian Energy Market Operator, 2014)

Figure 1 displays the current energy portfolio for Australia. As previously noted, the use of coal far exceeds any other source of energy. Because coal dominates the

electricity sector, price increases will be severe when implementing a carbon tax. Although the Australian carbon tax we already removed by this time, there was a large amount of proposed wind power. This large scale investment in renewable technologies could have been a side effect of the carbon tax policy causing wind to become more price competitive with coal and natural gas.

Analysis of the Australian carbon taxes impacts on Unemployment

Regression was chosen as the analytical tool for this question because it would allow us to understand the impact of the carbon tax policy on a number of variables. This may also give us a vague predictive model for how other national economies may react to a similar carbon taxation policy. We were interested in the taxes impact on average electricity prices, emissions, and a number of economic metrics.

Our methodology was based on the work by Lin et al. They investigated impacts that carbon taxes had on the Scandinavian countries that implemented them. (Lin & Li, 2011) To do this, they utilized a linearized differences in differences model. Ideally, we would have used a similar model if we were comparing the Australian economy to another economy undertaking a comparatively substantial policy approach (cap and trade, tax, et cetera). For control variables they used GDP per capita, industry structure, urbanization level, technological factor, and energy price.

Model

As with any analysis, looking at economies as a whole, there are a multitude of factors that can influence economic health. Aside from developing a massive simultaneous equation model, or obtaining access to a general equilibrium model, it would be difficult to eliminate specification error or bias from our model. The goal of this model is more to analyze relationships between econometrics and the carbon policy more so than developing a predictive model.

Data

The variables of interest were electricity demand, the population, the gross domestic product per capita, electricity prices, captured emissions, internet access, capital/labor ratio, and the average unemployment. We created a dummy variable to signify when the policy was active. GDP, capital/labor ratio, and unemployment are all indicators of the health of an economy. Internet access provides a means to determine substitution of capital for labor. We did not use either urbanization level or industry structure as these provide better information for comparisons across countries, than within a single country. As the policy only last two years, it would not be expected to have an impact on either industry structure or urbanization. As the unit of analysis is the entire country itself, and not each state, we do not have a point of comparison.

GDP, internet access, capital/labor ratio, and unemployment were provided by the Australian bureau of statistics in a quarterly format. Electricity prices and demand were

provided in half hour increments, and provided by the Australian Energy Market Operator. All datasets were adjusted to represent monthly data. We developed a total of three models. One focusing on price, one on unemployment and another analyzing the relationship between GDP per capita and Unemployment.

Price model results

Model 1 focusing on the impacts on average electricity prices produced interesting results. With the three main independent variables of interest, only our dummy variable representing carbon tax had a significant impact on prices. This is particularly interesting given that the usual culprit of electricity price fluctuations is the demand. We decided that because our model was more focused on finding relationships rather than accurate prediction estimates, the insignificant variables in the model were equally as important as the significant variable(s).

With an F-statistic of 33.82 the model was significant and our adjusted r-squared of 0.6677 indicates that almost 67% of the variation in price was due to our independent variables. Luckily our Durbin-Watson test revealed no autocorrelation. Our variance inflation factors and collinearity diagnostics revealed no cause for concern with near multicollinearity. The residual vs predicted plot indicated homoscedasticity. The one parameter estimate of interest came from our dummy variable, which was 30.503. This estimates that the average price after a carbon tax was $30 (Australian) higher than before the carbon tax. Upon closer inspection of the data this parameter estimate was somewhat correct, although we noticed the prices declining and stabilizing over the two year period. The initial month of the carbon tax implementation had more than a 100% increase in price, but as time went on the market shock dissipated.

Unemployment model results

Model 2 focused on the carbon tax impact on average unemployment. As expected, GDP per capita was highly correlated with unemployment. However the relationship was inverse to what we expected. This model indicates that as GDP per capita increased, so did average unemployment. Another regression was ran that focused solely on average unemployment as a linear function of GDP per capita which is examined below. Another important finding was that the implementation of a carbon tax did not have a significant effect on unemployment. This contradicts many of the claims brought upon by Australian politicians that fought for the repeal of this tax. This model as with the pricing model, was focused more on understanding the relationships between our variables of interest and not an accurate predictive model. Therefore we included independent variables in our final model to display the relationships.

Our initial OLS model was found to have autocorrelation. In order to adjust our model appropriately, we used the Yule-Walker estimates displayed in Model 2 as the better model. The total r-squared of 0.7477 indicates that almost 75% of the variation in average unemployment was due to our independent variables. Luckily our Durbin-Watson test in our new estimates revealed that autocorrelation had been removed. The OLS model had no apparent issues with multicollinearity and displayed homoscedasticity in the residual vs predicted plot (See Appendix). In order to develop a more accurate model both for relationships and accurate parameter estimates, more variables need to be added that describe the changes in average unemployment.

GDP per capita/Unemployment relationship

Our initial analysis of unemployment found that GDP per capita had a significant positive relationship with average unemployment. In order to further investigate this unpredicted relationship we ran a regression (Model 3) focusing on only those variables. While our R-squared suggests that only 50% of the variation in unemployment is due to GDP per capita, we found a highly significant relationship between the variables. The parameter estimates in our model suggest that for every Australian dollar in GDP per capita increase, the unemployment increases by 197 people.

Conclusion

The outcome of our work contradicts our initial hypothesis. We predicted that the presence of the carbon tax would lead to greater unemployment. Our modeling suggests that while yes, the policy did drive prices up, its presence did not significantly impact unemployment. If these results are accurate, the reason that Tony Abbott and the Australian Liberal party dismantled was not backed by empirical data. Our model does indicate that the presence of the policy lead to an increase in electricity prices.

These results should be taken with a grain of salt, as unemployment is a complex phenomenon with a multitude of factors influencing it. We believe that there are substantial areas of improvement for future research into this question. It is unlikely that the implementation of the tax policy would lead to immediate job losses outside of the energy sector. Due to the short amount of time the policy was in place, it would be difficult to capture lagged effects in unemployment.

The next step for this research would be the use of a general equilibrium model. General equilibrium models are systems of simultaneous equations meant to provide a

more accurate analysis of an economy. The US Environmental Protection Agency recommends their use when looking at the impacts of an environmental policy that will impact multiple sectors.

While it was only a byproduct, the model demonstrating growth in GDP per capita having a negative impacts on employment was interesting. This could indicate employment in the Australian economy was decoupling from economic growth. Such a phenomenon could be the result of capital substitution for labor, and a growing wealth gap. To further investigate this phenomenon, it would be important to look at GDP and unemployment data over a greater length of time.

Appendices

Appendix 1: Works Cited

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Appendix 2: Model Outputs

Model 1: The relationship between price and demand, GDP per capita, and the presence of the carbon policy

The REG Procedure
Model: MODEL1
Dependent Variable: price

Number of Observations Read	50
Number of Observations Used	50

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	8086.24247	2695.41416	33.82	<.0001
Error	46	3665.67297	79.68854		
Corrected Total	49	11752			

Root MSE	8.92684	R-Square	0.6881
Dependent Mean	43.16815	Adj R-Sq	0.6677
Coeff Var	20.67924		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate	Tolerance	Variance Inflation
Intercept	1	141.54237	169.35987	0.84	0.4076	0	.	0
demand	1	0.00000119	8.656374E-7	1.37	0.1776	0.13342	0.71422	1.40012
GDPpC	1	-0.00929	0.00979	-0.95	0.3475	-0.14386	0.29516	3.38797
dummy	1	30.50305	4.46015	6.84	<.0001	0.99482	0.32047	3.12042

Collinearity Diagnostics (intercept adjusted)

Number	Eigenvalue	Condition Index	Proportion of Variation		
			demand	GDPpC	dummy
1	2.23118	1.00000	0.07967	0.05089	0.05263
2	0.59587	1.93504	0.89209	0.04131	0.09269
3	0.17295	3.59179	0.02823	0.90780	0.85468

The SAS System

The REG Procedure
Model: MODEL1
Dependent Variable: price

Durbin-Watson D	1.433
Pr < DW	0.0083
Pr > DW	0.9917
Number of Observations	50
1st Order Autocorrelation	0.242

Model 2: Unemployment Model

This SAS printout displays the relationship between average unemployment with electricity demand, electricity prices, GDP per capita and the carbon tax. Both OLS estimates as well as Yule-Walker Estimates are included.

The SAS System

The AUTOREG Procedure

Ordinary Least Squares Estimates			
SSE	8.80322E10	DFE	45
MSE	1956271570	Root MSE	44230
SBC	1225.90125	AIC	1216.34114
MAE	31708.5591	AICC	1217.70478
MAPE	4.86900047	HQC	1219.98169
Durbin-Watson	0.7480	Regress R-Square	0.5756
		Total R-Square	0.5756

Parameter Estimates					
Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	-1497235	845473	-1.77	0.0834
demand	1	-0.006925	0.004375	-1.58	0.1205
price	1	969.3824	730.5294	1.33	0.1912
GDPpC	1	141.9699	48.9766	2.90	0.0058
dummy	1	-5355	31383	-0.17	0.8653

The AUTOREG Procedure

Yule-Walker Estimates			
SSE	5.23315E10	DFE	44
MSE	1189352034	Root MSE	34487
SBC	1204.35067	AIC	1192.87853
MAE	25609.931	AICC	1194.83202
MAPE	3.93618731	HQC	1197.24719
Durbin-Watson	1.5034	Regress R-Square	0.2602
		Total R-Square	0.7477

Parameter Estimates					
Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	-2030147	1199853	-1.69	0.0977
demand	1	-0.003462	0.003201	-1.08	0.2854
price	1	900.8769	553.0916	1.63	0.1105
GDPpC	1	168.2057	72.3267	2.33	0.0247
dummy	1	-17962	36276	-0.50	0.6230

We used the Yule-walker Autoreg procedure to correct the model for autocorrelation.

Model 3: GDP per capita regressed against average unemployment

The REG Procedure
Model: MODEL1
Dependent Variable: AverUnemp

Number of Observations Read	50
Number of Observations Used	50

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	1.096443E11	1.096443E11	53.82	<.0001
Error	48	97791332865	2037319435		
Corrected Total	49	2.074356E11			

Root MSE	45137	R-Square	0.5286
Dependent Mean	644207	Adj R-Sq	0.5187
Coeff Var	7.00655		

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|
Intercept	1	-2592093	441195	-5.88	<.0001
GDPpC	1	197.28124	26.89196	7.34	<.0001

Model 4: Original Unemployment model pre-Yule Walker estimates

The SAS System

The REG Procedure
Model: MODEL1
Dependent Variable: AverUnemp

Number of Observations Read	50
Number of Observations Used	50

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	1.194034E11	29850844931	15.26	<.0001
Error	45	88032220670	1956271570		
Corrected Total	49	2.074356E11			

Root MSE	44230	R-Square	0.5756
Dependent Mean	644207	Adj R-Sq	0.5379
Coeff Var	6.86577		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate	Tolerance	Variance Inflation
Intercept	1	-1497235	845473	-1.77	0.0834	0	.	0
demand	1	-0.00692	0.00438	-1.58	0.1205	-0.18552	0.68625	1.45719
price	1	969.38237	730.52942	1.33	0.1912	0.23073	0.31192	3.20594
GDPpC	1	141.96987	48.97661	2.90	0.0058	0.52319	0.28949	3.45432
dummy	1	-5354.94817	31383	-0.17	0.8653	-0.04157	0.15890	6.29322

Collinearity Diagnostics (intercept adjusted)

Number	Eigenvalue	Condition Index	Proportion of Variation			
			demand	price	GDPpC	dummy
1	2.79728	1.00000	0.03519	0.02710	0.03000	0.01839
2	0.78563	1.88695	0.61213	0.10296	0.00200	0.00698
3	0.31274	2.99071	0.33642	0.30932	0.49419	0.00136
4	0.10435	5.17743	0.01626	0.56063	0.47381	0.97328

Appendix 3: Carbon Tax Policies

Country/Jurisdiction		Type	Year Adopted	Overview/Coverage	Tax Rate
1	British Columbia	Sub-national	2008	The carbon tax applies to the purchase or use of fuels within the province. The carbon tax is revenue neutral; all funds generated by the tax are returned to citizens through reductions in other taxes.	CAD30 per tCO2e (2012)
2	Chile	National	2014	Chile's carbon tax is part of legislation enacted in 2014. The country is to start with measuring of carbon dioxide emissions from thermal power plants in 2017 and begin the tax on CO2 emissions from the power sector in 2018.	USD5 per tCO2e (2018)
3	Costa Rica	National	1997	In 1997, Costa Rica enacted a tax on carbon pollution, set at 3.5 percent of the market value of fossil fuels. The revenue generated by the tax goes toward the Payment for Environmental Services (PSA) program, which offers incentives to property owners to practice sustainable development and forest conservation.	3.5% tax on hydrocarbon fossil fuels
4	Denmark	National	1992	The Danish carbon tax covers all consumption of fossil fuels (natural gas, oil, and coal), with partial exemption and refund provisions for sectors covered by the EU ETS, energy-intensive processes, exported goods, fuels in refineries and many transport-related activities. Fuels used for electricity production are also not taxed by the carbon tax, but instead a tax on electricity production applies.	USD31 per tCO2e (2014)
5	Finland	National	1990	While originally based only on carbon content, Finland's carbon tax was subsequently changed to a combination carbon/energy tax. It initially covered only heat and electricity production but was later expanded to cover transportation and heating fuels.	EUR35 per tCO2e (2013)
6	France	National	2014	In December 2013 the French parliament approved a domestic consumption tax on energy products based on the content of CO_2 on fossil fuel consumption not covered by the EU ETS. A carbon tax was introduced from April 1, 2014 on the use of gas, heavy fuel oil, and coal, increasing to €14.5/tCO2 in 2015 and €22/tCO2 in 2016. From 2015 onwards the carbon tax will be extended to transport fuels and heating oil.	EUR7 per tCO2e (2014)
7	Iceland	National	2010	All importers and importers of liquid fossil fuels (gas and diesel oils, petrol, aircraft and jet fuels and fuel oils) are liable for the carbon tax regardless of whether it is for retail or personal use. A carbon tax for liquid fossil fuels is paid to the treasury, with (since 2011) the rates reflecting a carbon price equivalent to 75 percent of the current price in the EU ETS scheme.	USD10 per tCO2e (2014)
8	Ireland	National	2010	The carbon tax is limited to those sectors outside of the EU ETS, as well as excluding most emissions from farming. Instead, the tax applies to petrol, heavy oil, auto-diesel, kerosene, liquid petroleum gas (LPG), fuel oil, natural gas, coal and peat, as well as aviation gasoline.	EUR 20 per tCO2e (2013)
9	Japan	National	2012	Japan's Tax for Climate Change Mitigation covers the use of all fossil fuels such as oil, natural gas, and coal, depending on their CO_2 emissions. In	USD2 per tCO2e (2014)

				particular, by using a CO_2 emission factor for each sector, the tax rate per unit quantity is set so that each tax burden is equal to US$2/$tCO_2$ (as of April 2014).	
10	**Mexico**	National	2012	Mexico's carbon tax covers fossil fuel sales and imports by manufacturers, producers, and importers. It is not a tax on the full carbon content of fuels, but rather on the additional amount of emissions that would be generated if the fossil fuel were used instead of natural gas. Natural gas therefore is not subject to the carbon tax, though it could be in the future. The tax rate is capped at 3% of the sales price of the fuel. Companies liable to pay the tax may choose to pay the carbon tax with credits from CDM projects developed in Mexico, equivalent to the value of the credits at the time of paying the tax.	MexŚ 10 -50 per tCO2e (2014)* * Depending on fuel type
11	**Norway**	National	1991	About 55 percent of Norway's CO_2 emissions are effectively taxed. Emissions not covered by a carbon tax are included in the country's ETS, which was linked to the European ETS in 2008.	USD 4-69 per tCO2e (2014)* *Depending on fossil fuel type and usage
12	**South Africa**	National	2016	In May 2013 the South African government published a policy paper for public comment on introduction of a carbon tax. The paper proposes a fuel input tax based on the carbon content of the fuel. It was agreed that emissions factors and/or procedures are available to quantify CO2-eq emissions with a relatively high level of accuracy for different processes and sectors. The carbon tax will cover all direct GHG emissions from both fuel combustion as well as non-energy industrial process emissions and is expected to start in January 2016.	R120/tCO2 (Proposed tax rate for 2016)* *Tax is proposed to increase by 10% per year until end-2019
13	**Sweden**	National	1991	Sweden's carbon tax was predominantly introduced as part of energy sector reform, with the major taxed sectors including natural gas, gasoline, coal, light and heavy fuel oil, liquefied petroleum gas (LPG), and home heating oil. Over the years carbon tax exemptions have increased for installations under the EU ETS, with the most recent increase in exemption starting from 2014 for district heating plants participating in the EU ETS.	USD168 per tCO2e (2014)
14	**Switzerland**	National	2008	Switzerland's carbon tax covers all fossil fuels, unless they are used for energy. Swiss companies can be exempt from the tax if they participate in the country's ETS.	USD 68 per tCO2e (2014)
15	**United Kingdom**	National	2013	The U.K.'s carbon price floor (CPF) is a tax on fossil fuels used to generate electricity. It came into effect in April 2013 and changed the previously existing	USD15.75 per tCO2e (2014)
				Climate Change Levy (CCL) regime, by applying carbon price support (CPS) rates of CCL to gas, solid fuels, and liquefied petroleum gas (LPG) used in electricity generation.	

Table from: (World Bank Climate Change Group, 2014)

Appendix 4: Project SAS Code

```
data Australia;
input demand price Pop GDPpC AverUnemp ER TotEmiss CLratio Internet dummy;
datalines;
35367932.39 30.70813472 21964097 16002 580301.9 0 137500000 0.000749564 8950 0
36959116.83 26.8894328 22031750 16002 572037.1 0 136700000 0.000746971 9502 0
35987094.25 34.80334543 22031750 16002 559282.2 0 136700000 0.000746971 9502 0
33081920.87 22.6653125 22031750 16041 592066.0 0 136700000 0.000746971 9502 0
32744773.86 20.76513441 22104402 16041 589809.4 0 136500000 0.000745055 9502 0
32269481.88 21.76356667 22104402 16041 558233.4 0 136500000 0.000745055 9502 0
32759699.34 19.07093145 22104402 16069 561536.7 0 136500000 0.000745055 9502 0
34535746.89 52.43750134 22172469 16069 631061.8 0 136400000 0.000743845 10446 0
32496040.76 68.31818899 22172469 16069 662687.8 0 136400000 0.000743845 10446 0
34005428.97 25.38574597 22172469 16105 619232.4 0 136400000 0.000743845 10446 0
31321092.4126.22464444 22268758 16105 588206.2 0 136200000 0.000744531 0446 0
34797084.79 32.64177688 22268758 16105 589836.2 0 136200000 0.000744531 0446 0
34871550.9 28.12655139 22268758 16175 564216.1 0 136200000 0.000744531 0446 0
36140369.52 30.45566129 22340024 16175 562613.8 0 137600000 0.000743361 10906 0
34582612.59 30.1216129 22340024 16175 596992.9 0 137600000 0.000743361 10906 0
31899986.61 29.75260972 22340024 16288 620460.9 0 137600000 0.000743361 10906 0
32426523.64 30.45976747 22432039 16288 588677.1 0 138500000 0.000745833 10906 0
32489072.36 31.737175 22432039 16288 578080.6 0 138500000 0.000745833 10906 0
32074702.45 24.63053091 22432039 16407 601741.6 0 138500000 0.000745833 10906 0
33963245.61 29.25188306 22520298 16407 641963.8 0 137700000 0.000748126 11596 0
32375104.1729.46114511 22520298 16407 699106.2 0 137700000 0.000748126 11596 0
32639851.64 27.60324731 22520298 16480 659396.4 0 137700000 0.000748126 11596 0
30878570.35 31.95907639 22637127 16480 598958.2 0 137400000 0.000750103 11596 0
33908089.27 28.58742608 22637127 16480 620373.9 0 137400000 0.000750103 11596 0
34057258.38 33.53721667 22637127 16525 598760.3 0 137400000 0.000750103 11596 0
35049253.07 68.44282258 22728254 16525 582776.3 0 136500000 0.000746986 12036 1
34097920.26 55.48535484 22728254 16525 590087.4 0 136500000 0.000746986 12036 1
30571942.1 50.42737083 22728254 16540 660541.0 0 136500000 0.000746986 12036 1
31337676.26 51.08484946 22827799 16540 623082.9 1033721959 135400000 0.000744486 12036 1
31122872.3560.81600694 22827799 16540 588684.8 1033721959 135400000 0.000744486 12036 1
32002912.66 52.25081855 22827799 16544 637109.4 1033721959 135400000 0.000744486 12036 1
33901238.51 75.36250941 22920798 16544 695699.3 1033721959 136300000 0.000741734 12161 1
30479602.37 53.77685714 22920798 16544 740046.4 1033721959 136300000 0.000741734 12161 1
32701635.84 57.2167755422920798 16549 725020.8 1033721959 136300000 0.000741734 12161 1
30210284.48 56.29154028 23033925 16549 682030.3 1033721959 134600000 0.000741653 12161 1
32700354.5 64.24489247 23033925 16549 676098.0 1033721959 134600000 0.000741653 12161 1
32917888.04 68.20762917 23033925 16557 672647.3 1033721959 134600000 0.000741653 12161 1
```

33782695.79 59.65085887 23125868 16557 646402.6 1033721959 136200000 0.00073754 12358 1

32483927.59 57.36387366 23125868 16557 679903.1 1033721959 136200000 0.00073754 12358 1

29627074.51 52.35443889 23226424 16590 692786.3 1130475054 134000000 0.000735588 12358 1

30846955.73 51.67662769 23226424 16590 679794.9 1130475054 134000000 0.000735588 12358 1

30146629.49 49.7164166723226424 16590 657202.3 1130475054 134000000 0.000735588 12358 1

31311326.75 56.95543145 23310746 16649 694596.6 1130475054 133400000 0.000735589 12397 1

33349962.07 63.87805511 23310746 16649 772209.0 1130475054 133400000 0.000735589 12397 1

30138456.16 55.75411756 23310746 16649 837769.8 1130475054 133400000 0.000735589 12397 1

31818543.04 47.65537634 23422310 16714 767514.9 1130475054 134500000 0.000738583 12397 1

29767866.61 45.49494306 23422310 16714 714356.7 1130475054 134500000 0.000738583 12397 1

31863832.59 47.82097715 23422310 16714 718004.0 1130475054 134500000 0.000738583 12397 1

31818958.61 49.48053611 23490736 16760 722165.0 1130475054 134500000 0.000735973 12483 1

34020491.12 39.64067204 23490736 16760 718175.2503 1130475054 134500000 0.000735973 12483 1

;

```
run;
proc reg data = Australia;
model price = demand GDPpC dummy/ stb vif collinoint tol dwprob;
output r=resid p=pred;
run;
proc reg data = Australia;
model averunemp = demand price GDPpC dummy/ stb vif collinoint tol dwprob;
output r=resid p=pred;
run;
PROC AUTOREG DATA=Australia;
MODEL averunemp = demand price GDPPC dummy/METHOD=YW NLAG=1 ITER;
RUN;
proc reg data = australia;
model averunemp = GDPPC;
run;
```