Rethinking Trade Exposure: The Incidence of Environmental Charges in the Nitrogenous Fertilizer Industry

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September 2015

Abstract

The imposition of environmental regulations, such as greenhouse gas charges, to domestic manufacturing traditionally creates concerns over the impacts of those regulations on international competition and downstream product prices. The US Nitrogen fertilizer industry, an energy-intensive trade-exposed industry, has been considered by conventional metrics to be one of the most vulnerable to such effects. Since 2010 the industry has undergone increased concentration of producers and a dramatic reduction in US natural gas prices. While the decline in domestic gas prices has reduced production costs, it has not produced a corresponding decrease in fertilizer prices. Our research establishes that the pass-through of changes in natural gas prices, a key input to nitrogenous fertilizer, declined from roughly 80% prior to 2010 to effectively zero through 2014. One implication of this change in pricing dynamics is that the imposition of greenhouse gas (GHG) regulations on producers of nitrogen fertilizers would have almost no impact on fertilizer prices. Within the context of a GHG cap-and-trade program, the allocation of emissions allowances as considered under proposed Federal legislation, and as practiced in California today, would likely result in a transfer to fertilizer producers on the order of hundreds of millions of dollars with no impact on fertilizer prices or emissions.

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1 Introduction

Market-based environmental regulatory instruments, such as emissions taxes or emissions trading, have long been championed by economists as a means to efficiently mitigate the emissions of pollutants. In practice, however, real world conditions and institutional constraints have caused the implementation of such regulations to fall short of their theoretical ideal. Previous research has demonstrated the distortion to environmental regulations that can arise from market power (Fischer (2011), Kolstad and Wolak (2003)), economic regulation Fowlie (2010), and allocation policies (Fowlie and Perloff (2013), Bernard, Fischer and Fox (2007)). One concern that has been at the forefront of policy discussions is the issue of competitiveness impacts of environmental regulations. When an environmental charge, such as an emissions cap, is applied only locally, policy-makers often worry about the implications for balance of trade. Industries that face substantial international competition could see their market shares erode as the result of a local cost increase that is not borne by outside competitors. [1] These concerns are closely related to those of jurisdictional limits.[2] When emissions charges do not "reach" all relevant sources, as with charges related to greenhouse gasses, then the leakage of emissions to unregulated jurisdictions not only causes economic harm but also dilutes, perhaps substantially, the benefits of the regulation.

An additional important consideration when evaluating the impacts of market-based environmental regulations is the incidence (or pass through) of environmental costs to end-use consumers. This aspect of market outcomes is closely related to the competitiveness of the regulated industry, as well as the relative elasticities and curvatures of supply and demand. Depending upon market structure and conditions, the pass through of environmental fees may be heavily diluted, or could even exceed 100%. As noted by Seade (1985), in oligopoly environments taxes on outputs (or inputs) can increase margins and under some conditions lead to more than 100% pass-through of the tax. The interactions of cost shocks and product prices can be quite complex and are largely dependent upon characteristics of the demand function.[3]

In the environmental context, the question of incidence is particularly important when the pollutant is regulated upstream from the source of emissions (Mansur (2012)) or when the emissions price is derived endogenously across multiple industries, as under a cap-and-trade system. In either case, the optimal pigouvian tax under perfect competition could be heavily distorted by the time it is faced by end-users, depending upon the incidence.

In this paper we study the question of pass-through and environmental charges in the

[1] Fowlie (2012).

[2] Bushnell, Peterman and Wolfram (2008), Fowlie (2009), Fischer and Fox (2009).

[3] Weyl and Fabinger (2013) derive a general framework for modeling the incidence of taxes under imperfect competition.

context of the nitrogenous fertilizer industry. This industry is one of the most carbon intensive sectors to be covered under carbon trading regimes in Europe and California, as well as the US national carbon trading system proposed under the American Clean Energy and Security Act (HR 2454, also known as Waxman-Markey) legislation of 2009. Nitrogen-based fertilizers are a significant contributor to greenhouse gasses both upstream in its production and downstream in its application through the emissions of nitrous oxide (N_2O).

During the same time period, the industry began to undergo a substantial transformation. Domestic production of nitrogenous fertilizer had declined steadily through the early 2000's due largely to higher local costs of the key input, natural gas. With the onset of the fracking boom in natural gas during the late 2000's this situation stabilized and US producers found themselves instead with a growing production cost advantage relative to offshore sources. Within the United States, the industry also underwent a period of consolidation in the late 2000's, culminating in a significant merger of two leading producers in 2010. As a result of the combination of cost advantages and a consolidation of the market structure, the industry has enjoyed particularly large margins since 2010. Despite the much-noted decline in the prices of domestic natural gas, fertilizer prices have remained high and more closely respond to demand-related drivers such as corn prices, than to local cost drivers since 2010.

One implication of these changes to the industry is that the incidence of any greenhouse gas regulation would be extremely muted. This in turn implies that any abatement from reductions in the volume of fertilizers that would induced by an emissions trading scheme would be minimal, particularly relative to what was assumed by policy analysis at the time HR 2454 was under consideration. Abatement resulting from emissions trading would thus be pushed into other sectors covered under the same cap-and-trade scheme. At the same time, key elements of HR 2454 provided additional protections to industries such as the nitrogenous fertilizer industry, which were judged to be "energy intensive and trade exposed" (EITE). Our results imply that these incentives that would have been provided under EITE would have been nearly completely unnecessary in terms of its stated goal of protecting local producers, while at the same time constituting a substantial windfall to those same producers.

2 Environmental Regulation and Trade Exposure

The trade impacts of local environmental regulations has long been of concern and interest. From an environmental perspective, the concern stems from the prospect of emissions leakage, where emissions intensive industries relocate to unregulated areas but maintain their output levels and emissions. The form of the regulation can play an important role in the strength of this effect (Bushnell, Wolfram and Peterman, 2008). From an economic perspective, the concern is that leakage can lead to a loss in economic activity and employment, as well as limit the environmental gains of a regulation.

There are several tools that have been proposed and implemented to attempt to address these concerns (Frankel and Aldy, 2008). One is the implementation of border tax adjustments (BTAs) that would place an environmental charge on goods as they enter the country that could in theory be symmetric with the charge faced by local producers. The border tax would level the playing field with importers and eliminate the incentive for local producers to relocate in order to avoid paying the fee. However, the most commonly invoked mechanism to address trade exposure has been the use of allowance allocation as an implicit subsidy for domestic production. Under output-based updating each firm receives an allocation of emissions permits that is proportional to its total product production. In the fertilizer context, for example, this means each firm receives an allocation that is proportional to the tons of product produced domestically within the regulatory jurisdiction. The effects of output-based updating have been a subject of much research.[4] In general, it is believed that output-based updating is effective in mitigating leakage, as firms are rewarded (in the form of permits) for domestic production.

Output-based updating is also widely believed to result in lower product prices than alternative forms of allocation. While one strain of the academic literature has focused on the detrimental efficiency effects of such a price impact, it has an appeal to policymakers. Despite the political appeal of this product price effect, these "lower" prices can lead to inefficient over-consumption as the externality cost of the pollution is not adequately reflected in product prices.[5] Output-based allocation comes at considerable opportunity cost to public expenses, as allowance revenue that could otherwise be used as public funds is given freely to targeted industries. There has been considerable focus on the general equilibrium benefits from using the revenues from environmental regulations to offset existing tax distortions (see Goulder et al. (1999) and Fullerton and Metcalf (2001).), and it is important to recognize that any form of free allocation prevents the use of allowance revenues for more efficient purposes.

One paper that combines many of these considerations is Fowlie, Reguant and Ryan (2015) (FRR), which examines the prospective impacts of environmental charges on the cement industry. That industry is carbon intensive, subject to both local market power and in some places competition from overseas imports. Fowlie et. al demonstrate that for this industry, an output based updating mechanism dominates a border tax, because the pro-competitive impacts of a border tax outweigh any concerns over suppression of the external costs in retail prices.

[4]see Jensen and Rasmussen (2000), Fischer (2003), and Fischer (2011).

[5]See Palmer, Burtraw and Kahn (2006) for a discussion of the various impacts of updating.

While we address a similar question to FRR, we take a different methodological approach. Unlike cement or many other manufacturing industries, marginal cost in the nitrogen industry is dominated by a single input, natural gas. Where FRR apply structurally estimated cost and market parameters to simulations of hypothetical emissions charges, we utilize the observed variation of a key input factor, natural gas, on fertilizer prices. While the more detailed picture of production costs allow FRR to simulate the dynamic responses to regulations, we are less reliant upon functional form assumptions that can dictate the curvature of residual demand and play an important role in predicting the incidence of a hypothetical emissions charge. By using natural gas costs as a proxy for that environmental charge, we can directly estimate the impact of change in input costs from an environmental charge.[6]

2.1 Trade Exposure and the Nitrogen Industry

In this paper we focus on the greenhouse gas implications of nitrogen production and utilization. Significant greenhouse gasses are emitted in the production of ammonia and other nitrogenous fertilizers, but even larger amounts are attributed to the conversion of N fertilizer to Nitrous Oxide (N_2O), a potent greenhouse gas with a global warming potential of nearly 300 times that of carbon dioxide. Globally, the production and application of fertilizers are estimated to constitute 2.5% of annual Greenhouse Gas emissions.[7] The US EPA estimates that fertilizer contributes about 1.5% of US annual GHG emissions, with about 10 mmTon CO2e coming from ammonia production, another 15 mmTon coming from other nitrogen-based industrial processes, and about 60 mmTon CO2e from N_2O emissions attributed to the application of synthetic fertilizer.[8] This is coming from an overall agricultural N consumption of just under 13 million nutrient-tons.

While fertilizer may not be the largest source of GHG emissions, it is one of the most carbon intensive industries. The 2009 American Clean Energy and Security Act, (HR 2454), would have established a GHG cap over broad set of greenhouse gas sources, including the production of nitrogenous fertilizers. One of many controversial aspects of HR 2454 was its potential impact on the costs and competitiveness of GHG-intensive U.S. industries. According to an interagency study which included the US EPA and Department of Energy, nitrogenous fertilizer manufacturing would have been the 2nd most GHG intensive industry covered under the law, with both direct and indirect GHG costs amounting to 18.5% of 2007

[6]One shortcoming of our approach relative to FRR is that the impact of any dynamic responses we can measure is limited to our sample, which lasts about 5 years after the decline of US natural gas prices.

[7]International Fertilizer Association, 2009

[8]"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 to 2013." United States Environmental Protection Agency. April, 2015. These figures include the N_2O emissions only attributed to synthetic fertilizers.

revenues.[9] In other words, this analysis implies that absent other provisions, and under full pass through, a \$20/ton CO2 price would have raised N fertilizer prices by nearly 20%.

Both competitiveness concerns, and likely concerns about alienating agricultural constituencies, motivated additional measures in HR 2454 to mitigate such impacts. In the highly sensitive environment in which HR 2454 was developed, the prospect of mitigating price impacts to key constituencies, such as the agricultural sector, was an important negotiating tool. Fowlie (2009) describes both the policy process and welfare implications of the approach that was adopted. The main provision included awarding emissions allowances to domestic producers under a process known as output-based allocation. Under output-based allocation, fertilizer producers would have received an implicit subsidy on their production in the form of emissions allowances that are award per unit of output. In this way output-based allocation differs critically from allocations based upon exogenous factors such as historic emissions. One implication of the allocation approach to mitigating leakage is that product prices will not rise with the costs of the GHG regulation.

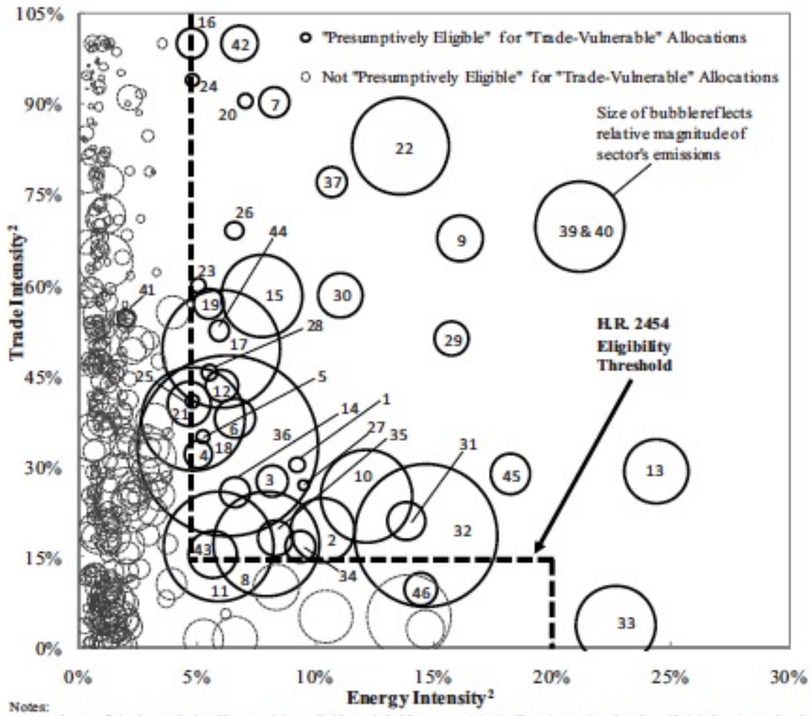
Indeed, a USDA analysis of HR 2454 (USDA, 2009) emphasized the fact that output-based allocation greatly mitigated any potential price increases of fertilizer. While the study estimated that "in the absence of EITE provisions, higher fertilizer costs could lead to an average annual increase in crop production expenses of \$1.4 Billion," its primary estimate which incorporates the EITE provisions estimated an annual increase of less than \$100 Million.[10] Importantly, all these analyses implicitly assumed 100 % pass-through of upstream GHG charges *in the absence of output based updating*, an assumption that was perhaps defensible prior to 2010 but increasingly tenuous afterward. Despite passing the House in 2009, HR 2454 and its variants never passed the US Senate, leaving California as the only state to apply greenhouse gas charges to nitrogenous fertilizer production. In the following section, we explore the hypothetical impacts of HR 2454 on fertilizer prices in the context of both pre and post 2010 market conditions.

3 The Nitrogenous Fertilizer Industry

Nitrogenous fertilizer utilize nitrogen, one of three primary nutrients essential for plant growth. The foundational product in the industry is anhydrous ammonia (AA), the largest volume chemical produced from hydrocarbon feedstocks and a key intermediate product in the production of fertilizers such as urea and ammonium nitrate. Ammonia is also used in several industrial applications, but about 90% of global 2010 consumption went to directly or

[9] US EPA, EIA and Treasury, 2009.

[10] USDA, page 7.



Notes:
1. Petroleum refining is not depicted because it is explicitly excluded from H.R. 2454's allocations to "trade-vulnerable" industries. Also, 91 other sectors, with 126 MMTCO$_2$e of emissions, are not depicted due to lack of trade intensity data. One of these, iron and steel pipe and tube manufacturing from purchased steel (331210; 2.5 MMTCO$_2$e) is expected to be eligible based on language in the bill. Four others meet the energy-intensity threshold, each with 2 to 3 MMTCO$_2$e of emissions: beet sugar manufacturing, broadwoven fabric finishing mills, steel foundries (except investment), and metal heat treating. Twelve sectors with a calculated trade intensity greater than 100% are depicted here with an intensity of 100% (the maximum possible intensity). The two copper sectors (212234 and 331411) do not meet the energy or trade intensity thresholds specified in H.R. 2454 but are expected to be eligible based on other language in the bill.
2. Energy intensity and trade intensity measures are as defined in H.R. 2454 and elsewhere in this report.
Source: EPA analysis.

Figure 1: Energy Intensive and Trade Exposed Industries: Nitrogenous Fertilizer is Industry 22.

indirectly to fertilizer applications.[11] In the United States, fertilizer manufacturing overall generates roughly $30 Billion in annual revenues and is closely linked to the agricultural sector. During the 2000's the industry's growth followed that of the corn industry, which was in turn strongly influenced by biofuel policy and demand.

Outside of China, the key input to ammonia production is natural gas. Natural gas costs comprise over 80% of production costs of AA.[12] As most other costs are fixed, one would expect marginal costs to be dominated by natural gas prices. While natural gas is a key driver for the ammonia industry, the reverse is not necessarily the case. Only about 1/3 of natural gas is consumed by the industrial sector - the largest share is dedicated to electricity generation - and ammonia production constitutes about 1/4 of industrial sector demand. Ammonia is a globally traded product, but the costs of transporting it are considerable relative to the value of the product. As a volatile liquid chemical with applications in the manufacture of explosives as well as agriculture, both technical transport costs and regulatory barriers are high. WenYuan (2009) estimates that overseas transport from the Middle East or Black Sea regions represents 50% of the cost of ammonia shipped to the US gulf coast. While nearly 40% of U.S. ammonia consumption is met through imports, the vast majority of these imports come from either Canada or Trinidad and Tobago. The bulk of the remaining, modest share is met through imports from the Middle East, Russia, and Ukraine. Urea, an increasingly popular nitrogen fertilizer product that is derived from ammonia, is a more stable easily transported solid, and is accordingly more widely traded on global markets.

Within North America there are substantial geographic price-spreads in Ammonia and Urea prices, but these differences are extremely stable and roughly mirror the cost of transportation from the producing regions of the US gulf coast. The periodic shocks and long-term trends that have impacted the natural gas industry have in turn stimulated adjustments in both short-term commodity flows and long-run investment in the fertilizer industry.

During the early 2000s the U.S. nitrogen industry suffered during periods of relatively high U.S. natural gas prices, which peaked in 2006. High demand from a strong agricultural sector kept U.S. producers marginally profitable but there was a large shift of production to Trinidad and Tobago during the early 2000s. Importantly much of this investment was by the same firms. The large players in the industry maintained their dominance, but in a fashion that shifted production offshore to the carribean. The industry also went through a period of consolidation culminating in the merger of CF Industries and Terra. These were the market conditions pertaining to the industry at the time the trade exposure metrics in HR 2454 and California were developed.

These conditions have reversed since the onset of the U.S. fracking boom in the natural gas industry. With U.S. natural gas consumers enjoying relatively low prices on a global

[11] "Ammonia and Urea Strategic Business Analysis Prospectus." 2013. *ChemSystems*.

[12] Kim et al. (2002).

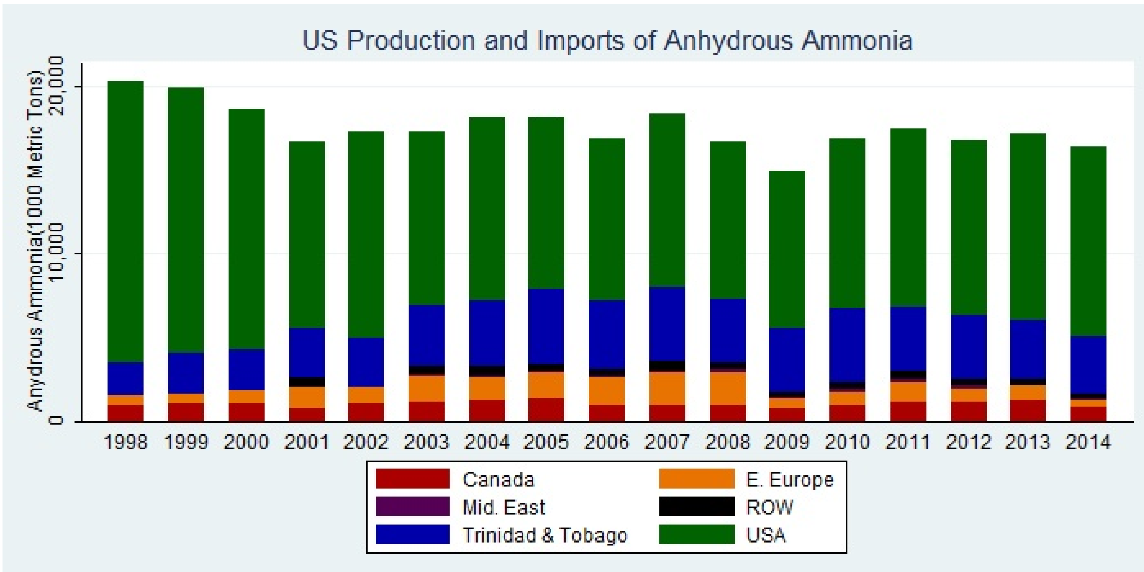


Figure 2: Sources of US Consumption of Ammonia.

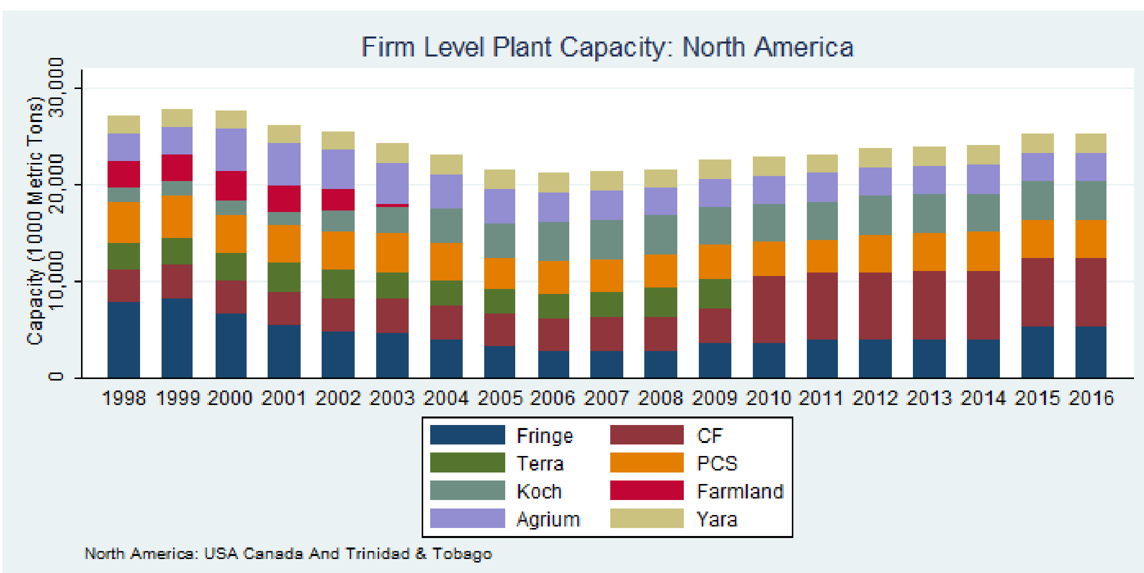


Figure 3: North American capacity of the top five producers of ammonia.

scale, industries reliant on natural gas have enjoyed a growing cost advantage in global markets.[13] Wholesale ammonia prices in North America did not decline nearly as dramatically as production costs. Figure 4 plots an approximate index of gas input costs against an index of the U.S. wholesale ammonia price.[14] Prior to 2010 the most notable activity in market prices surrounds the period of the commodity boom from roughly 2006-2008. While overall margins grew during this period, this partly reflects a tightening of ammonia production capacity in the US. After 2010, the separation between ammonia and natural gas prices becomes pronounced as the decline in gas prices is to a large extent not passed through to wholesale ammonia. Overall, it is clear that domestic margins have grown dramatically since 2009. One implication of this is that domestic prices have become increasingly decoupled from domestic production costs, as we document below.

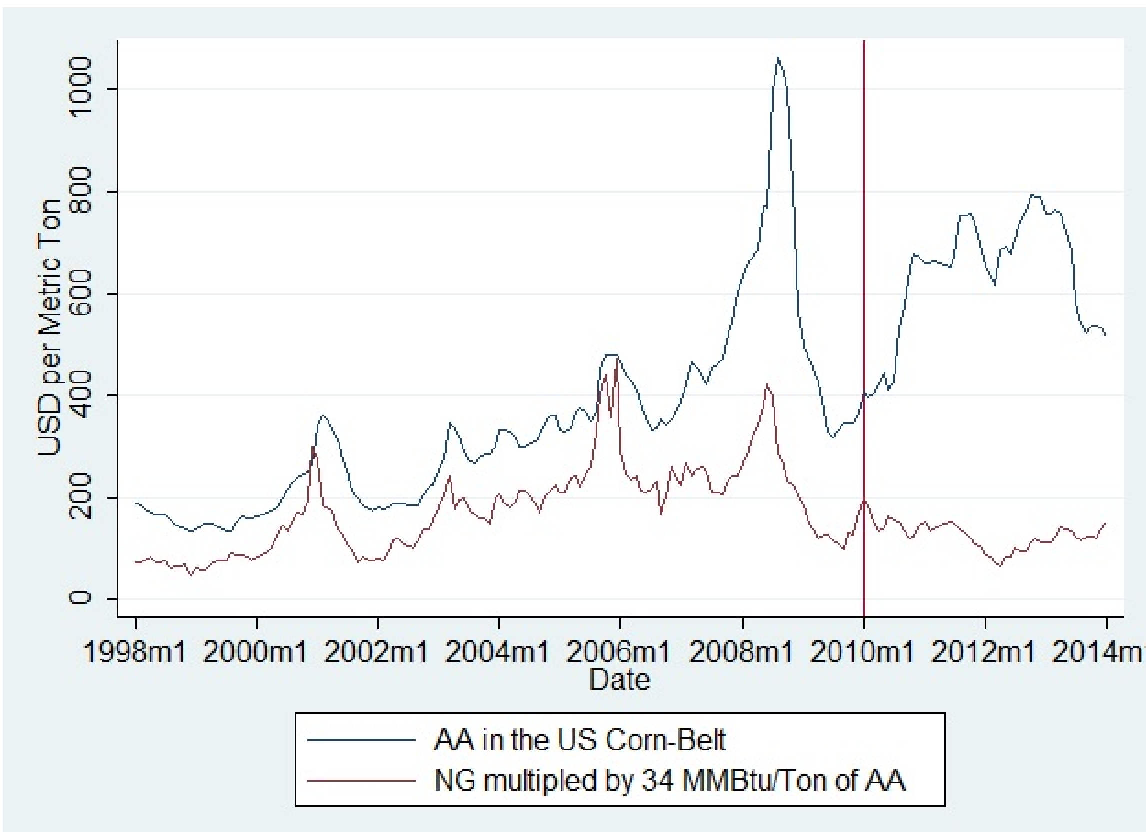


Figure 4: North American Wholesale Ammonia and Natural Gas Prices.

[13]Hausman and Kellogg (2015).

[14]For this calculation we utilize an industry standard conversion rate of 34 mcf of natural gas per 1 ton of ammonia. Actual conversion rates at individual facilities vary somewhat but according to a Canadian study fall within a range of 32-40 mcf/ton.

4 Data and Analysis

Our approach to examining the perspective impacts of upstream GHG-based charges on nitrogenous fertilizer production is to utilize variation in the key cost-driver to N-production, natural gas, as a proxy for the impact of an environmental charge. As noted above, natural gas can account for 80% of the marginal cost of production of ammonia depending upon the natural gas price. As such, in a perfectly competitive market one would expect to see long-run pass through rates in this range unless the industry were capacity constrained. Increases in horizontal concentration and therefore market power, which coincided somewhat with the fracking boom, can usually be expected to lower pass-through rates.

We explore the pass through of natural gas prices to nitrogenous fertilizer prices using several specifications. In doing so we rely primarily on two price series, wholesale anhydrous ammonia prices and natural gas prices. Wholesale prices of anhydrous ammonia prices are obtained from Green Markets, a third party data provider of nitrogenous, potassium and phosphorus fertilizer prices. Green Markets obtains all price data by surveying numerous buyers (retailers) and sellers (wholesalers) of various fertilizers. Price are collected on a weekly basis and originate from within the United States as well as internationally. All prices within this analysis are aggregated to a monthly frequency by taking an unweighted average of weekly prices within a given month. A monthly periodicity of price data is chosen because it is the most amicable for examining the long-run pass-through relationship between natural gas and anhydrous ammonia prices.

Generally speaking, picking an origin of the anhydrous ammonia (AA) price quotes is somewhat arbitrary for our analysis. This is because anhydrous ammonia prices series across the United States and the world in general are highly correlated as well as co-integrated with one another. Price spreads across these regions, therefore, are generally fixed at the cost of transportation between regions. We take this as evidence that anhydrous ammonia is traded on one global market rather the several regional markets. Figure 5 below depicts three anhydrous ammonia price series at major points within the international supply chain of anhydrous ammonia: the Black Sea port, the United States Tampa port and the United States Corn-belt.[15] Prices of the anhydrous ammonia at the port in the Black Sea reflect the price of fertilizer sold by Eastern European countries. Countries like Russia and the Ukraine, as mentioned above, are large producers of anhydrous ammonia and provide anhydrous ammonia and other nitrogenous fertilizers to Western Europe, China, India and to a lesser extent the United States. The Tampa port within the United States, in contrast, represents the main point of entry of nitrogen fertilizer originating from outside of Canada. One reason for the importance of the Tampa port is that Floridian phosphorus fertilizer producers use anhydrous ammonia as an input in the production of phosphorous fertilizer like Diammonium

[15] The Corn-belt is comprised of Ohio, Indiana, Illinois, Iowa, Missouri and Nebraska.

phosphate (DAP) and Monoammonium Phosphate(MAP). Finally, the United States Corn-belt consumes vast amounts of anhydrous ammonia for agricultural purposes and therefore represents a major end-point user within the fertilizer supply chain.

Table 1 depicts the results of an augmented dickey fuller test, Dickey and Fuller (1979). In each case the null hypothesis of a stationary process can not be rejected in logs. The null hypothesis, however, can be rejected in first differences implying that the data follows a I(1) process. Table 2 suggests that each pairwise combination of the above mentioned set of anhydrous ammonia prices are co-integrated, Johansen (1991). This all withstanding, for the below analysis price quotes of anhydrous ammonia from the United States Corn-belt are used. Our result, not surprisingly, are robust to other fertilizer prices.

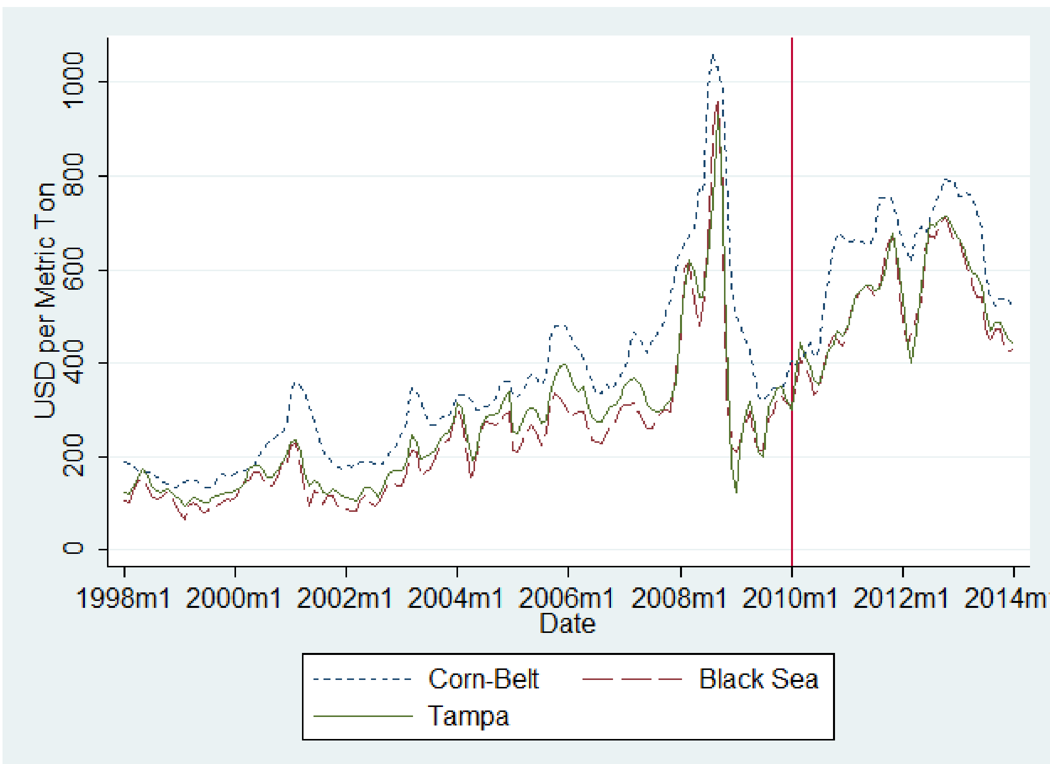


Figure 5: Prices of Anhydrous Ammonia.

Monthly natural gas prices are obtained from the Energy Information Administration and reflect the spot prices of natural gas (NG) at the Henry Hub. Again, in table 1 NG prices are shown to follow an I(1) process. Interestingly, as seen below in table 3, the price of natural gas and anhydrous ammonia are only co-integrated during the period of 1998 and 2010.

Table 1: Augmented Dickey Fuller Test Statistics[a,b]

	Logs	**Logs Differences**
	ADF Stat.	ADF Stat.
Corn-Belt	-2.96	-6.95***
Black Sea	-3.00	-9.89***
Tampa	-2.90	-10.14***
Natural Gas	-2.280	-9.21***

[a] Significance levels: *** p ≤ .01, ** p ≤ .05 and * p ≤ .1
[b] Lag length selection is accomplished with the Akaike information criterion

Table 2: Johansen Test Statistics: Fertilizer Prices[a,b]

	Corn-Belt and Tampa	**Corn-Belt and Black Sea**	**Tampa and Black Sea**
r =0	29.04**	30.24**	34.48**
r ≤ 1	2.82	3.17	2.42

[a] Significance levels: *** p ≤ .01, ** p ≤ .05 and * p ≤ .1
[b] Lag length selection is accomplished with the Akaike information criterion

Table 3: Johansen Test Statistics: Corn-Belt and Natural Gas[a,b]

	Corn-Belt and Natural Gas Full Sample	**Corn-Belt and Natural Gas Pre 2010**
r =0	12.48	17.44**
r ≤ 1	1.91	3.63

[a] Significance levels: *** p ≤ .01, ** p ≤ .05 and * p ≤ .1
[b] Lag length selection is accomplished with the Akaike information criterion

Summary statistics for AA prices and NG prices are reported for the full sample as well as two time periods, before and after January 2010, in table 4. A clear trend is present within these tables as the means of all time series change markedly before and after 2010. Across this time period of Anhydrous Ammonia prices increases substantially. As a result of the fracking boom, the mean of natural gas prices, in contrast, show a clear decrease.

Table 4: Summary statistics of Prices

	Mean	**Std. Dev.**	**Min.**	**Max.**
	Full Sample			
Anhydrous Ammonia	411.827	213.652	135	1062.5
Natural Gas	4.848	2.352	1.47	13.92
	Pre 2010			
Anhydrous Ammonia	336.398	183.187	135	1062.5
Natural Gas	5.231	2.57	1.47	13.92
	Post 2010			
Anhydrous Ammonia	639.687	114.376	397.5	794
Natural Gas	3.691	0.735	2.004	5.475

4.1 Pass-Through Regressions

Before analyzing a potential change in the NG to AA pass-through rate as a result of the fracking boom, we first analyze pass-through rate for the entire sample, January 1998 until January 2014. The literature on pass-through utilize two different pass-through estimators. The distributed lag approach adopted within Nakamura and Zerom (2010), Gopinath and Itskhoki (2010), Goldberg and Campa (2010) and Knittel and Stock (2015) is specified below.

$$\Delta log P_t = \alpha + \sum_{l=1}^{L} \beta_l \Delta log C_{t-l+1} + \sum_{j=1}^{3} \rho_j S_j + \epsilon_t.$$

Above, P_t represents the nitrogen fertilizer prices. The cost measure, C_t, is represented by natural gas prices. Seasonal fixed effects, S_j are also included within the pass-through equation. The long run pass-through rate is therefore $\beta_{LR} = \sum_{l=1}^{L} \beta_l$. Utilizing monthly data, we estimate the long-run pass-through rate for $L = 3, 6, 12$, a 3, 6 and 12 month window, in table 5.

Alternatively Li and Hong (2013) adopt a K^{th} lagged difference approach. In contrast, estimates of pass-through are obtained as the change in price over a K horizon against a change in cost over the same K horizon.

$$\Delta^K logP_t = \alpha + \beta^K \Delta^K logC_t + \sum_{j=1}^{3} \rho_j S_j + \epsilon_t.$$

The Δ^K above is a time-difference operator defined as $\Delta^K logP_t = logP_t - logP_{t-K}$. For this specification the long run pass-through rate is simply β^K. Again utilizing monthly data, we estimate the long-run pass-through rate for K = 3, 6, 12 below in table 6.

In an effort to control for the presents of autocorrelation and heteroskedasticity within the data, standard errors in table 5 and 6 are obtained by utilizing a Newey West estimator, Newey and West (1987). The truncation parameter, as suggested in Stock and Watson (2011), is set to $.75T^{1/3}$ were T represents the the sample size.

Table 5: Long-Run Pass-Through of Distributed Lag: Nat. on Ammonia

	$L = 3$	$L = 6$	$L = 12$
Long-Run Pass-Through	.52**	.60**	.67**
	(.35, .68)	(.38, .82)	(.40, .95)
Season Fixed Effects	Yes	Yes	Yes
Newey West Errors[b]	Yes	Yes	Yes
R^2	.28	.31	.32
N	181	181	181

Significance levels: *** p ≤ .01, ** p ≤ .05 and * p ≤ .1

Table 6: Long-Run Pass-Through of K^{th} Lagged Difference: Nat. Gas on Ammonia

	$K = 3$	$K = 6$	$K = 12$
Long-Run Pass-Through	.29**	.48**	.53**
	(.14, .43)	(.34, .63)	(.39, .67)
Season Fixed Effects	Yes	Yes	Yes
Newey West Errors	Yes	Yes	Yes
R^2	.19	.42	.43
N	181	181	181

Significance levels: *** p ≤ .01, ** p ≤ .05 and * p ≤ .1

The results in table 5 and 6 are generated from a log-log specification and therefore can be directly interpreted as percentage changes. For example, in table 6 when $K = 12$ the coefficient estimate is .53 . This implies that a 1% change in natural gas prices elicits a .53% change in AA prices. The NG to AA pass-through rates are relatively high, however, as will be depicted below in section 4.3 pass-through rates change significantly around January

2010. The above pass-through rates are therefore essentially a data weight average of two very different NG to AA pass-through rates, i.e. pass-through rates before and after 2010. With this in mind, the implications of pass-through rates is reserved for section 4.3. It is encouraging, however, that both the long run distributed lag and the K^{th} lagged difference estimator yield similar pass-through results. As will become apparent, the advantage of the K^{th} lagged difference approach is that fewer parameters are estimated. Consequently, for small sample sizes, estimation of the K^{th} lagged difference possesses more degrees of freedom.

4.2 Structural Break

Our maintained hypothesis throughout this paper is that as US and World natural gas price decoupled and the US industry became more concentrated, US fertilizer prices became less responsive to natural gas prices. To test this hypothesis we test the pass-through regressions in section 4.1 for a structural break in the NG to AA pass-through relationship. In doing so, we treat the structural break as unknown and estimate the most likely break in the data spanning our sample, January 1998 until January 2014. This allows us to find the mostly likely date at which the NG to AA pass-through relationship broke. In section 4.3 below we utilize the findings from this test to choose the correct data to partition our pass-through regressions and analyze pass-through rates before and after the identified structural break. Additionally, treating the break as unknown allows use to test our maintained hypothesis that the fracking boom was the cause of this structural break in the NG to AA pass-through relationship.

The test for an unknown structural break is preformed by first specifying a Wald statistics[16] which tests whether the long run pass-through rate are statistically different before and after a time period t. After removing the first 15% and last 85% of data from testing,[17] t is rolled over the remaining sample and Wald statistics are calculated for each period of time. Figures 6 and 7 below depicts these Wald statistics for both the distributed lag and K^{th} lagged difference specification. Using the 5% critical values derived in Andrews (1993) we find evidence supporting our maintained hypothesis across both pass-through specifications. The maximum Wald statistic for both the distributed lag and K^{th} lagged correspond to March 2010 and October 2009 respectively and therefore represent the most likely period in time which the pass-through relationship between natural gas and anhydrous ammonia experiences a structural break.

[16]In an effort to control for both auto-correlation as well as heteroskedascity present in the data the Wald statistic is used in contrast to the usual F statistic. The Variance Covariance matrix is estimated using the a Newey West Estimator.

[17]In practice, removing first 15% and last 85% from testing is common. The remaining sample of data used to generate Wald statistics is April 2001 until Oct 2011. Our results are robust to different trimming of the data.

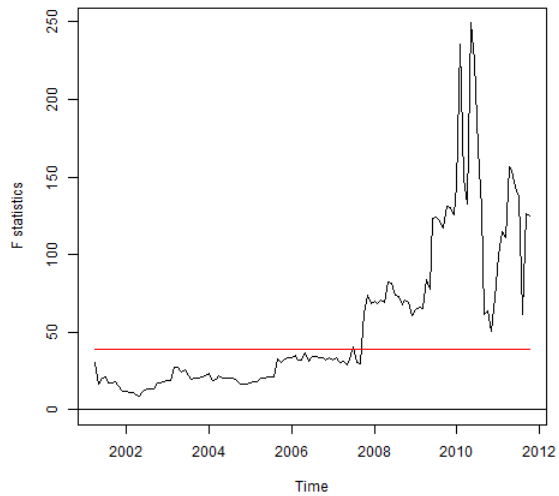


Figure 6: Wald Statistics Distributed Lag.

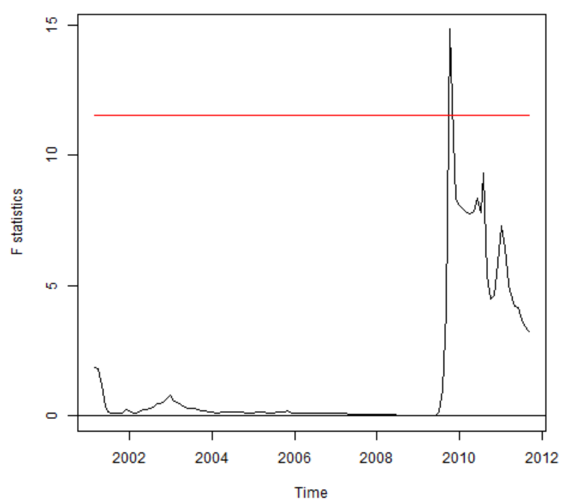


Figure 7: Wald Statistics K^{th} lagged difference.

4.3 Partitioning of Pass-Through Regressions

Given the evidence of a structural break within the NG to AA pass-through rates, we now estimate both pass-through specifications before and after January 2010. The data of January 2010 roughly represent a mid-point between our finding of breaks on March 2010 for the distributed lag specification and October 2009 for the K^{th} lagged difference specification. Consequently, we choose this date to ensure both pass-through specification are estimated on the same sample and therefore are directly comparable. The results for the distributed lag and the K^{th} lagged difference estimators are presented in tables 7 and 8 respectively. Both specification reveal that pass-through rates of natural gas to anhydrous ammonia before and after the fracking boom differ substantially. The pass-through results in tables 7 and 8 make it clear that after the fracking boom the pass-through rate of NG to AA is both smaller as well as statistically insignificant. Therefore, insofar as these pass-through rates represent a proxy of an environmental charge, it is clear that the efficacy of such a charge would be severely muted in this post 2010 time period.

Additionally, we note above that natural gas as an input in production represents about 80% of the marginal cost of producing anhydrous ammonia. Interestingly, when both specification are estimate with data predating the 2010 fracking boom, the distributed lag and K^{th} lagged difference specification respectively fall within and just outside of this range. This finding is suggestive of the fact that US producers of AA were both highly competitive and that potential AA capacity constraints were relatively slack during before the 2010 fracking boom.

A potential concern is that that number of observations from January 2010 onward is relatively small. In contrast to the K^{th} lagged difference specification, the distributed lag specification requires the estimation of L short-run pass-through parameters. This limits the degrees of freedom for estimation and may potentially raise concerns of its validity. For this reason the K^{th} lagged difference specification is our preferred pass-through estimator.

4.4 Robustness

In table 9 we check the robustness of our pass-through results to different specifications. We accomplish this by estimating the K^{th} lagged difference specification for the full sample were K=12. In addition to including the usual log-log specification we also include a pass-through specification in levels within table 9. To interpret the level specification, it is first essential to understand the units of measure for each time series. Natural gas prices are quoted in terms of USD per MMBtu. The Anhydrous Ammonia prices, in contrast, are reported in USD per Metric ton. The long term pass-through rate in levels can therefore be interpreted as the response of AA prices to a 1 dollar increase in natural gas prices over the course of a

Table 7: Long-Run Pass-Through of Distributed Lag: Nat. Gas on Ammonia

	$L = 3$		$L = 6$		$L = 12$	
	Pre 2010	Post 2010	Pre 2010	Post 2010	Pre 2010	Post 2010
Long-Run	.63***	.13	.76**	-.17	.81**	-.29
Pass-Through	(.45, .81)	(-.19, .44)	(.56, .96)	(-.58, .25)	(.56, 1.07)	(-1.16 .58)
Season F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Newey-West	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.41	.07	.46	.17	.48	.28
N	132	49	132	49	132	49

Significance levels: *** p $\leq$ .01, ** p $\leq$ .05 and * p $\leq$ .1

Table 8: Long-Run Pass-Through of K^{th} Lagged Difference: Nat. Gas on Ammonia

	$K = 3$		$K = 6$		$K = 12$	
	Pre 2010	Post 2010	Pre 2010	Post 2010	Pre 2010	Post 2010
Long-Run	.36***	.05	.56**	.10	.64**	-.16
Pass-Through	(.19, .52)	(-.20, .30)	(.40, .72)	(-.10, .30)	(.50, .78)	(-.46, .15)
Season F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Newey-West	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.26	.12	.55	.06	.64	.04
N	131	50	131	50	131	50

Significance levels: *** p $\leq$ .01, ** p $\leq$ .05 and * p $\leq$ .1

year. Interestingly, the estimated level coefficients mirror known NG to AA conversion rates of 34 MMBtu per ton of AA.

Additionally, we report pass-through specification with and without seasonal fixed effects. Specifications in both levels and logs do not differ substantially.

Finally, we include a quadratic term within the pass-through regression,

$$\Delta^K logP_t = \alpha + \beta^K \Delta^K logC_t + \beta^{K2}(\Delta^K logC_t)^2 + \sum_{j=1}^{3} \rho_j S_j + \epsilon_t.$$

The inclusion of the quadratic term is meant to capture a potential non-linear relationship within the NG to AA pass-through rate. If $\beta^{K2} > 0$, this suggests a convex relationship and therefore large changes in NG prices will elicit even larger AA price changes. In contrast, if $\beta^{K2} < 0$, this suggests a concave relationship and therefore large changes in NG prices will elicit relatively smaller AA price changes. In table 9 $\beta^{K2} < 0$, however, the estimated quadratic parameter is not statistically different from zero at the 10% level of significance.

Table 9: Long-Run Pass-Through of 12^{th} Lagged Difference: Nat. Gas on Ammonia

	Logs			Levels		
Long Run	.53***	.53***	.51***	38.02***	38.00***	35.17***
Pass-Through	(.36, .70)	(.37, .69)	(.36, .65)	(19.3, 56.7)	(21.6, 56.3)	(19.2, 50.4)
Quadratic			-.14			-2.43
Term			(-.32, .03)			(-4.81, .06)
Season F.E.	Yes	No	Yes	Yes	No	Yes
Newey West	Yes	Yes	Yes	Yes	Yes	Yes
R^2	.43	.43	.45	.33	.33	.36
N	186	186	186	174	174	174

Significance levels: *** p $\leq$ .01, ** p $\leq$ .05 and * p $\leq$ .1

4.5 Discussion

The analysis in previous section documents that domestic ammonia prices have become largely decoupled from the marginal cost of production. An immediate corollary to this finding is that any tax that increases (at least modestly) the domestic marginal cost of production would have very little impact on domestic ammonia and fertilizer prices. It is worth considering the market conditions that might produce this result, as it helps to inform the contrast between this industry and others, such as the portland cement industry, for which output based updating is believed to be effective. The first condition to note is the shift in the domestic supply function relative to that of imports, as illustrated in the top two panels of Figure 8.

The shift in relative production costs has created a kink in the domestic residual demand, possibly at levels above the production costs of all domestic producers. First consider the potential market power of these domestic producers. Under perfect coordination, a monopolist would set prices just below the level at which imports enter the market. This is illustrated in the left panel of Figure 9. Under these conditions, shocks to domestic marginal costs would produce no changes in the market price. Alternatively, if the domestic production were perfectly competitive, such conditions would again maintain if north america production was operating at its capacity limit, as illustrated in the right hand panel of Figure 9. Again, prices are set by the importing fringe and again a tax on domestic production would have no effect on market prices. Importantly, a border tax would have a very different effect on both equilibria. A tax on imports as well as domestic production (or alternatively on downstream sales) would effectively shift up both the kink point on the residual demand curve and the marginal cost of producers. Prices would continue to be set by importers, but now inclusive of the emissions charge.

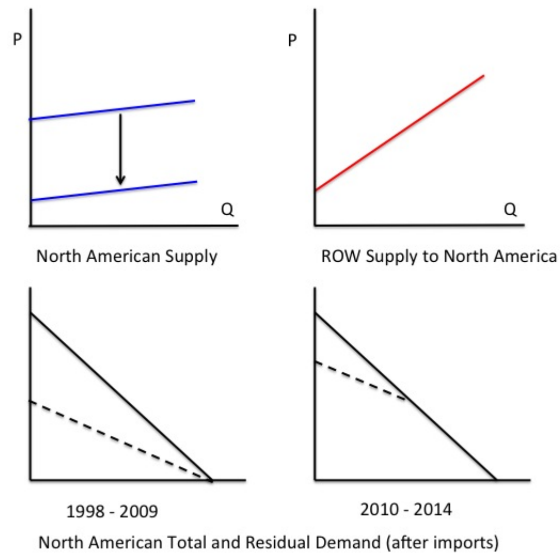


Figure 8: Residual Demand and Domestic Costs.

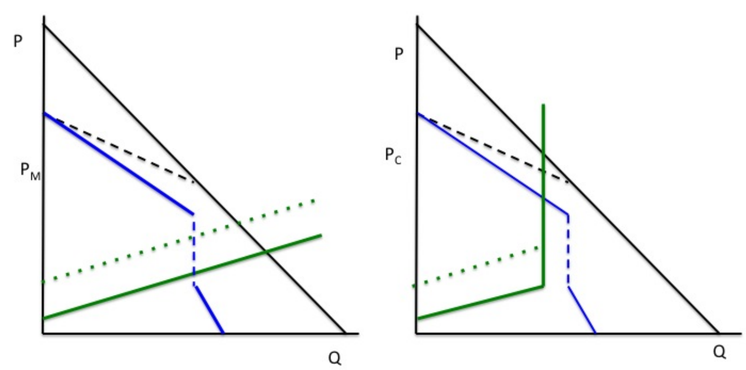


Figure 9: Potential Equilibria.

Our central question regarding the efficacy of an emissions charge and necessity for output-based allocation therefore does not depend upon which of these two conditions are more reflective of the industry today. However, it is worth noting the evidence that is inconsistent with each of these two explanations. First, despite the apparent significant advantage in production costs, the domestic market continues to receive imports not just from its low-cost neighbors, but also from Russia, the middle east, and to a lesser extent Ukraine. A perfect cartel would be able to maximize its market share by expanding output to levels just sufficient to replace the production of these competitors. Of course, continued importation is also consistent with a perfectly competitive yet capacity constrained industry. Available data indicates that this also does not appear to be the case.

We have assembled estimates of country level utilization rates from a collection of sources.[18] Table 4.5 summarizes the annual capacity and production of North American ammonia facilities, including Canada, T&T, and the US. Recall that all three of these markets feature many of the same producers, each with production in several countries. Utilization rates peaked during the commodity boom when US natural gas prices were near their highest historical levels. Since the fracking boom began in 2009, there is no discernible trend in utilization rates except in T&T where they have declined. A second source of information comes from the US EPA, which has reported the greenhouse gas emissions of major US stationary sources since 2010. Again we see no discernible trend in emissions, and under the assumption that emissions rates (which remain unregulated) remained constant, this implies that output has not dramatically increased at US facilities despite the significant cost advantages they enjoy.

While these data may be too approximate to constitute definitive evidence of market power on the part of the domestic producers, they do paint a picture that is consistent with an oligopoly operating in an environment similar to the left hand panel of of Figure 9. While a cartel may be able to exclude imports, imperfect competitors would require a great deal of precision and knowledge of each others plans to replicate such an outcome. In such a setting, it is plausible that oligopolistic firms, wishing to ensure prices in the market be set by high cost imports, maintain output levels that jointly ensure that outcome with some degree of imported quantities.

More generally, the presence of a relatively high cost import supply curve makes the residual demand for the North American market more concave than it would have been before the shift in relative costs. This has important implications for the pass-through of input costs in an oligopoly environment. As described by Seade (1985), pass-through

[18] Canadian and Trinidad & Tobago production totals come each countries energy statistics offices. Production for the United States comes from the Department of Commerce and the International Fertilizer Association. Production capacity values come from the International Fertilizer Development Association (IFDC), which collects data on production capacity worldwide.

Table 10: Ammonia Capacity and Utilization in the North American Region

Year	United States		Canada		Trin & Tob		Total North America		
	Cap.	Prod.	Cap.	Prod.	Cap.	Prod.	Cap.	Prod.	Util.
2006	10601	9136	5181	4623	5413	5155	21195	18914	0.892
2007	10693	9787	5256	4431	5413	5219	21362	19437	0.910
2008	10920	9702	5256	4729	5432	4974	21608	19405	0.898
2009	11187	9507	5261	4161	6085	5417	22533	19085	0.847
2010	11330	10255	5431	4432	6085	6082	22846	20769	0.909
2011	11606	10633	5431	4764	6085	5636	23122	21033	0.910
2012	12131	10414	5497	4725	6085	5416	23713	20555	0.867
2013	12131	11064	5497	4881	6085	5135	23713	21080	0.889

Note: Capacity and production in metric tons.

of marginal cost shocks decreases with concavity in the demand (or in this case residual demand). In an environment of Cournot competition, pass-through will also increase with the number of firms (Kimmel, 1992). The nitrogen fertilizer industry experienced both an increase in the convexity of residual demand and a decrease in the number of firms between 2008 and 2010. Therefore our results, demonstrating reduced pass-through, are consistent with an equilibrium in which the north american producers are behaving as oligopolists in the face of an increasingly convex residual demand.

One remaining question relevant to the question of emissions charges and trade policy is the production response within the US from changes in input costs. The evidence above demonstrates that product prices have decoupled from natural gas prices but does not address the question of local production. Production data are relatively sparse but are available on a quarterly basis from the Department of Commerce prior to 2009 and from the International Fertilizer Association after 2007. Unfortunately the two data sources do not align during the periods in which they overlap so we are reluctant to combine the two time series. Here we examine the IFA data, which is the same source summarized in table utilization above. Figure 10 plots a scatter of the log of natural gas against the natural log of ammonia output in the post 2010 period. There is no obvious relationship between input costs and output in the 5 years since 2009. A simple OLS regression of $ln(AA\_production)$ on $ln(natural\_gas\_price)$ in the post 2009 period produces a *positive* but insignificant coefficient of .02. Under the assumption that natural gas prices are an acceptable proxy for an emissions charge in the ammonia industry, this evidence supports the conclusion that such charges would have no impact on domestic production.

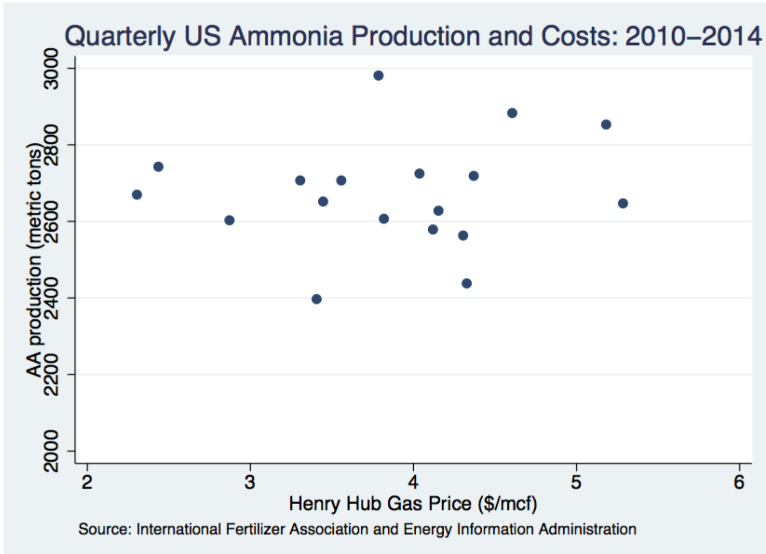


Figure 10: US Production Response to Cost Shocks

5 Evaluation of Policy Options

The fact that the nitrogen fertilizer industry since 2010 has demonstrated very little pass-through of cost shocks - either due to market power, capacity constraints, or both - has several implications for the efficacy of carbon pricing or other environmental charges. First, a carbon tax or cap-and-trade obligation such as proposed under HR 2454 would have had minimal impact on domestic fertilizer prices. Second, our analysis indicates such a charge would also have had little impact on North American production, although at very high levels it could induce some shift of production within North America. Third, because the carbon costs would not have been passed through anyway, output-based updating would also have had almost no impact on downstream fertilizer prices.

In this section we calculate, roughly, the impact alternative regulatory approaches would have had on GHG emissions and ammonia consumption. We use the year 2012, for which all the needed data are available, as a benchmark year for this analysis. Taking the prevailing wholesale prices and quantities for ammonia, emissions intensity of both production and downstream use of ammonia, and values for the elasticity of demand for ammonia, we calculate the implied changes in prices, quantities and emissions that would have prevailed under either with output-based updating, a border tax, or no adjustments for trade exposure. For this analysis we focus on ammonia, following the logic that ammonia is the key input to all downstream nitrogen based fertilizers so that emissions associated with producing N fertilizers are ultimately sourced in the production of ammonia.

5.1 Data Sources for Emissions and Market Quantities

Data on ammonia and other fertilizer production quantities were taken from the International Fertilizer Association, which reports quarterly production, imports, and exports of various fertilizer products for most major producing countries. As described above, prices for ammonia come from Green Markets.

There are multiple sources for the emissions of the ammonia or nitrogen industry, all of which measure slightly different things. For the direct emissions we follow FFR (2015) and use the European Union's value for emissions intensity that is used for their output-based allocations under Europe's carbon trading program. In the EU allowances are allocated to the Ammonia industry according to a benchmark emissions level of 1.619 tons CO2e per metric ton of ammonia (or 1.47 per short ton).[19]This value is slightly higher than the 1.2 tons CO2e per ton used by the EPA in their 2015 inventory of GHG emissions in the United States,[20] but the US inventory value excludes emissions associated with fuel combustion and only includes chemical process emissions.

There are two additional types of indirect emissions to consider. The first is the emissions associated with electricity consumption at the production facilities and the second is the downstream emissions associated with both the production of derivative nitrogen fertilizer products and the emissions associated with the use of fertilizer in agriculture and urea in industrial applications. For the latter we utilize the EPA Inventory, which assigns roughly 10 mmTons of CO2e to the production of nitrogen fertilizer derivatives, and about another 5 to the industrial usage of urea. For the former we utilize the US Interagency report, which attributed roughly 4% (1.5 out of 38.4 mmTons) of emissions from the sector to the electricity consumed in production. All together we attribute 8.146 tons of CO2e (upstream and downstream) to the production and consumption of 1 ton of ammonia.

As members of an emissions intensive trade exposed industry, US fertilizer manufacturers would have been eligible to receive allowances equal to 100% of the average emissions in their industry, adjusted for output levels. Therefore manufacturers would have on average, received subsidies equivalent to 100% of their compliance cost through 2025. After 2025, the allocations were scheduled to phase out at a pace somewhat at the discretion of the President.[21] Therefore one can reasonably quantify the subsidy received in aggregate by the industry by taking its total emissions multiplied by the assumed allowance price.

[19]European Commission Decision of 27 April 2011 determining transitional Union-wide rules for harmonized free allocation of emission allowances pursuant to Article 10a of Directive 2003/87/EC of the European Parliament and of the Council. Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011D0278&from=EN

[20]Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 2013. US EPA, April 2015.

[21]US Interagency Report, page 34.

A significant body of literature exists that estimates the own price elasticity of nitrogen fertilizer within the US agricultural sector. The majority of this research suggests that the own-price demand of elasticity is inelastic and ranges from -.2 to -.9, (see Burrell (1989) for a literature review as well as Denbaly and Vroomen (1993) and Hansen (2004) for more recent contributions). For this reason we examine elasticities ranging from -0.2 to -1.0 as these demand elasticities correspond roughly to the prevailing literature.

The above literature focuses on estimating how farmers respond to increases in the price of nitrogen fertilizer in general rather than the price of anhydrous ammonia specifically. We, therefore, estimate the following demand equation for the use of anhydrous ammonia in the agricultural sector,

$$logQ_t^{AA} = \alpha + \beta logP_t^{AA} + \delta logP_t^C + \epsilon_t.$$

The dependent variable is the log of anhydrous ammonia used annually by US farmers. This data spans 1960 until 2011 and is obtained from the USDA's Agricultural Resource Management Survey. Given the annual periodicity of the dependent variable, estimation of the above demand specification requires that anhydrous ammonia prices, P^{AA}, be aggregated to an annual periodicity. This is accomplished by taking an unweighted average of existing monthly anhydrous ammonia prices within a given year. Finally, we also consider the price of corn as a potential demand shifter. Annual corn prices, P^C, are constructed by obtaining a time series of weekly corn futures contracts, from the Chicago Board of Trade, that have the nearest possible maturity date. This data set is then aggregated to an annual periodicity by taking an unweighted average of weekly prices within a given year. Finally, we also instrument for the potential endogeneity of anhydrous ammonia prices by using natural gas prices as a supply shifter.

Table 11 summarizes our estimation results for two specifications with robust standard errors reported in parentheses. The point estimate of the own-price elasticity of demand within the first specification is essentially zero. The second specification, in contrast, produces a point estimate of the own-price elasticity of demand that is both statistically significant and inelastic. The drastic difference between specification 1 and 2 is driven by the commodity boom which occurred between 2007 and 2008. During this period of time the price and use of anhydrous ammonia were both relatively high. However, much of the increase in fertilizer use, during this time period, can be attributed to relatively high crop prices. A potential limitation of the demand elasticity estimates in table 11 is they are estimated using a mere 14 observations. This was made necessary by the fact that the data on anhydrous ammonia prices and use only overlap between 1998 and 2011.

The above demand literature as well as estimates of demand elasticities in table 11 are derived for the US agricultural sector. To the authors knowledge, there is no information available on the elasticity of demand for ammonia or urea in industrial applications nor is there sufficient data to estimate a demand elasticity.

Table 11: Demand Elasticity Estimates

	(1)	(2)
	Log(AA Consumption)	Log(AA Consumption)
Log(AA Prices)	-0.008	-0.14*
	(-0.17)	(-2.47)
Log(Corn Prices)		0.21***
		(3.63)
Constant	15.28***	14.85***
	(52.39)	(55.70)
N	14	14
First Stage F-test	22.31	210.33

Significance levels: *** $p \leq .01$, ** $p \leq .05$ and * $p \leq .1$

Table 5.1 summarizes our calculations for the ammonia industry. For three demand elasticity values (-0.2, -0.5, and -1) we also calculate the impact of emissions charges of either \$20 or \$40 per ton. The rows labeled “post 2010” assume output-based allocation and our estimated post-2010 pass-through rate. The allocation values we list is the estimated allocation to ammonia producers, but not to other downstream nitrogen producers. The rows labeled 15% reflect a hypothetical scenario where ammonia prices our highest estimated post-2010 pass-through rate and there is no border adjustment of any kind. The rows labeled “border tax” assume that both domestic and imported ammonia is charged a carbon price evaluated at 1.61 tons CO2e per ton of AA. For both the 15% and border tax scenarios we assume that no allocations are made to the industry.

The main implications of these calculations are that under current market conditions output-based allocation to ammonia producers would distribute between about \$350 to \$700 million to producers and have no effect on upstream or downstream producers. Under the conditions that maintained prior to 2010, this allocation would have effectively shielded downstream consumers from emissions costs. However if a border tax were instead applied, shifting upward the residual demand faced by north american producers, then price increases on the order of \$25 to \$50 per metric ton would reduce downstream consumption, resulting in a reduction of 2 to 4 million tons of CO2e (mostly in the form of N_2O emissions).

Prediction of the emissions leakage in the industry under an environmental is more difficult as at some level of charge the cost advantages enjoyed by domestic producers would be eroded and offset by the emissions costs, creating pressure for increased imports. Using the above numbers, the marginal production cost impact of a \$20-40/ton CO2e charge would be

Table 12: Impacts of Alternative Competitiveness Policies

	Δ Price	Allocation Value		$20/ton CO2 Elas. -0.2	Elas. -0.5	Elas. -1
post 2010	0.00	345	Change in	0.00	0.00	0.00
15%	4.86	0	Consumption	-24.33	-49.87	-99.74
Border Tax	25.73	0	(1000 Tons)	-128.90	-322.25	-644.50
post 2010	0.00	345	Change in	0.00	0.00	0.00
15%	3.98	0	CO2e	-0.20	-0.41	-0.82
Border Tax	25.73	0	(mmTons)	-1.06	-2.64	-5.28
				$40/ton CO2		
				Elas. -0.2	Elas. -0.5	Elas. -1
post 2010	0.00	690	Change in	0.00	0.00	0.00
15%	7.96	0	Consumption	-39.90	-99.74	-199.49
Border Tax	51.46	0	(1000 Tons)	-257.80	-644.50	-1289.00
post 2010	0.00	690	Change in	0.00	0.00	0.00
15%	7.96	0	CO2e	-0.33	-0.82	-1.63
Border Tax	51.46	0	(mmTons)	-2.11	-5.28	-10.55

roughly equivalent to a $1-2 mcf change in natural gas prices. Such variation is seen within our sample post 2010, with no discernible impact on domestic production levels. Another way of viewing this is to compare the $37/ metric ton carbon fee to the approximate domestic margins in ammonia production of between $300 and $600 per ton in the post-2010 period. Margins measured the same way averaged approximately $100 per ton between 2000 and 2010. One last comparison would be to the approximately $130 per ton cost of shipping ammonia from either the middle east or Black Sea region. With each of these comparisons, a carbon fee in the $40 - $70 per metric ton of ammonia range would not be enough to eliminate the domestic production cost advantage, again assuming that relative natural gas prices remain within the levels experienced post 2009.

6 Conclusions

In industries where input costs can be volatile both over time and geography, the estimation of trade exposure using domestic market shares can be particularly problematic. It is useful to consider the situation of three prominent energy intensive and trade exposed industries:

cement manufacturing, petroleum refining, and nitrogenous fertilizer. All three of these industries receive output-based allocations of allowances in the EU and in California under their respective cap and trade programs, and would have received comparable support under the American Climate and Energy Security Act.

While all are capital intensive industries, the dramatic changes in the market structure and input markets in the nitrogen industry provide an interesting contrast to the relatively stable cement industry. As we document in this paper, input costs have dramatically shifted the geographic competitive landscape in the nitrogen industry, but without a comparable transformation in either domestic production or of wholesale or retail prices. Given the highly capital intensive nature of the industry, it could be that we are in the process of a decades-long adjustment. However, it is also possible that the specter of more dramatic shifts in the geographic landscape of the industry can forestall a full adjustment to current input price conditions. Producers in the California gasoline market consistently enjoys higher local prices than neighboring states, yet the price disparities have not been sufficient to draw sufficient imports to equalize prices or expand local production enough to eliminate imports. Like the US nitrogen industry, California gasoline refining has grown increasingly concentrated and it is not implausible that a degree of local market power is helping to maintain these conditions. In either case, we see in the nitrogen industry today a situation where domestic producers enjoys an extremely favorable competitive position *and* continues to import product at levels that conventional measures would label as "trade exposed."

The implications for environmental policy, particularly climate policy, are that input cost conditions, and likely market structure, need to be weighed carefully in assessing the trade exposure of an industry. Using natural gas price variation as a proxy for an emissions charge, we find an extremely weak relationship between input cost shocks, product prices, and output in the industry after 2009. Unlike the conventional conclusion that output-based updating would be effective in both changing local producer behavior and in mitigating downstream price increases, we find that the regulation, with or without updating, would have almost no effect on the domestic nitrogen industry. We do not directly consider the opportunities for process abatement, so there could be some abatement from producers as a result of the incentives provided by a carbon price, even under output based updating. Such an incentive would exist with or without updating, however, and in both cases the opportunities for effecting downstream emissions, which are more than 3 times larger than the production emissions, are lost. It is also possible that the industry eventually adjusts to what it considers to be a "new normal" in international gas prices. Even if a decades-long process erodes the current margins in US nitrogen markets, ten years of allowance allocation would imply transfers on the order of $ 5 Billion dollars to the industry before such an adjustment took root.

The merits of a border tax are more difficult to interpret. If US fertilizer prices are being artificially inflated by the market power of domestic producers, it is possible that this market power is already raising prices by more than would be justified by the environmental externalities. If the US market is instead capacity constrained, over time the dynamic inefficiencies identified by Fowlie, Fabra, and Ryan (2015) could play a role in limiting US capacity expansion. One last consideration is the global equilibrium effects of changes to the US agricultural industry. Research by Elobeid, et al., (2013) indicates that a 10% increase in US fertilizer costs would result in shifts to global agricultural that, although reducing US N_2O emissions would produce a net increase of emissions globally.

With regards to output based updating however, our results indicate that there is almost no public purpose to awarding allowances to the US fertilizer industry. Like the petroleum industry in California, it appears that this industry has been enjoying sizable and durable margins stemming from a combination of advantageous local production costs and relatively high transportation costs. Based the response of these industries to input cost shocks, it appears that GHG regulation, and therefore any offsetting allowance allocation, would have little to no effect on their output levels or downstream product prices.

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