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E21134-TEK

Critical review of a recent report on cost pass-through and carbon leakage

Fertilizers Europe
17 February 2016

Authors:
Helge Sigurd Næss-Schmidt, Partner
Martin Bo Hansen, Managing Economist
Christian Giødesen Lund, Economist
Christoffer Haag Theilgaard, Analyst

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Executive summary

In November 2015, the consultancies CE Delft and Oeko-Institute published a report, CE Delft (2015) that assessed the extent to which a selected number of energy-intensive manufacturing industries increased their sales prices as they experienced higher input costs from being included in the ETS system.

The report was commissioned by the European Commission with the underlying purpose to shed light on the risk higher production costs for EU producers caused by EU climate policies cause production and investment in these industries to move to non-EU location. This is what has been called carbon leakage.[1] In this note, we focus on the part of the report looking at the fertilizer industry, but most of the arguments put forward and the conclusions drawn are general and do not hinge on sector-specific characteristics.

Based on our analysis, we conclude that the report essentially fails to provide a credible answer to two important questions relevant for carbon leakage:

- Did the fertilizer industry increase sales prices as input costs rose in the two-year period after the fertilizer industry was included in the ETS system in 2013?[2]
- Will the fertilizer industry be capable of passing on input costs going forward with a potentially tighter ETS system with much higher allowance prices that are sustained over a much longer period and are not necessarily matched by comparable rises for competitors in non-EU countries?

Our conclusions are based on two sets of arguments:

- The results are counterintuitive and fail to capture the basic underlying economic characteristics of the fertilizer industry.
- The counterintuitive results stem from a number of methodological weaknesses in the applied econometric model that we identify.

The counterintuitive results

Based on our analysis, we argue that the estimated results from the econometric models are inconsistent with the underlying economics of the fertilizer industry. We highlight four key points:

Firstly, the estimated price elasticities from the econometric model and the resulting calculated pass through rates are inconsistent with the basic economics of the fertilizer industry. Natural gas is the main input in production of fertilizers and accounts for approximately 80 per cent of the total production costs. The ETS costs in the observed period (January 2013-February 2015) accounted for approximately 3 per cent.[3]

1 Carbon leakage encompasses both loss of market shares to non-EU producers (production leakage) and relocation of production facilities through investments (investment leakage).

2 Two countries opted in nitrogen fertilizer installations in the ETS from 2009 and 2011 respectively.

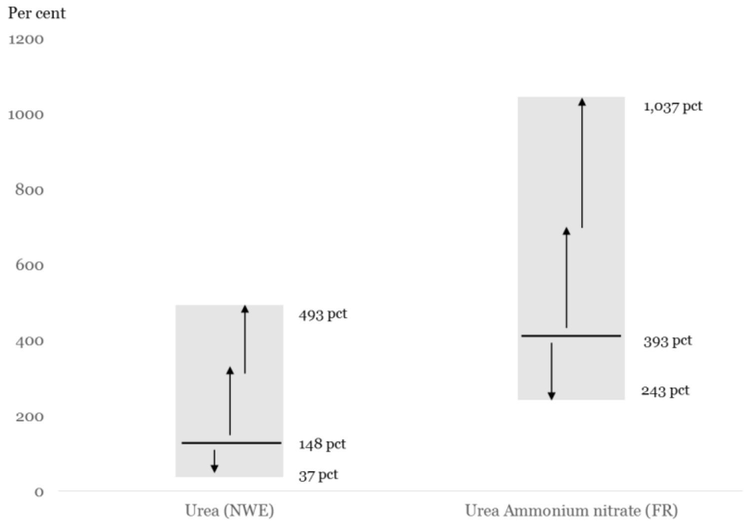
3 The small share is primarily due to the low ETS price in the period.

This implies that a one per cent increase in the price of natural gas must have a significantly higher impact on the total production costs, and therefore on the output price than a similar increase in the ETS price. This is not consistent with the estimates in CE Delft (2015). Moreover, the estimated CO_2 cost pass through rates are between 150-400 per cent for different products, while the estimated natural gas cost pass through rates are only around 17-21 per cent.

Rather, the results in CE Delft (2015) imply that fertilizer producers have been able to significantly increase the price of fertilizers whenever the ETS price increased, but that they have not been able to do so when the natural gas price increased. This is counter-intuitive. Indeed, the opposite should be true as the ETS cost is only imposed on EU producers, while the natural gas price in the EU (to some extent) is correlated with gas prices in competing countries and therefore the production cost of competing fertilizer producers outside the EU.

Secondly, the estimated results are not robust to conservative sensitivity analyses. By making two plausible sensitivity analyses, the calculated cost pass through rate of urea ammonium nitrate, for example, goes from almost 400 per cent to above 1,000 per cent, cf. Figure, highlighting the enormous uncertainty attached to the results in CE Delft (2015).

Figure Large uncertainty of cost pass through estimates



Note: Our first sensitivity is to consider the 10 per cent confidence interval around the estimated price elasticity coefficient in both directions (the traditional 5 per cent interval would result in an even larger span).

Our second sensitivity is to use the actual ETS prices in the observed period of app. €5/ton on average instead of the app. €10/ton used by the authors (with the odd reasoning that the estimates should be comparable with estimates from other industries)

Source: Copenhagen Economics based on CE Delft (2015)

Thirdly, the authors seem to interpret the results from most of their estimations as long run relationships, while the econometric results imply that they are in fact to be interpreted as short run dynamics. This means that the estimations are capturing week-to-week variation instead of the relevant underlying adjustments in the price of fertilizers due to changing production costs. Such short run dynamics provide statistical power to the estimation procedure but do not add any explanatory power to the long run dynamics of cost pass-through that the authors try to detect.

In fact, in 7 out of 8 circumstances the estimation process rejects that there is a long-run relationship between ETS costs and fertilizer prices, which should be interpreted as evidence of no pass-through.

Fourthly, the estimated cost pass through rates are inconsistent with basic economics such as the expected negative relationship between trade intensity of a given product and the cost pass-through rates. The authors claim that their estimated cost pass-through rates of different industries are weakly related to the industries' trade intensity – which they should be - when looking across industries. However, the estimations for the fertilizer industry in fact show an opposite pattern, hence questioning the reasonability of the results. Moreover, the authors have not been able to reproduce some of the other expected relationships between cost pass-through and e.g. EU market shares, market concentration and transportation costs.

The methodological problems

The reasons for these counter-intuitive results are also relatively straightforward.

Firstly, the analysis is based on a very short time-period namely from January 2013 to February 2015.[4] This is a very short period for any estimation, and particularly for a price-estimation, as price formation to underlying cost changes is quite rigid. To compensate for the short period, the authors has opted for using weekly rather than monthly data. This is however more likely to do harm in the form of false confidence than to solve the problem, as it will capture short term noisy movements and not the more long term price formation dynamics. The problem is amplified by the fact that the authors interpret short-run results as long-run relationships and as a result extrapolate their short term results to long term impacts.

Secondly, a number of very important control variables are not included in the estimations. The authors are not including the increased demand for fertilizers nor any measure for production costs for non-EU producers. The problem is that the ETS price may wrongly be ‘given credit’ for an effect on the market price which is in fact driven by e.g. underlying changes in demand (multicollinearity). The authors indeed recognise this problem, but are not addressing it in the actual estimations.

Not relevant for risk of carbon leakage going forward

Even if the estimates in CE Delft (2015) had been based on a solid methodology, we argue that they would not add useful information on the risk of leakage going forward. The key point is that a high pass-through rate in the short time period analysed, with a low ETS price (app. €5/ton) says nothing about the scope for cost pass-through in a situation with an ETS price of €30 or €50 not matched by similar rises in production costs for competitors in other regions.

In particular, it is important to understand that the risks of carbon leakage is not proportional to the cost differential between producers inside and outside the EU. With small cost differences, some of the extra costs can be absorbed by process innovation as well as the protection offered by nearness to markets and lower transport costs for domestic producers. Consequently, EU producers may increase prices without losing substantial market shares. However, once the cost differential exceeds a certain level, prices cannot be raised without a serious loss of market share.

To maintain use of existing capacity in EU, companies might prefer to lower margins rather than market shares. However, when the cost differential becomes high enough, production is shifted out of EU and investments stop, eroding EU production capacity. If the ETS cost contributes to raising the cost differential above this ‘tipping point’ this will lead to production and investment leakage (carbon leakage).

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4 For most of the fertilizer products analysed.

Chapter 1

Assessment of CE Delft (2015) study on cost pass-through

In November 2015 a report about so called *cost pass-through* written by CE Delft and Oeko-Institut was published by the EU Commission. The analysis seeks to determine whether the cost incurred by EU industry due to the ETS has been passed through to final customers through higher prices. The report considers six traditional leakage industries. In this note, we focus on the fertilizer industry.

In order to measure the impact on product prices, CE Delft (2015) conducts an econometric exercise based on a simple model relating the product price to the cost of its inputs. Due to challenges in terms of data, relatively advanced econometric techniques are applied.

From econometrics they estimate a price elasticity between CO_2 and the output price indicating how many per cent the output price has increased when the ETS price increased by 1 per cent. For three out of eight fertilizer products the relationship is insignificant. They then make a illustrative calculation of by how much the price should have increased if ETS costs were to have been passed through fully (100 per cent), and compare this with the estimated price elasticity.

The report concludes that in the period 2013-2014, the fertilizer industry has been able to pass through the increased costs from the ETS price to final consumers. In fact, the results indicate that more than 100 per cent of the ETS costs have been passed through and in some instances, even 400 per cent of the ETS costs have been passed through.

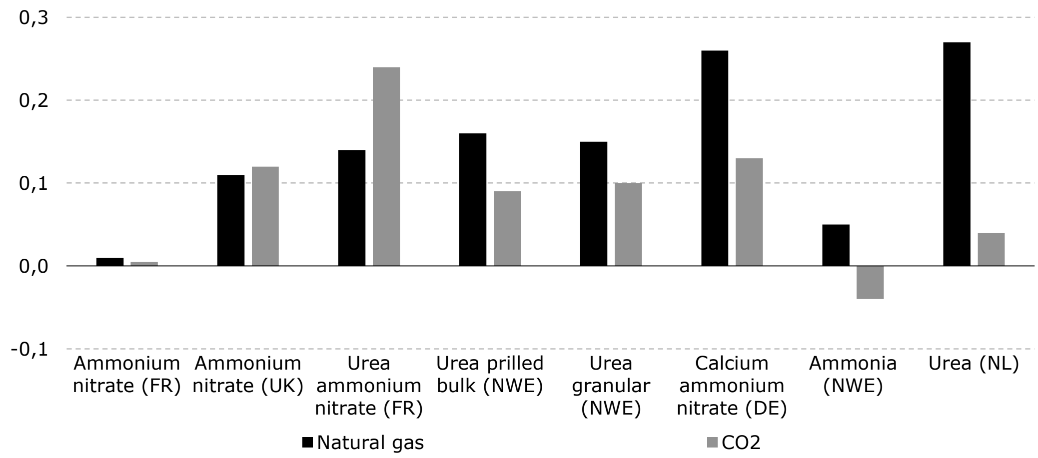
Based on our analysis in this note, we argue that these estimates are highly sensitive and inconsistent with key facts and underlying economics of the fertilizer industry.

1.1 Results inconsistent with basic business economics of the fertilizer industry

CE Delft (2015) attempts to separate the effects of the ETS and natural gas prices respectively on the price of fertilizer products. That is: will an increase in the ETS price have a different effect on the output price than an increase in the natural gas price?

They find quite varying results across different products: for some products the effects are similar, for other products the ETS price elasticity is highest and for other products the natural gas price elasticity is highest, cf. Figure 1.

Figure 1 Estimated price elasticities for CO_2 and natural gas



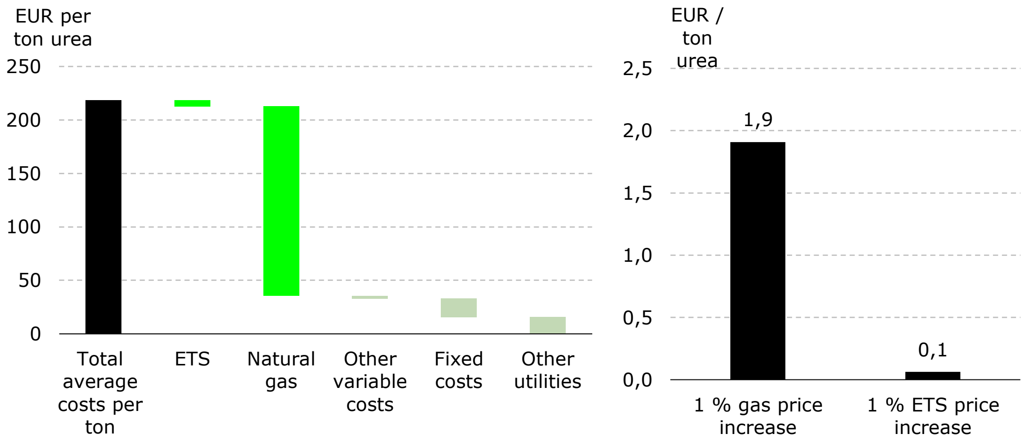
Note: The estimates for Urea (NL), Ammonium nitrate (FR) and Ammonia (NWE) are produced by running different models than the other estimates. The authors warn that these results should not be compared with the results of the other estimates, but relationship between the CO_2 and natural gas elasticities is still informative.

Source: Numbers taken from CE Delft (2015), Tables 19 and 56-58. There are examples where the numbers are inconsistent in the two tables. In that case we have used the ones from the main report: Table 19.

This is inconsistent with the basic business economics of the fertilizer industry. The cost of natural gas constitutes app. 80 per cent of total costs, which is substantially above the ETS cost share of app. 3 per cent, cf. Figure 2 (left panel).[5] This implies that when the price of natural gas increases by 1 per cent total costs increase by app. 1,9 €/ton product. This is app. 30 times more than if the ETS price increases by 1 per cent (€0.06/ton), cf. Figure 2 (right panel).

5 When using the ETS prices from the analysed period of 2013-February 2015.

Figure 2 Natural gas costs dominates production costs



Note: We have used an average price for the period in question: January 2013 - February 2015 for both natural gas in Europe and the ETS price

Source: Copenhagen Economics based on Integer Research, European Energy Exchange and SendeCO2

Consequently, we would expect the price elasticity of natural gas in this period to be massively higher than the price elasticity of ETS, which is not replicated by CE Delft (2015). This has indeed been found in other studies investigating the relationship between fertilizer and energy prices, who all report a large effect of energy prices on fertilizer prices, and are all based on longer time periods, cf. Table 1.

Table 1 The relationship between fertilizer and energy prices

Study	Main driver of fertilizer prices	Size of effect	Method	Data period
Chen et al. (2013), 'Modelling the Effects of Oil Prices on Global Fertilizer Prices and Volatility'	Crude oil prices	Large effect. The price elasticity of fertilizers with respect to crude oil is above 1 for all specifications. Crude oil prices are an important driver of fertilizer prices	Econometrics, ARDL and GARCH models	Weekly, 2003-2008
US General Accounting Office (2003), 'Domestic Nitrogen Fertilizer Production Depends on Natural Gas Availability and Prices'	Natural gas prices	Large effect. No direct estimate. A large correlation is determined. As natural gas accounts for a large share of total costs of producing fertilizers they conclude that 'natural gas and fertilizer prices are closely related'	Descriptive analysis, co-movement of natural gas and fertilizer prices	Monthly, 1998-2003
Ott (2012), 'Fertilizer markets and their interplay with commodity and food prices'	Energy prices	Large effect. No direct estimate. It is concluded that 'Causality test clearly reveal that energy prices caused an increase in the price of fertilizers'	Econometrics, VAR model	Monthly, 1967-2012
Sanyal et al. (2015), 'Impact of Energy Price Variability on Global Fertilizer Price: Application of Alternative Volatility Models'	Crude oil and natural gas prices	Large effect. Many specifications are run. Concludes that 'the mean effects of lagged crude oil prices and lagged natural gas prices considerably have positive and significant impact on the fertilizer price series'	Econometrics GARCH and GJR models	Monthly, 1993-2012

Source: Copenhagen Economics

This point becomes even clearer, when considering the calculated cost pass-through rates. Using the estimated coefficients and the same methodology for calculating cost pass-through as in CE Delft (2015), we find that the estimated pass-through rate for natural gas is app. 17-21 per cent, which is significantly lower than the estimated rates for CO_2, cf. Table 2. This is a problem for the analysis. Basically it implies that whenever the natural gas price increases, firms are only able to increase the price slightly (17-21 per cent) while the price can easily adjust when it is the ETS price increasing – even up to an extent where 400 per cent of ETS costs are passed through. One could even easily argue that the pass through rate of natural gas should be higher than that of the ETS, as the ETS price is a cost affecting only producers within EU, while European natural gas prices to some extent is correlated with non-EU producers' cost through their local gas prices.[6]

Table 2 Cost pass-through rates in CE Delft (2015) for CO_2 and natural gas

Product	Cost pass through rate for CO_2 as *reported* in CE Delft (2015)	Cost pass through rate for CO_2 as *calculated* in CE Delft (2015)	Cost pass through rate for natural gas*
Ammonium nitrate (UK)	>100%	197%	17%
Calcium ammonium nitrate (DE)	>100%	213%	
Urea ammonium nitrate (FR)	>100%	393%	
Urea granular (NWE)	100%	164%	21%
Urea prilled bulk (NWE)	100%	148%	21%
Urea (NL)	Not significant	66%	
Ammonium nitrate (FR)	Not significant	8%	1%
Ammonia (NWE)	Not significant	-66%	

Note: We have calculated the cost pass-through rate for natural gas based on the estimates for the price elasticity given in Appendix D.2, Table 57, page 192, and based on the price of natural gas and the average share of natural gas costs to the price.

Source: Copenhagen Economics based on CE Delft (2015)

The authors have chosen to report the calculated cost pass through rates as >100% for a number of fertilizer products. This hides the actual estimation results, which for several products are between app. 200-400 per cent implying that the fertilizer industry has been able to increase the output price to an extent that an increase in the ETS costs has made its money back up to four times for industry, which is counter intuitive. As we show in a sensitivity analysis in section 1.4, for very reasonable parameter adjustments, the cost pass through estimate can rise to over 1,000 per cent illustrating the very high uncertainty of the results.

1.2 The authors are rejecting a long-run relationship and therefore any cost pass-through

It appears that the authors are interpreting the results of their estimations incorrectly, which has quite substantial implications for the overall conclusions of the exercise. In 7 out of 8 fertilizer products, the authors choose either a so-called *ARDL in first differences*

[6] The correlation is not strong, as natural gas market to a large extent are local.

or a *VAR in first differences* model as their preferred model. In the procedure to get to these models, the authors are testing for cointegration and are rejecting that this is the case. This implies – also according to the authors' own theoretical section (section 3.3.2) – that they are statistically rejecting that ETS costs should have led to cost pass-through in the period.

After having rejected this relation, the authors proceed to estimate the models (ARDL in FD and VAR in FD). These models contain per definition only short-run dynamics; that is variations in the price that 'die-out' after a short period of time, instead of the relevant underlying price adjustments due to changing production costs, which constitutes 'cost pass-through'. Nonetheless, it appears that the authors present these results as long-run relations and conclude that they constitute indications of cost pass-through.[7] The authors do in fact recognise the problem in a footnote while downplaying the quite influential implications.[8]

We present more elaborate argumentation for this conclusion in Appendix A.

1.3 Results not consistent with traditional economic variables

One of the important drivers of whether or not it is possible to pass through costs, is if the industry is exposed to foreign competition. If foreign competition is high, EU-based costs such as the ETS cannot be passed through to product prices without losing significant market shares.[9] A typical way to assess whether an industry is exposed to foreign competition is through the measure of trade intensity. As a result, one would expect a clear negative relationship between cost pass-through and trade intensity.

To provide credibility to the results, CE Delft (2015) claims to have established a weak link between their estimated cost pass-through rates and observed trade intensity when looking across all sectors. We argue that the link CE Delft find is very weak, especially in the fertilizer industry, and that the link completely disappears when we re-include two of the estimated fertilizer products, which the authors for some reason have not included in this particular assessment. Consequently, instead of depicting the clear negative relationship between pass-through and trade intensity, as would be expected, the results depict a positive relationship –if any, cf. Figure 3.

Furthermore, the average trade intensity of the products where the authors estimate a significant pass through rate is also higher (by 4 percentage points) than the average trade intensity of the products with insignificant pass through.

The opposite relationship found between trade intensity and cost pass-through draws the estimated pass-through rates into question, as they are not consistent with one of the most important drivers of cost pass through.

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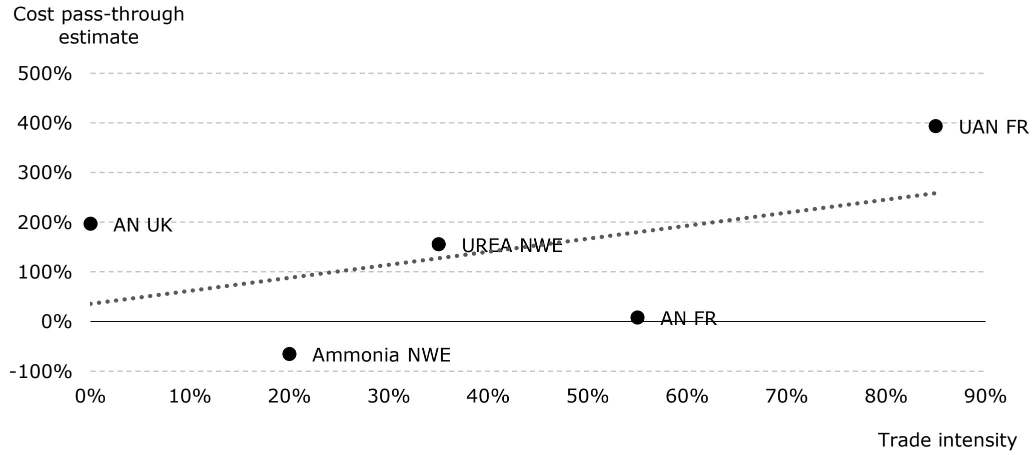
7 Table 19, page 107.

8 CE Delft note in a footnote 51 on page 106: "*Although estimating the model in first differences gives a somewhat less strong indication of the long run effect, the accumulated effect of the first difference can still indicate whether there is cost pass through or not and its magnitude can be interpreted and compared to cost shares in order to estimate the rate of cost pass-through.*"

9 See Copenhagen Economics (2015).

Figure 3 Inconsistent relation between estimated pass-through and observed trade intensity



Note: The trend-line indicates the best fit between the observations

The calculations on trade intensity in CE Delft (2015) does not include estimates for UAN (FR) and Urea (NEW). We have collected readily available trade intensity data on for these two products so they could be a part of the analysis. This is especially important, as they are quite trade intensive products.

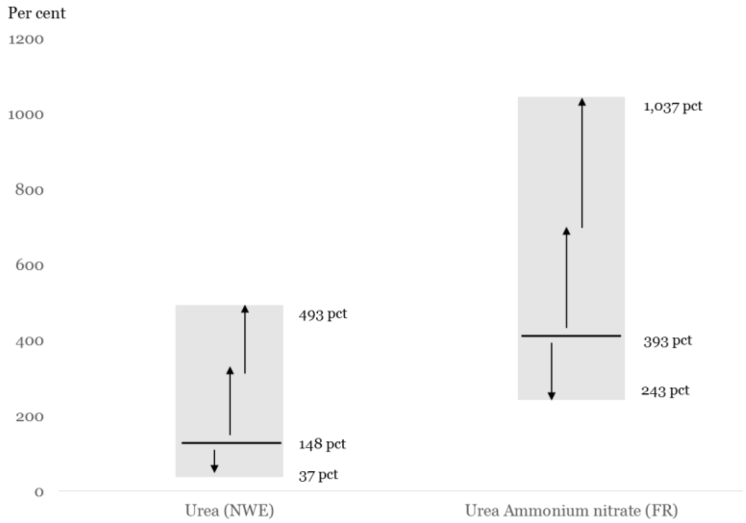
Source: Copenhagen Economics based on CE Delft (2015) and data from Eurostat's Prodcom database for production value and Comext database for import and export values

The authors also investigate other traditional drivers of cost pass-through rates, such as EU market shares, market concentration and transportation costs. In all these situations, the authors cannot replicate the theoretically expected relationships, among others due to scarce data.

1.4 Results are volatile beyond reasonable magnitude

As shown earlier, the authors find that the estimates of pass through are large and of varying magnitudes. The significant estimates are in the range of 150-400 per cent and the insignificant results are in the range of -66 – 66 per cent. This is a remarkably broad range of estimates. However, even this very broad range of estimates is not robust to a conservative sensitivity analysis. By making two plausible sensitivity corrections, the calculated cost pass through rate of urea ammonium nitrate goes above 1,000 per cent for UAN and down to 37 per cent for Urea, cf. Figure 4, highlighting the enormous uncertainty in the exercise.

Figure 4 Sensitivity check on calculated pass through rates



Note: Our first sensitivity is to consider the 10 per cent confidence interval around the estimated price elasticity coefficient in both directions (the traditional 5 per cent interval would result in an even larger span).

Our second sensitivity is to use the actual ETS prices in the observed period of app. €5/ton on average instead of the app. €10/ton used by the authors (with the reasoning that the estimates should be comparable with estimates from other industries)

Source: Copenhagen Economics based on CE Delft (2015)

Throughout the technical chapters in the report, the authors acknowledge the large uncertainty in both their estimation methodology and the subsequent cost pass through calculation. This uncertainty is, however, not reflected in the presentation of results in the executive summary, where conclusions are surprisingly strong, cf. Box 1.

Box 1 Passages from the report

Passages from the report highlighting how uncertain the results are:

The estimation procedure:

"Furthermore, the sum of all coefficients in the long-run relationship often exceeded 1 which is another sign of misspecification as the total share of costs should not exceed unity (or substantial losses are made by the sector)."

- *Page 105 paragraph 4*

"Whilst our estimation procedure fails to find significant evidence of cost pass through for pure ammonia, we do find significant pass through for ammonium nitrates, as well as urea. However, this difference should not be overstated, as our estimation framework led us to use a different model for the estimation of pure ammonia and ammonium nitrate (France), i.e. a VAR in first differences, whereas for the remaining output prices an ARDL model was applied. The fact that the ARDL model exhibits a more sophisticated lag structure than the VAR as well as allowing for the inclusion of delays of the explanatory variables, may drive the difference in results."

- *Page 109 paragraph 4*

The cost pass-through rates as a tool for policy:

"Therefore, we would state that the estimated cost pass-through rate in this research is only giving an indicative value and can by no means be interpreted as 'absolute truth'. It provides a conjectured estimate of the amount of costs that seem to be passed through in the product prices. It is by definition true that this amount is larger than 0%, but the exact amount of costs passed through is difficult to discern precisely. This also implies that it is difficult to base a decision regarding carbon leakage risk and the free allocation of emission allowances on estimated cost pass-through rates alone."

- *Page 61*

"The potential to pass-through carbon costs cannot unequivocally be interpreted in terms of carbon leakage. It may have been the case that costs were passed through but that market shares were lost"

- *Page 147*

Passages from the executive summary:

The econometrics

"Finally, the results show that econometrics can be a valuable method to determine whether or not product prices contain carbon cost components for products with a relatively high carbon content."

- *Page 11*

The cost pass-through rates as a tool for policy:

"This study indicates that, in practice, industry often passes through a substantial share of the opportunity cost of freely obtained allowances."

- *Page 10*

Linking the estimates and their significance to trade intensity, market power, and transport costs:

"… this study presents quantitative evidence on other factors potentially influencing the process of price formation such as utilisation rates, market power and trade intensity…" … "Market power, both of the EU global markets and the concentration of power within EU markets, also seem to be important variables.

- *Page 10*

1.5 Reasons for implausibility of estimates

Far too short data period

An econometric analysis uses variation in data to reveal the underlying relationships between different variables. To do this, one needs sufficient variation in the data. For fertilizers, the analysis uses a period of 2 years (2013-Feb 2015), as this is where the vast majority of installations was included in the ETS.[10] This is a remarkably short time period, especially given the traditional long term price dynamics, and the enormous complexity of pricing in an industry with huge historical capital investments, large international trade flows and assets with a typical lifetime of 30 years. This makes it unlikely that an econometric analysis will be able to detect substantial effects from ETS price variations in a two-year period.

This problem is also acknowledged by the authors:

> *"we consider the data situation for econometrically estimating cost pass-through as far from ideal. In general, price data showed much unexplained variation and models did not always behave very well. Labour costs were insignificant in most of the cases which is unlikely…"*

The authors attempt to 'fix the obvious problem' by using data at a weekly level instead of monthly to '*ensure enough observations for a meaningful estimation*'.[11] However, this approach is more likely to do harm in the form of false confidence than to solve the problem of too few observations. In general, the frequency within the time period should match the frequency of the underlying economic process. Except for very liquid markets such as many financial products, price formation is quite rigid and price changes may not happen within several months.[12] This implies that adding high-frequency data does not add explanatory power to the long-run dynamics the authors are seeking to detect, but instead add short run dynamics, which in this instance is noise, disguised as statistical power.

Lack of important control variables

The authors are estimating a model where the domestic price is only based on domestic input costs. This is inconsistent with the fact that there is significant import of fertilizers in the EU. Urea is being imported into EU at the highest level ever,[13] implying that the total cost of producing abroad and delivering into EU should also play a role in determining the price in the EU. Factors such as the natural gas price in competing regions and transport costs into EU should have been included in the analysis.

Importantly, the authors do not include any effect from changes in demand in the period. The problem is that the ETS price may wrongly be 'given credit' for an effect on the output price which is in fact driven by changes in demand. This is likely to be true, as the global

10 Except for two time series: AN in UK (Jan 2011-Feb. 2015) and Urea in NL (Sep 2009-Dec 2014).

11 CE Delft (2015), page 100.

12 For EU intermediate products on average, price changes occurs approximately in 4 month intervals, cf. Vermeulen et al. (2007).

13 Almost 4.000 kt. according to Eurostat and data from Fertilizer Europe.

demand for fertilizers and the ETS price have increased simultaneously in the period of consideration[14]. Moreover, the same increase in demand is likely to reduce the negative impact on the fertilizer price due to the falling natural gas price. This is also recognised by the authors, but is not incorporated into the econometric exercise.[15]

Critique of the cointegration selection process and interpretation

In CE Delft (2015), the test for cost pass-through rest on the test for cointegration. We have identified a number of issues related to their estimation and model selection procedure, which are likely to lead to unreliable test results and misinterpretations.

Firstly, the authors do not seem to test and specify the lag-length correctly before testing the residuals. Given their selection procedure, this may incorrectly favour the use of an ARDL model over the VECM whereby their test for cointegration and thus long-run cost pass-through becomes unreliable.[16]

Secondly, the authors essentially test for cointegration twice in the same model, without adjusting their testing criteria accordingly. Hereby, the test procedure has a *trial-and-error form*, resulting in a positive bias towards not rejecting cointegration and thereby cost pass-through in the model. Specifically, the authors test for cointegration both in the VECM and again in the ARDL model, while seemingly forgetting that the ARDL model is nested in the VECM.[17] From the principals of general-to-specific testing, if the test for cointegration is rejected in a model, it is rejected in all models that are nested within this model.

In addition to this, there are a number of other issues with the estimation procedure, which we illustrate in Appendix A.

Not enough variation in the ETS cost

An econometric analysis basically requires variation in the underlying variables to detect relationships between the variables. However, the ETS price remained very stable as well as very low during this period. [18] By contrast, other and much more important costs elements changed considerable cf. Figure 5 but with no estimated effect on sales prices. This creates many risks in terms of getting biased results.

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14 See for instance FAO (2015).

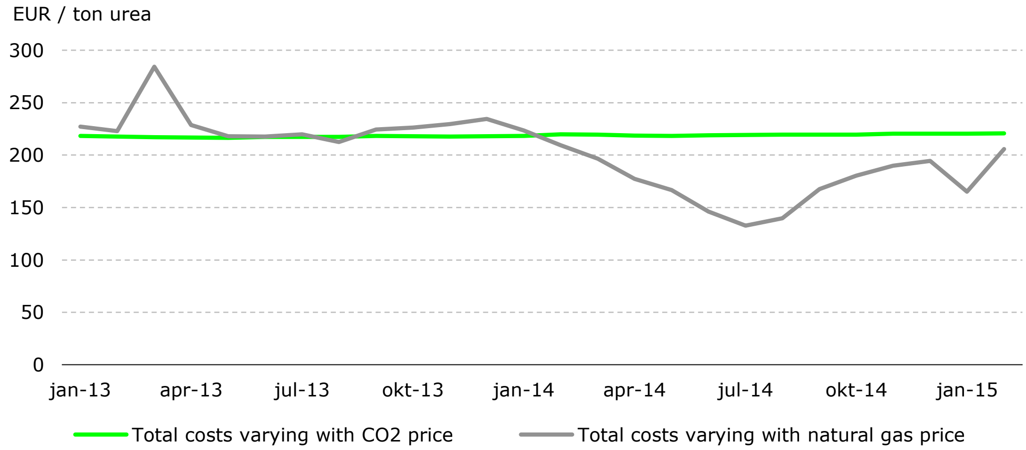
15 See e.g. page 109 in CE Delft (2015).

16 When using an incorrect lag-length, the authors will often reject the test for well-specified residuals, and their model selecting procedure suggests the use of an ARDL model, meaning that all other variables beside the fertilizer price is restricted as exogenous. Since the latter restriction is done on the basis of wrong initial specifications, the test for cointegration will be unreliable.

17 An ARDL model can be found as a reparameterization of a VECM with only one exogenous variable. This means that after restricting the VECM to only having one exogenous variable, the likelihood for the VECM and ARDL is the same.

18 According to data from SendeCO2, the ETS price varied between 3,5 €/ton and 8,5 €/ton over the period considered here.

Figure 5 Changes in total production costs from ETS and natural gas prices



Note: We have used an average price for the period in question: January 2013 - February 2015 for both natural gas in Europe and the ETS price

Source: Copenhagen Economics based on Integer Research, European Energy Exchange and SendeCO2

This problem is also recognised by the authors:

"As CO_2 costs are relatively small, the results are very sensitive against the quality of the data, especially regarding the price of outputs."

"Low carbon costs may hamper the econometric analysis... Cost pass-through of carbon costs representing only a small share of the final product price are therefore more difficult to discern than cost pass-through of substantial carbon cost shares."

1.6 Implications for leakage-policy design

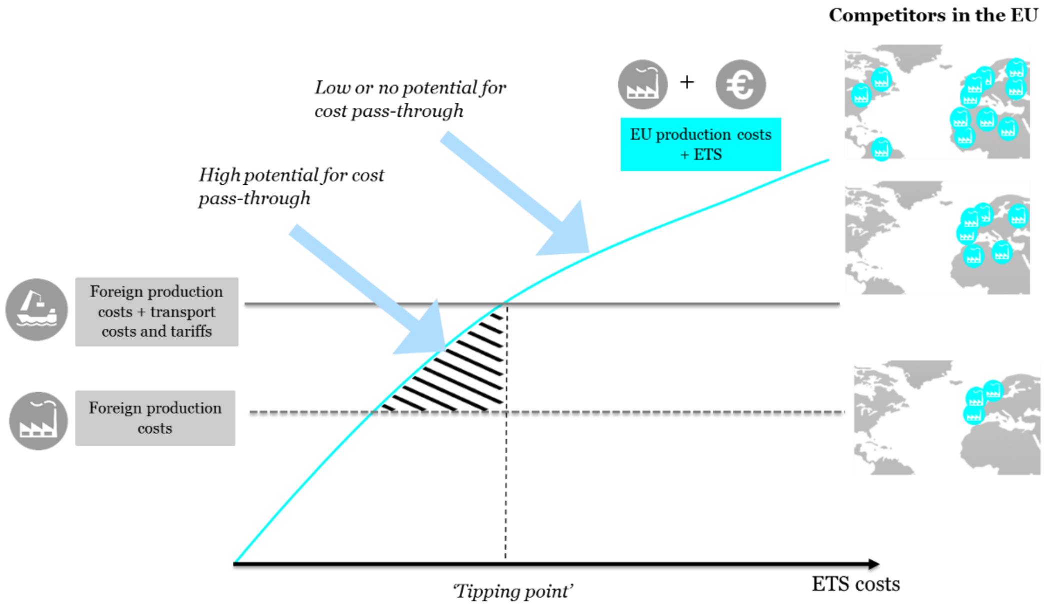
In this section, we explore how a positive CO_2 cost pass through estimate should be interpreted in the debate on future leakage-policy design. We argue that even if the CE Delft (2015) results had been accurate, they would not add useful information on the risk of leakage going forward.

Our main point is that the risk of carbon leakage is crucially linked to the cost differential with respect to competing countries.

An industry such as the fertilizer industry is characterised by tradable, homogenous goods and non-trivial transport costs. The resulting market structure is relative local geographical markets as long as production costs are quite similar. However, as cost differentials increase, the 'shield' offered to domestic producers by transportation costs (and tariffs), will not be strong enough. We refer to the point where foreign produces goods becomes economical as the 'tipping point':

As long as cost differentials are below this 'tipping point', EU producers will have a potential to pass through costs without facing significantly increased foreign competition (the shaded area in the figure), cf. Figure 6. In this area, the cost pass through potential will depend on the elements such as the competitive nature between EU firms and the price elasticity of domestic consumers.

Figure 6 Pass through dynamics and the 'tipping point' in tradable but not fully commoditised industries



Source: Copenhagen Economics

However, when the cost differential between EU and non-EU production exceeds 'the tipping-point', the potential to pass through increased ETS costs is significantly reduced, as the new competitors are <u>not</u> facing the same costs. In this situation, it is no longer the price responsiveness of domestic consumers that determine the pass through potential, but domestic consumers' willingness to substitute domestically produced goods for foreign goods.[19] If this elasticity is high (which it is for homogenous goods e.g. fertilizer products such as urea), and foreign production capacity is available, the ETS cost pass through potential is effectively zero. The larger the cost differential between EU and non-EU production, the higher the number of potential foreign competitors and the less possibility to pass through ETS costs.

19 Referred to as the Armington elasticity in economic modelling literature.

Our argument is that while it may be the case that EU producers have been able to pass through costs in the period of January 2013-February 2015, this provides no valuable information about the risk of carbon leakage in the future nor the right policy to address it. The average ETS price in that period was app. €5/ton. Going forward this is likely to increase perhaps tenfold, affecting the cost differential to competing producers substantially. Consequently, any potential for cost pass through can quickly be eradicated. This may even take place for relatively small cost increases if the cost differential is already close to the 'tipping point'.[20]

Moreover, even if cost pass-through rates can be sustained e.g. by a strong advantage from having nearness to the market, carbon leakage may still occur in the absence of sufficient leakage-compensation. This is the case if EU based producers can benefit from moving production facilities abroad while still profiting from its near-market relationships.[21] Major EU based companies like Yara, Borealis and OCI have in fact already started investing abroad, seemingly with an intention to cater for the European market.

20 See Copenhagen Economics (2015) for more on this.
21 See e.g. Yara (2015), Borealis (2015) and OCI (2015).

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Appendix A
Technical critique of the cointegration estimation

In this appendix, we argue that the estimation approach applied in CE Delft (2015) is problematic on a number of issues. Issues that cast doubt over the validity of the estimates and importantly their interpretation.

How can cost pass-through be tested in a Vector Error Correction Model and an Error Correction/Autoregressive Distributed Lag model?
These models can predict either a long-run mechanism or a short-run mechanism in the behavior of the prices: 1) The long-run mechanism indicates whether the prices are structurally and over time affected by the variables in question (equilibrium relations) and 2) The short-run mechanism where shocks to a price may have an influence on other prices in the short run, but where the effects fade out over a relatively short horizon.

Whether or not a cost (such as the ETS) will be passed-through in product prices is a question of whether there is a long-run relation between the ETS price and the product price. There are three necessary criteria that must be fulfilled to establish that ETS costs have been passed through:

1. That a long-run equilibrium mechanism exists between the prices, i.e. that cointegration is not rejected in the model.
2. That the equilibrium adjustments happen through the output-prices, i.e. that the coordinates of ϕ representing the effects on the output price are significantly negative in equation (M1*) (see below)
3. That $\beta 1$ is significantly positive (equation M1*).

Let P_t represent a vector of non-stationary endogenous price variables for $t = 1, \dots, n$ with $P_t = (P_t^j, P_t^c, P_t^L, P_t^E, P_t^M, P_t^K)$ and j the fertilizer product, C carbon, L labour, E energy, M materials, and K capital. Then the estimated VECM model is

$$\Delta P_t = \Pi P_{t-1} + \sum_{k=1}^{p-1} \Gamma_k \Delta P_{t-k} + \epsilon_t \ ,$$

where the matrix Π contains information about the long-run relationships among the price of the product and the prices of its inputs. For the single-term cointegration case,

$$\Pi P_{t-1} = \phi \left(P_{t-1}^j - \alpha^j - \beta_1 P_{t-1}^C - \beta_2 P_{t-1}^L - \sum_n \beta_{3n} P_{n,t-1}^E - \sum_q \beta_{4q} P_{q,t-1}^M - \beta_5 P_{t-1}^K \right) \ (M1^*).$$

Here, there are several kinds of energy and material inputs, α_j is the long run price level, and β_1 is the effect of the carbon price.

If any of criteria 1.-3. is rejected, any price pass-through is also rejected.

Problems in the estimation procedure of CE Delft

While the theoretical section 3.3 of CE Delft (2015) is broadly consistent with the approach outlined above, in practice there are important deviations. Specifically, the criteria for price pass-through, which the authors state as being correct, is not what is actually being done in both the general section 3.3.4 and in the specific analysis on fertilizers in section 4.4.6.

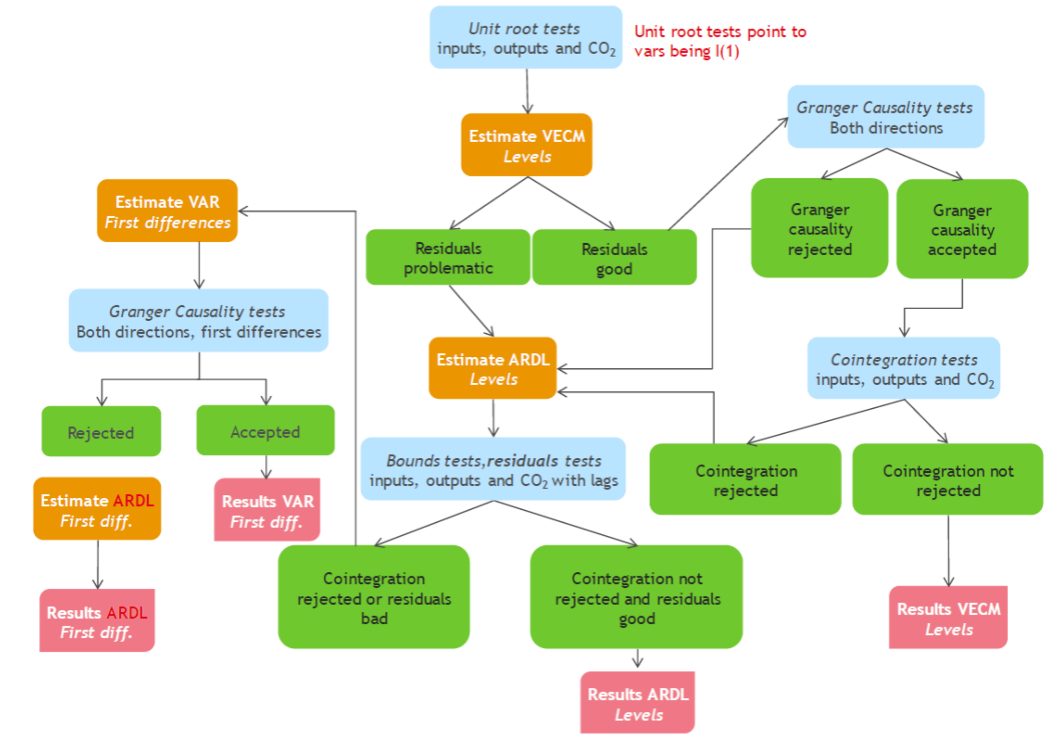
The most important problem is that the perceived evidence of cost pass-through strongly appear to be misinterpreted by the authors.[22] For 7 out of 8 fertilizer products, the authors are actually rejecting the long-run cointegration relation. This implies that the authors are in fact rejecting that there have been any cost pass-through between the ETS and the 7 fertilizer products.

Yet, CE Delft (2015) proceeds to estimate an ARDL in FD model and VAR in FD, which by definition only contain short-run dynamics, and presents these results as long-run relations between ETS and the fertilizer prices in Table 19, page 107. This is wrong, and in contradiction to the authors' own theoretical section in Section 3.3.2.

In addition to this, there are a number of other issues with the estimation procedure (depicted in Figure A.1) that questions both the validity of the results and their interpretation:

[22] CE Delft (2015) Table 19.

Figure A.1 The estimation procedure in CE Delft (2015)



Source: CE Delft (2015), page 55

Issue 1:
The authors seem to be testing the residuals before testing for the correct lag-length. This is problematic – especially in the test for autocorrelation – because if the lag-length is incorrect there is a high risk that the model will be poorly specified. This is especially a concern as the authors use data of rather high frequency.

Issue 2:
After having found a well specified model with 'good residuals' (which includes testing more than just for autocorrelation in the residuals as the authors state), the procedure should go directly to the cointegration test (and not the Granger Causality test). The reason is that the trace test and other tests for cointegration are robust to a situation where some variables are specified as endogenous even if they actually are exogenous. However, the cointegration tests are not robust to a situation where some variables that actually are endogenous are specified as exogenous.

Issue 3:
After the test for cointegration one may test for weak exogeneity of the variables, but such a test does depend on the cointegration rank, which is why it is critical to test for cointegration (finding the cointegration rank) before testing for weak exogeneity.

Issue 4:
In the case that all other variables beside the output price are weakly exogeneous, we end up in the situation with a univariate VECM model, i.e. an ECM model. This is actually the same as an ARDL model, just with rearranged terms. As a result, it is not correct to say that an ARDL model is better or easier to estimate / more flexible – it is basically the same model and has the same log-likelihood.[23]

Issue 5:
As there is no difference between an ECM and an ARDL model – it will be wrong to do any tests, and especially the test for cointegration, multiple times, as the authors are doing. If the cointegration test (and therefore the test for price pass-through) is rejected once it is rejected for good. It is not common practice to perform the same test multiple times with marginally different specifications. If done, the chance of not rejecting the hypothesis naturally increases.

[23] It may be the case that some statistical packages are more flexible or have more features when estimating a ARCL model, but that is another matter. In an ECM model, it is also possible to estimate with flexible number of lags for different exogenous variables.

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