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Methods for Evaluating the Performance of Emissions Trading Schemes

Discussion paper

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About Climate Strategies

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Table of Contents

1. INTRODUCTION

Robust analysis of emissions trading schemes (ETS) and their design is crucial for improving performance, and learning lessons from pilot exercises. It has been a vital component in the evolution of maturing programmes such as the European Union Emissions Trading Scheme (EU ETS). A range of options is available to conduct evidence based *ex-post* analysis, drawing on methodologies from a range of fields. This report provides a short summary of assessment methodologies that have been used to evaluate different operational aspects and outcomes of existing trading schemes, a literature which to date draws primarily from the EU ETS experience. We also discuss the applicability of these different methods for evaluating the performance and design aspects of the Chinese pilot schemes.

In Section 2, we review literature evaluating the **operational aspects** (e.g. prices, market activity, transaction costs) of emissions trading. These aspects are key to understanding the functioning of ETS as a trading market, and can be assessed from the very inception of the schemes and throughout their lifetime. Section 3 reviews the literature evaluating **the outcomes** (e.g. emissions reductions, innovation activity, trade effects and employment) of ETS schemes. These evaluations tend to be conditionial on the availability of panel data, hence can be conducted once the trading scheme has become more established. This review is focused on the areas identified to be of key interest for evaluating Chinese pilot schemes and where empirical evaluation has already been conducted.

Sections 2 and 3 give a synthesis of how empirical assessment of these operational aspects and outcomes has been conducted to date, by focusing on the following key questions:

- *Why is it an important dimension for evaluation?*
- *What methods and metrics have been used for assessment?*
- *What data are required?*

Section 4 provides key recommendations for evaluating the Chinese pilot schemes. Overall recommendations are made in light of timings and availability of data, as well as specific recommendations for each dimension of assessment discussed in this report.

2. EX POST ASSESSMENT OF THE OPERATIONAL ASPECTS OF EMISSIONS TRADING

Operational aspects are important to assess the efficient functioning of an emissions trading market, which enables meeting emissions reduction goals at least cost. Evaluating and comparing the performance of the Chinese pilots on these aspects can provide better understanding of how the different designs influence the operation of the carbon markets. It can also help identify the most suitable market design structure in the Chinese context, in terms of both efficiency and feasibility.

2.1. Carbon Prices

Why is it an important dimension for evaluation?

The prices of carbon allowances are a key indicator for the functioning of any ETS. They can reveal a great deal about the efficiency of the scheme. Moreover, price data is readily available and the high frequency of the data makes it ideal for statistical analysis. At the most basic level, examining the prices at which allowances are traded can provide information on the overall costs of the system to business, along with the marginal abatement cost at any one time. At a system level, examining the evolution of prices can inform as to whether there has been over-allocation of allowances, compared to demand. A key indicator that the EU ETS in Phase I had allocated far too many allowances, and therefore didn't create a binding constraint on firms, was the collapse of prices to almost zero in 2006. In addition to informing on allocation, prices are also a key indicator of market health (in terms of the price reflecting scarcity and providing economic incentives to drive mitigation). Examination of the evolution of prices in an efficiently operating market can help to understand what the marginal abatement option has been at any particular time, and how this evolves with the market and time. Comparing prices between different systems then indicates the variability of marginal abatement options across jurisdictions. Allowance prices can also provide crucial information about whether trading has been effective in reducing abatement costs. For example Ellerman et al (2010) used the evolution of carbon prices in the EU ETS to identify coal gas switching in the power sector as the key marginal abatement option used in Phase I of the scheme.

What methods and metrics have been used for assessment?

Allowance prices are one of the easiest metrics to assess. Data is often readily accessible from exchanges and is easy to compare across jurisdictions. Even though low volumes and distorted prices can cast doubt on the usefulness of price data to analyse the external factors driving price development, it is still of value to check the prices and their variance in order to assess the effectiveness of any price stabilization tools/mechanisms used in schemes. In-depth analysis of what is driving prices, and how they have evolved requires complex techniques, depending on the exact question being asked.

A key question asked of carbon allowance prices is what the underlying drivers of price changes have been, and how large of an effect different potential drivers such as energy prices and weather have had on overall prices. Examples of studies exploring this issue include Wei et al. (2008), Alberola et al. (2008), Creti et al. (2012), Mansanet-Batallier et al. (2007) and Hintermann (2010). Techniques for examining this depend on the exact nature of the question being asked and how authors have perceived the relationship between variables. Multivariate linear regression is the most basic tool that has been applied to these types of questions and is a simple and easy methodology to implement. Alberola et al (2008) used the technique to examine the drivers of carbon prices in Phase I of the EU ETS finding that energy prices,

extreme changes in weather and crucially political institutional decisions were the most prominent factors in determining price changes. However, this technique may be problematic, as it requires treating likely endogenous variables such as electricity prices as exogenous, leading to potentially biased coefficients. Other methods that have been applied to answer similar questions are cointegration techniques that are more relevant when it is believed that there is an inter-dependency between variables and potentially bi-directional causality (see Wei et al. 2008), Creti et al. 2012), such as between energy and carbon prices; and structural modelling (see Hintermann et al 2010). Cointegration techniques are probably the most suitable technique to examine these questions, given the lack of strict exogeneity between key variables such as carbon and energy prices. This technique should be used with caution, however, to avoid the identification of spurious long-term equilibrium that are not grounded in theory. To understand how the introduction of carbon prices may change the long-term equilibrium of emissions and economic activity baseline shift decomposition analysis can be utilised such as that used in Delaquil et al (2012) in the US.

A further area of examination in relation to carbon prices has been on the factors that explain volatility, and whether this changes as emission trading systems evolve. Examples of studies that examine this question include Obendorfer (2009), Benz and Truck (2009), Feng et al (2011). This area of work has drawn heavily on methodologies adopted from the financial economics literature such as Markov switching and Generalised Autoregressive Conditional Heteroscedasticity (GARCH) models. These techniques allow examination of the drivers of price fluctuations and whether they are stable across time. Important findings from the literature on the EU ETS are: the relationship between carbon price changes and stock market performance of large European electricity firms (see Obendorfer, 2009), the importance of both internal market mechanisms and the heterogeneous external environment in driving price volatility (see Feng et al, 2011). These methods provide useful information on the nature of the volatility that carbon prices have experienced, thus informing the nature of the price formation process. They are also superior to alternative techniques in financial economics such as Auto-regressive Conditional Heteroscedasticity (ARCH) models that require estimation of a wider set of parameters. The main limitation is that it does not reflecting asymmetric behaviour, i.e. treating positive and negative returns in the same manner, and a tendency to underestimate events at the extreme ends of the distribution. Nonetheless it is currently considered the most appropriate technique to examine carbon price volatility.

What data are required?

The examination of the determinants of carbon prices, and how they have evolved in relation to other factors requires large quantities of price data and also data on factors such as weather and energy prices. Most analysis that has been conducted in this area has used daily price data. Although this is a data-intensive area this data is readily available in most jurisdictions through weather stations and energy exchanges.

2.2. Market activity

Why is it an important dimension for evaluation?

An important element to examine in assessing the overall performance of ETS is the market activity, above and beyond price dynamics. Important questions to ask are who has been involved in buying and selling allowances? how many different firms are purchasing? how many are not trading? and why? One key motivation for this investigation is to determine whether market power is present, making the system vulnerable to manipulation of markets by key actors.

Such assessments of market activity are crucial to understand whether markets are operating efficiently – allowing the full benefits of emissions trading to be realised. These assessments are of value to investors, risk managers and environmental policy makers alike and are vital in understanding what incentives are being created for firms to invest in low-carbon technologies and what carbon management strategies are being employed. Conducting such analyses across schemes with different design features, such as the pilots in China, are useful in helping to understand the impact that these different features, and sectoral coverage, have had on overall market efficiency.

What methods and metrics have been used for assessment?

Market activity encompasses a number of different dimensions and questions and thus a range of methodologies and metrics have been utilised to examine the area. Many of these methodologies have been adopted from the field of financial economics and focus on viewing the emissions market as similar to other commodity markets – however broader metrics can be adopted if clear objectives of the emissions trading scheme are outlined although this has not been widely conducted in the literature to date. A key concept tested in the literature has been the efficient market hypothesis. This hypothesis states that markets can be thought to be efficient if current prices incorporate all available information, and therefore no actors are obtaining rents. This basic hypothesis has formed the basis for a number of papers that have examined the question with regard to the EU ETS. These examinations have focused on techniques adopted from the finance sector such as variance ratio tests of prices and serial correlation tests of spot and future market data (for example see Montagnoli and de Vries, 2010). One interesting methodology adopted has been the comparison between trading strategies based on technical analysis rules and naïve forecasts to examine the potential returns available given the market data (see Daskalakis and Markellos, 2008). A key question asked in this analysis is how 'thick' or 'thin' trading has been – i.e. whether there has been a large or low level of trading. Too thin trading can affect, adversely, the efficiency of the market – negating potential gains from trade. Understanding the level of trading, whether through examination of trade volumes, or through econometric analysis of prices as conducted by Montagnoli and de Vries (2010) is an important first step towards understanding market activity.

Further questions that require different methodologies are whether firms have exercised market power. Via examination of allowance holdings Hintermann (2015) found that excessive holdings of allowances by some electricity firms in the EU ETS was consistent with strategic price manipulation. Similar examination of allowance holdings has underpinned much of the work undertaken by the NGO, Sandbag, who have examined the behaviour of firms and market power across a number of studies. These assessments are relatively simple to undertake, if suitable data on allowance allocation, trading and holding, and verified emissions are available, or can be computed from comparable data. The work undertaken by Sandbag in Europe demonstrates that simple data analysis can produce powerful results. The limiting factor is often the availability of data.

Beyond the EU ETS an interesting approach to the question was adopted by Coria et al (2010) who examined trading behaviour in Chile's particulate matter and NOx emission trading system. They aimed to examine questions as to who was trading, and crucially who wasn't and why not. Given the lack of available quantitative data they adopted a qualitative methodology, interviewing firms regarding their activity. This technique is extremely useful in situations where quantitative data is unavailable, but can be problematic in terms of eliciting accurate responses from firms, and being able to access the key decision-makers with these firms with the right expertise. These problems could be partly overcome through careful design of the qualitative instrument used, and a combination of self-reported and objective, observable metrics for firms within the ETS.

What data are required?

In order to assess market activity and behaviour detailed information on prices, trading volumes, and allowance allocations is required. The experience from Chile, however, shows that in the absence of this data analysis is still possible through the collection of primary qualitative data regarding firms' behaviour. A combination of these approaches may offer the strongest analysis.

2.3. Transaction costs

Why is it an important dimension for evaluation?

Transaction costs are defined as the resources required to establish programmes, comply with, and trade in an ETS. Both governments and firms can incur them. According to Ellerman et al (2009), in aggregate, transaction costs are usually small compared to the costs of abating emissions. However, there are many different types of transaction costs. For firms, transaction costs include setting up emissions monitoring and reporting, hiring an emissions verifier each year and trading allowances. For governments, there are transaction costs to establish the legal framework, processes for monitoring and accreditation of verifiers, establishment of

an emissions registry and trading platforms and allocation activities. Additionally there are transaction costs associated with enforcing compliance. The existence of transaction costs will impact on the economic efficiency of an ETS, i.e. reduction emissions at least cost. They represent "deadweight losses," as they divert resources away from efforts to abate emissions. It is therefore necessary to identify the different types of transaction costs faced by both firms and governments, and evaluate the incidence and permanence of these costs.

What methods and metrics have been used for assessment?

Although the academic literature highlights the impact of transaction costs on market efficiency, only a handful of studies exist that estimate the incidence of such costs and few are disaggregated into individual cost components. For examples, see Aether (2010), Frasch (2007), Heindl (2012), and Jaraite et al. (2010). These analyses are predominantly based on small samples, using firm-level transaction costs data and survey techniques with market participants. Due to time and financial constraints, there is a trade off between depth, breadth and certainty of analysis. In-depth interviews with a small number of market participants will reveal the type and value of transaction costs faced by individual firms. However, the number of interviewees will need to be sufficiently high to ensure certainty and objectivity of responses or else the analysis should be highlighted as indicative. In-depth studies may be most suitable for highly concentrated industries. For example, Frasch (2007) interviewed multiple employees at three firms that have a high, medium or low exposure to the EU ETS. The high exposure firm is one of four companies in the German power market. A typology of transaction costs is offered to interviewees including: application, implementation of emissions management, monitoring, reporting, abatement measures, trade and strategy. Different typologies of transaction costs are offered across the reviewed literature. Generally, the higher the number of survey respondents, the more aggregated the typology of transaction costs. This makes comparisons across studies challenging. More detailed interviews will enable researchers to identify, if any, design aspects of an ETS that could be adapted to reduce the incidence of different transaction costs. However, given the high number of market participants, a more limited survey might be most appropriate for evaluating the Chinese provincial and future national ETS.

When designing a survey, further consideration could be given to whether the firm resources are spent internally (e.g. staff costs or capital investments) or externally (e.g. consultancy costs or external verification costs), if costs are one-off (e.g. early implementation costs) or regular and if the costs vary with the number of allowances traded. Once collected, these transaction costs can be presented in their individual subcomponents (see Jairaite et al., 2010) or in aggregate or as a percentage of the allowance price (see Fransch, 2007). Given the different design features and sectoral coverage of the Chinese Pilot ETS, transaction costs as a proportion of total allowance costs may provide a useful comparison across schemes. Responses may be aggregated by industry (see Aether, 2010), by company size (see Jairaite et al., 2010) or may be scaled up and used to estimate the aggregate transaction costs for all

market participants (see ETG, 2008). There are no established methodologies for estimating and categorising the transaction costs incurred by governments. Ex-post evaluations may be conducted internally and may include disaggregated measures such as time spent by staff in meetings for particular policies or more aggregated measures such as budget spent by government departments, legislators and public agencies. McCann et al (2005) offer a useful typology of transaction costs associated with public policies and who incurs the cost.

Ex-ante estimates are obviously less certain. Recognising the challenge of accurately estimating administrative costs, the European Commission (2008) limits their assessment of different design options on transaction costs to a relative assessment (i.e. + or -). Alternatively, transaction costs could be estimated based on the costs of implementing a policy of an equivalent scale or a trading platform of equivalent anticipated size in the same jurisdiction as the proposed ETS. An example of this approach can be found in Pope & Owen (2010).

What data are required?

If conducting surveys of firm level transaction costs, a registry of participants is first required to ensure a representative sample. If the study aims to distinguish between early implementation costs and on-going transaction costs, interviews should be conducted with firms at least 1 year after the ETS commencement according to Jaraite et al. (2010). Due to the difficulty of isolating firm-level ETS transaction costs from other operational and investment costs, it may be worthwhile considering developing a typology of transaction costs that link to MRV systems. For example limiting the measurement of firm level internal transaction costs to the monitoring and reporting of emissions.

3. EXPOST ASSESSMENT OF THE OUTCOMES OF EMISSIONS TRADING

Assessing outcomes is important in order to understand the extent to which the objectives of the ETS are met: in terms of providing a carbon price signal aligned with the long term mitigation objectives of regulated sectors. This is both in the short term through incentivising energy efficiency improvements and changes in operational behaviour, and also the long term through providing incentives for investment and innovation in low carbon technologies. Strong carbon price signals will not emerge if incentive distortions arise from the design of ETS.

In addition, policy goals need to be balanced with multiple impacts of ETS, such as on pollution, employment, trade, productivity and innovation. Understanding how ETS impacts these outcomes is important because estimates of these effects will foster the fine-tuning of policy choosing designs that are most suitable and efficient for the national Chinese ETS in the future.

3.1. Emissions

Why is it an important dimension for evaluation?

The main objective of an ETS is to incentivise participants to reduce greenhouse gas emissions. To evaluate the effectiveness of an ETS, emissions reductions will need to be compared to a counterfactual baseline that approximates the level of emissions that would have occurred without an ETS. Emissions reductions can be measured this way at an economy-wide and industry level.

What methods and metrics have been used for assessment?

According to Ellerman (2009), a simple way of estimating a country-level counterfactual emissions baseline is to extrapolate the historical relationship between GDP and emissions. However, many additional factors could also influence annual fluctuations in emissions including weather, energy prices and changes in the structure of an economy. Econometric modelling using time-series data has often been used to quantify all ETS and non-ETS drivers of economy-wide emissions. The counterfactual emissions baseline is then calculated as the emissions that would have arisen without an ETS and this is compared to actual verified emissions. Examples of studies which use this approach include Ellerman & Buchner (2008), Delarue et al. (2008), Deutsche Bank (2010), New Carbon Finance (2009), Abrell et al. (2011) and Egenhofer et al. (2011). An important challenge, which has not yet been addressed fully in the literature, is to isolate the effect of ETS from other climate policies including renewable technology policies.

Carbon prices can be used as an explanatory variable in assessing the introduction of abatement measures for a particular industry. The most common example of this is the role of carbon pricing in changing the relative prices of fuel, which can lead to fuel switching in the power sector when the dispatch order can be changed. The likelihood of an ETS leading to fuel switching can be calculated ex-ante by estimating price elasticities of fuel demand in power stations in the proposed ETS region. In the literature, elasticities have been calculated using Translog cost functions, generalised Leontief cost functions, or discrete choice models. Ex-post analyses to determine the impact of a particular carbon-pricing scheme on fuel switching can also be conducted using econometric methods. For examples see Considine & Larson (2012) and Kirat & Ahamada (2011).

What data are required?

A precursor to any study estimating the emissions reductions due to an ETS is credible installation emissions data. In the case of the EU, this is publicly available information from the European Union Transaction Log. There is a time lag before the data is published to avoid disclosure of competitive information. For ex-post analyses, emissions data is also required before the scheme's inception to ensure the accuracy of a business-as-usual counterfactual. When the aim is to estimate the impact of carbon pricing on changes in emissions, additional time series data is needed on

output (for example on the value and volume of output at both the installation and macro-level) and inputs (for example fuel prices, and technical fuel switching potential for individual power plants) both at the local and national level to develop counterfactual scenarios.

3.2. Innovation and productivity

Why is it an important dimension for evaluation?

In today's knowledge-based economy, innovation is a key factor in determining firms' long-term competitiveness. It is no surprise therefore that researchers have been keen to establish if there is a link between environmental regulations and technological change. If the carbon price signals are sufficiently robust, ETS can offer regulated firms an economic incentive to make operational changes and investments that reduce the emissions intensity of their output. The 'induced innovation' hypothesis proposed by Porter (1991) suggests that part of this new investment will be directed towards developing new emissions-reducing technologies. At the same time, because pollution control diverts some production factors away from production towards non-productive activities, including other R&D investments, environmental regulation may also hamper productivity growth.

What methods and metrics have been used for assessment?

Most studies that have investigated the innovation impact of the EU ETS rely on interview-based methodologies, to elicit information on whether the carbon prices arising from the ETS affects the innovation activities of regulated companies. However, most studies analyse small unrepresentative samples. For examples see Hoffmann, (2007); Tom´as et al. (2010), Anderson et al. (2011). Martin et al. (2011) takes extra precautions to ensure consistency across interviews with different firms, and they conduct the largest study to date covering 450 EU ETS firms in 6 countries.

Calel and Dechezleprêtre (2014) is the most comprehensive quantitative study exploring the link between carbon pricing and innovation, using firm level patent portfolios as a proxy for innovation activity. They use a non-parametric matching econometric approach matching regulated with non-regulated firms. They show that the EU ETS has increased innovation activity in low-carbon technologies among regulated companies by 10% compared to a counterfactual scenario. They also assess if increased innovation activity in low carbon technologies is crowding out innovation in conventional technologies and find no such effect. Alternatively, the impact of carbon pricing on innovation activity can also be assessed by identifying their effect on R&D expenditures (see Jaffe and Palmer, 1997), environmentally related patents (see Brunnermeier and Cohen, 2003) or the development of energy efficiency technologies (see Popp, 2002 and Verdolini and Galeotti, 2011). It may be that increased costs of compliance work to crowd out general R&D expenditures, and this should show up in empirical work in the area.

What data are required?

Using matching method to develop a counterfactual such as in Calel and Dechezleprêtre (2014) is an ambitious undertaking and requires very disaggregated high quality data on firm level patenting data, firm level data on key characteristics of firms (main activity, age, size, output, assets, employee number and so on), and regulatory status with respect to carbon and other environmental regulations. In the Chinese context as the regulated entities are registered with local/National Industrial and Commercial Administrative Bureaus this should be a practical task.

3.3. Trade and investment

Why is it an important dimension for evaluation?

Assessing the impact of ETS on trade is mainly driven by concerns that implementing climate policy triggers production of carbon intensive goods to migrate to regions with relatively lax climate policy. "Operational leakage" is the replacement of domestic with foreign production triggered by climate policy. "Investment leakage" is the replacement of investment in domestic production capacity with investment in foreign production capacity due to climate policy. Finally "carbon leakage" is the implied environmental consequences if production shifts abroad because of climate policy, because emissions will also be transferred abroad, such that part of the emissions reduction achieved by the policy is offset and the contribution to the overall reduction of global GHGs emissions is reduced.

What methods and metrics have been used for assessment?

The effect of ETS on trade is highly heterogeneous across sectors depending, for example, on transport costs. Hence as a starting point, it is important to first identify the sectors that are genuinely at risk of leakage, and focus the assessment of trade effects on these sectors. To do so, two quantitative metrics have been developed in the literature: carbon intensity and trade intensity. These metrics have also been applied in to Chinese data at the national level by Wang (2010).

To quantify the trade effects, Reinaud (2008) uses a simple linear regression to study the effect of the EU ETS on EU's trade in aluminium. She regresses net imports of aluminium on the year-ahead EUA price and other control variables (EU 27 aluminium consumption, aluminium prices, price premiums for delivery in Europe and US/EU exchange rate) using quarterly data from 1999- 2007. The model is problematic because it does not allow for separating the effect of the EU ETS from other factors that cause the upward trend in net imports during the period. She also uses a Chow test to see if the introduction of the EU ETS leads to a structural break in net imports, but found no evidence to support this. Sartor (2012) similarly examines the effect of the EU ETS on net imports of aluminium using linear regression, but uses different controls including coal and natural gas prices, and finds no trade effect. Ellerman et

al (2010) also uses a simple linear regression and finds no trade effect in the EU ETS Phase 1, for aluminium, cement and steel.

Costantini and Mazzanti (2012) uses a more sophisticated econometric regression using a dynamic specification with fixed effects (system GMM or generalised method of moments) proposed by Blundell and Bond (1998) and a gravity model framework to control for other determinants of trade flows. They regresses the impact of EU ETS Phase 1 on net imports for a broader range of sectors and find positive and negative effects depending on the sector. Branger et al (2013) uses a longer panel (monthly data from 1999 to 2012 with carbon prices from 2004), controls for EU construction levels and industrial output, uses a new variable which proxies international demand (industrial output in BRICS countries), and also uses several time-series estimation techniques (ARIMA and Prais-Winsten estimation), all of which contributes to improving the robustness of the results. They find the EU ETS has had no effect on cement and steel trade in Phase 1 and 2.

Neuhoff et al (2014) instead uses non-econometric methods to assess whether the EU ETS caused operational leakage and investment leakage in Phase 1 and 2 in the cement sector. They use descriptive statistics to illustrate the relationship between consumption, production and net imports of clinker, and find that the main driver for rapid growth in clinker imports leading up to 2008 was the imbalance between EU capacity and demand. They also used interview methods, to elicit cement industry executives views on the likelihood of investment leakage, and concluded that thus far it is very small.

What data are required?

Assessing the relative exposure risk of sectors to leakage and competitiveness impacts in terms of the carbon intensity requires detailed data on their emissions (including direct, indirect from electricity and process emissions) and a common denominator, such as sector gross value added. In addition to assess their ability to pass on carbon costs to consumers using the trade intensity metrics, data on imports and exports volume is necessary both locally and internationally.

To look at trade effects or operational leakage for the Chinese pilots, first and foremost, a panel of trade data for the regulated sectors (or companies) in the region covered by each pilot is required. The data must be disaggregated by sector or company such that the sample can be specific to regulated sectors/ companies. The data should also distinguish between trade with the rest of China or against international trade partners, so that the domestic and international leakage can be assessed separately. In addition, estimating the effect of ETS on trade requires controlling for factors also influencing trade flows such as local demand, prices, input prices and so on, and data on these are necessary at the correct level of regional disaggregation.

Investment leakage by its nature requires a longer time frame to observe impacts, and is not necessarily correlated with carbon prices, and analysis would require qualitative data for example through industry interviews.

3.4. Employment

Why is it an important dimension for evaluation?

Potential changes to employment are a key economic concern for governments in an era of unilateral carbon pricing policies. In addition to creating the incentive for emissions reductions, carbon prices may also change the cost structure for firms. In the EU there has been a lot of discourse on the risk of leakage, if economic activity relocates to outside of the carbon-pricing region there could also be a relocation of labour. However, it is extremely challenging to isolate the impact of an ETS on changes in employment in a carbon-pricing region. For example, in Arlinghaus (2015) it was concluded that both job creation and job losses could be attributable to changes in output, labour productivity, and the structure of the economy. These other factors are likely to have a stronger impact on employment than any ETS. In a review paper by Martin et al. (2014) there has been limited evidence that the EU ETS has impacted employment in firms covered by the scheme.

What methods and metrics have been used for assessment?

Only a limited number of studies empirically analysed the employment impacts on firms in the EU ETS. The most detailed study is by Abrell et al (2011). Here the authors match EU ETS firm across all Member states with a firm of similar observable characteristics in a non-ETS sector via propensity score matching. Chan et al (2013) use a similar approach but match ETS firms with non-ETS firms in the same sector over a longer period of analysis using a 'difference in differences' technique. Both studies find that the ETS had no impact on employment.

Commins et al. (2011) use a panel regression to evaluate the impact of carbon taxes on employment levels for ETS and non-ETS companies between 1996-2007. Anger and Oberndorfer (2008) use a simple ordinary least squares regression with instrumental variables to evaluate the impact of ETS allocation methods on employment. Employment can also be included as one of a number of impact variables in ex-ante analysis using general equilibrium models. For examples of this see Manders & Veenendaal (2008) and Alton (2014).

What data are required?

As discussed, matching techniques are data intensive, particularly if they focus on firm level micro data, which may come from a number of different sources. According to the findings in Abrell at al. (2011), firm level data, correctly categorised by sector, is necessary as the employment impacts will not be uniform across all participants. If

the focus of the analysis is on the impact of allocation methods on employment, only a few years of data before and after the ETS's inception is required. However, due to labour market rigidities, there are likely to be lags in the impact of employment impacts of firms covered by an ETS so a longer time series is required if all impacts are to be evaluated. The availability of data will guide which methodological approach is chosen.

4. RECOMMENDATIONS FOR THE EVALUATION OF CHINESE PILOT SCHEMES

This report has examined the assessment methodologies that have been used to examine three types of operational aspects and four major outcomes (desired or otherwise) of emissions trading schemes. A wide-range of techniques has been applied to examine each of these areas, with a number of lessons for their application to developing future trading schemes. Much learning has happened in pioneer schemes such as the EU ETS and a number of recommendations can be drawn from this experience for conducting evaluation of the Chinese pilot schemes. Here we present some overarching recommendations for assessment, along with recommendations specific to each of the seven examined dimensions.

Overarching recommendations

- The Chinese ETS pilots have all been developed under different regulatory frameworks. It would be useful to assess possible regulatory differences in the various pilot projects and identify best practices to inform the creation of a national Chinese ETS market.
- A key recommendation is to focus initially upon the dimensions that can be assessed with the available data. This is likely to be focused upon operational aspects, for which the data should be available throughout the duration of the schemes, and emissions impact from the outcome section, for which again data should be readily available.
- Assessment of the other outcomes requires high-quality data, which only emerged in the EU ETS a number of years after the Phase I, the pilot phase. This delays the time-scale on which these aspects can be assessed and evaluated. However even if these aspects cannot be evaluated yet, data relevant for later evaluation could and should be collected in order to conduct later analysis.
- Understanding what has driven prices, and how emissions may have deviated from BAU scenarios are perhaps the two key aspects of understanding the impact of ETS, and specifically how design features that vary across the different pilots may have had differential impacts on objectives. These are relatively easy aspects to assess, with data more likely to be readily available

and prioritisation of these dimensions of operations and outcomes may be beneficial.

- Data transparency is a key issues for facilitating assessment of emissions trading schemes. Standardised MRV systems and regulations including common boundaries of measurements and timings of data collection as well as clarity on emission factors used can go a long way in removing obstacles for the comparative evaluation of different ETS schemes. While disclosure of firms' confidential and competitive data is a major concern, it has been shown that in the EU this can be overcome by disclosing the data with a lag or 2 years or so, whether such a lag is suitable in a Chinese context needs to be examined.
- A number of challenges have arisen in the EU regarding reconciliation of emissions and allowance data at the installation level, with economic data available at the firm level. In the Chinese context, the emissions data is collected at the firm level rather than the installation, hence challenges may arise when matching firm level emissions data with sector level data on output or trade, particularly with large firms operating across several sectors. Addressing these issues at an early stage and working to reconcile available data is a valuable exercise.
- An integrated approach to assessment should be adopted that evaluates impacts of multiple policies, including price and non-price, to reflect the wider policy environment. This will allow an understanding of the relative effects of emissions trading vis-à-vis non-price policies to be understood and evaluated.

Carbon prices: Analysis of the evolution of prices is a vital first step in the examination of the functioning of any ETS. Data is likely to be available and examination of prices across schemes can help to highlight any difficulties with allocation of allowances or the functioning of markets. It may also help to highlight different marginal abatement opportunities that may have arisen in different jurisdictions due to differing economic or geographic factors or sector coverage.

Market activity: It is recommended that analysis of the differing levels of market efficiency be conducted across different market designs. This will allow elucidation of the key features from each that can most assist in creating a strong, credible efficient national market.

Transaction costs: Uniquely to China, there may be the opportunity to evaluate transaction costs across different design features of the schemes if an equivalent sample of stakeholders were interviewed across the schemes. Such an analysis would need to consider the trade offs between cost and accuracy and perhaps prioritise which transaction costs are most of interest or could be influenced by the policy design. It may also be beneficial to evaluate transaction costs on an industry-by-industry basis, trade volume basis or by company size.

Emissions: The main objective of an ETS is to incentivise emissions reductions. Emissions reductions can only be measured if a credible counterfactual baseline can be provided. If regional data on economic output, market activity and additional possible explanatory variables such as weather is available, a consistent method of establishing an emissions baseline is possible. Otherwise, the focus should be at industry level, including the impacts of carbon pricing on fuel switching in the power sector.

Innovation and productivity: A comprehensive study on the effects of ETS on innovation requires high quality and detailed data at the level of the regulated entity such as a firm, including a variable that captures their level of activity in technology innovation. The most used proxy in the literature is patent counts, however, those using Chinese patent data have encountered problems in the past regarding reliability. This is less the case for technology patents, more relevant to the present case, though it would be valuable if alternative measures of innovation of ETS regulated and non-regulated firms could be sought and collected, including R&D expenditure. To use matching techniques, data has to be collected also for non-regulated firms, in order to provide a counterfactual to assess the effect of ETS on regulated firms. The combination of data constraints and low carbon prices to data to date suggests it is not advisable to prioritise the quantification of innovation effects for the pilot schemes in the short term, however, interview techniques such as those used in Martin et al. (2011) will be useful for obtaining information on how best to reform ETS in order help drive innovation in regulated companies.

Trade: While carbon prices are low, limited trade effects are expected. It is legitimate to assess potential trade effects if China's carbon price in the future is expected to be significantly higher than its trading partners. If it is the case that the effect of international trade is of concern, rather than domestic trade, the analysis of trade effects should focus on those pilot schemes that cover plants that are particularly exposed to foreign competition (e.g. export dedicated plants). Given the nascent nature of carbon pricing in China and the absence of a historic data to conduct ex-post analysis here, potential leakage effects will be better evaluated through the use of sector specific in depth analysis using descriptive data and qualitative methods as used by Neuhoff et al (2014).

Employment: Similar to studies on innovation, employment studies require highly disaggregated and detailed firm level data over a number of years. For studies using matching techniques, additional data may also be required on for non-ETS firms. Given the data requirements and limited evidence of employment impacts in existing ETS schemes, this should also be a low assessment priority in the short term.

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