Assessment of Shanghai Emissions Trading Scheme's impacts on targeted sectors and the city economy

Contract n°TA-8178 PRC: Advancing Shanghai Carbon Market through Emissions Trading Scheme

Consortium leader: SinoCarbon Innovation & Investment CO., Ltd

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List of acronyms

AIM	Asia-Pacific Integrated Model
AR5	Fifth Assessment Report of the IPCC
AUD	Australian dollar
BASIC	Building and Strengthening Institutional Capacities on Climate Change in Brazil, India, China and South Africa
BAU	Business as usual
CES	Constant Elasticity of Substitution
CGE	Computable general equilibrium
CO_2	Carbon dioxide
DART	Dynamic Applied Regional Trade
DRC	Development and Reform Commission
ELC	Extremely low carbon
ETS	Emissions Trading Scheme
EUR	Euro
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IETA	International Emissions Traders Association
IMACLIM	IMpact Assessment of CLIMate policies
IPAC	Integrated Policy Model for China
IPCC	Intergovernmental Panel on Climate Change
LC	Low cabon
MMRF	Monash Multi-Regional Forecasting
NDRC	National Development and Reform Commission
PRC	People's Republic of China
PRCGEM	PRC General Equilibrium Model
RECIPE	Report on Energy an Climate Policy in Europe
RMB	Renminbi
SEEE	Shanghai Energy and Environment Exchange
SHEA	Shanghai Emissions Allowance
UNFCCC	United Nations Framework Convention on Climate Change
USD	US Dollar

I. Introduction

Background information

The main objective of this document is to help in the assessment and the analysis of the Shanghai cap-and-trade scheme for the control and the reduction of atmospheric pollution in Shanghai in the People's Republic of China (PRC). The modeling tools reviewed and presented are intended to help policy makers and regulators define a target for emissions reductions and understand the pros and the cons of the various targets.

This document is part of a larger exercise funded by the Asian Development Bank, on "Advancing Shanghai Carbon Market through Emissions Trading Scheme". The latest intends to answer to such questions as: What are the impacts exerted by ETS on Shanghai's overall economic development and certain industries? How to set the total emissions for Shanghai as a whole and for certain industries in order to encourage carbon mitigation at the same time, boosting economic growth in Shanghai? How to allocate allowances? How to set up rational baseline allocation standard for specific industries? How to develop and regulate carbon market? How to improve market liquidity and deliver a booming market by carbon finance innovation?

The document focuses on how to use models to set total allowances cap for Shanghai as a whole and for certain industries. This is a central part of any ETS and thus determines whether emissions reduction can be realized and whether it is effective or not. The cornerstone of a sound ETS is to set rational total allowances cap and allocate allowances to all included enterprises, which requires thorough information including emission data of included industries and enterprises, technological development, emission reduction potential and future economic growth demand. Pilot cities among which is Shanghai, must overcome the difficulties caused by the lagging development of statistics system and lack of basic data and make sure to allocate allowances to included enterprises in a fair and rational way.

Shanghai is at a rapid development stage and PRC is the world's largest developing country. As the first developing country in the world that has established a carbon cap and trade system, PRC has rather limited international experiences to learn from in terms of solving the conflict between an ambitious emission target and economic development.

On November 12, 2014, President Xi announced targets to peak carbon dioxide emissions around 2030, with the intention to peak sooner.

At the same time, the need to reduce emissions is becoming more urgent, as recommended by the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) published in 2014. And China, as the main emitter, with a total amount of emissions in 2012 of 9,860,000,000 tons of CO_2, or 7.1 tons per capita, is increasingly concerned by reducing its CO_2 emissions. In this vein, on November 12, 2014, President Xi announced targets to peak carbon dioxide emissions around 2030, with the intention to peak sooner.

Scope of the report

The purpose of this document is to provide a preliminary assessment of the economic impacts on targeted sectors and the whole city economy of Shanghai under different emission caps through economic modeling. It provides some insights on the existing ETS. It explains how to build a scientific and rational economic model and how to use it. This requires reviewing existing researches on the modelling approach. Existing models are presented about economy impacts of carbon market policy, in order to define the most appropriate model approach.

Generally speaking, the models used for impact assessment of climate and energy policy are divided into two types: top-down models and bottom-up models. Both of the two types of models can be used in an ETS's impact assessment. An important aspect about modeling lies on the assumptions made and policy scenarios. For defining the modeling approach, key modeling assumptions based on Government plan and other former researches are discussed.

Due to the fact that it was not possible to access to all the data, the report does not enable to present quantitative results. Instead, some options are recommended about policy scenarios and compare GHG emissions abatement costs estimates in the Chinese and Shanghai context. In Shanghai, most of CO_2 emissions come from several sectors, like ferrous metal processing industry, petrochemical industry, chemicals industry, power industry and aviation industry. But data are not made available for confidentiality reasons. Reviewing former researches and field surveys enabled however to complete a GHG emissions abatement cost analysis. Finally, recommendations to develop a model to capture and assess the likely economic impacts of Shanghai ETS on the targeted sectors and city economy, and to the ETS cap and sector caps of Shanghai ETS pilot, are provided.

The Shanghai ETS: from the preparatory work to the first anniversary

The modeling approach relies on an economy where risk neutral firms produce goods to satisfy an inelastic demand and are endowed with permits by the regulator in order to offset their pollution at compliance time and avoid having to pay a penalty. This is the key policy development proposed in the outline of the 12th Five-Year Plan on National Economic and Social Development in 2011.

The 12th Five-Year Plan sets targets to cut carbon intensity by 40% to 50% by 2020 and to reduce per capita GDP emissions by 17% by 2015, relative to the 2005.

In this 12th Five-Year Plan, the idea is to cut carbon intensity by 40% to 50% by 2020 and to reduce per capita GDP emissions by 17% by 2015, relative to the 2005 levels. In order to reach these objectives, the decision was made to gradually build up a national emission trading system.

Issued in November 2011, the Work Plan for Controlling Greenhouse Gas Emissions during the 12th Five-Year Plan Period reiterated the significance of creating a carbon market in PRC. Around the same time, the General Office of National Development and Reform Commission released the Notice on Carrying out Pilot Program of Emissions Trading Scheme (hereinafter referred as the "Notice"), approving the seven pilots, in 4 municipalities (Beijing, Tianjin, Shanghai, Chongqing), 2 provinces (Hubei and Guangdong) and in one special economic zone (Shenzhen).

Shanghai is one of the seven pilots to implement an Emissions Trading Scheme (ETS) in China.

These above mentioned seven trial operations kicked off end of 2013/beginning of 2014, aiming to drive carbon market mechanism development in PRC, and to achieve the target of reducing greenhouse gas emission at lower cost and speed up the low carbon transformation.

As one of the pilot, Shanghai has been actively planning and advancing the overall design of an emission trading scheme in Shanghai pilot. Shanghai Development and Reform Commission (DRC) is in charge of the overall design and implementation work. Also, Shanghai DRC released the list of covered enterprises on November 29, 2012. In the design and implementation stage, Shanghai may run into problems and challenges, to name just a few, how to set its overall emission target that aligns with PRC's national emissions control target, how to set total emission targets for different sectors, how to allocate allowances to company level, how to promote carbon market development and how to diversify carbon finance products.

Some of these difficulties can be dealt with by drawing the experience of countries and regions including the European Union, California, Australia, etc. Some international models developed for the design and implementation of these ETS will hence be presented.

On November 27, 2013, the Shanghai ETS was launched, the second after Shenzhen, with a quotation of the price under the Shanghai Environment and Energy Exchange (SEEE). On June 30, 2014, it completed its first compliance period.

Three years of permits for free were handed over in a one-off allocation in 2013, and it allows companies to bank surplus permits to use over the following years. 160 million permits were issued overall for the compliance year 2013, and more than 1.5 million permits changed hands in the seven first months since the market opened. Approximately one year later, the price fluctuated to a highest price of 50 RMB.

In the first part of the document, we are undertaking a state of the art of the economic research on the economic impacts of carbon markets. The question of the availability of the data and of aggregation is also discussed. We then raise the issue of the abatement costs estimates in Shanghai, given the limited access to data and information.

Part two is reviewing in details different CGE models used for carbon mitigation policies. Models developed for China have also been identified and analyzed, in order to select the most relevant parameters and develop a modeling approach for the assessment of the economic impacts of an ETS in Shanghai. Top down and bottom up models are enumerated with their advantages and drawbacks.

The construction of a CGE model is also presented. We discuss the different hypothesis, assumptions and parameters before constructing the model. Scenarii and targets of the model are defined.

A last part is dedicated to recommendations given on how to implement the Shanghai ETS, presenting some first analysis of the first year during which the Shanghai ETS was implemented.

II. What does the economic research say about emissions reduction?

Back to basics: a short theoretical background

On the theoretical point of view, the question of how to best reduce emissions reductions has been discussed at length by economists. Market-based instruments, such as cap-and-trade mechanisms, are generally preferred over taxation because the cost of emitting provides flexibility to the emitters at least cost, and create a continuous incentive for improvement. The principle of an ETS is that, through a market mechanism, a carbon price is reflecting the marginal cost of emitting an extra unit of carbon dioxide (or of any other greenhouse gas measured in terms of its carbon dioxide equivalent). Hence, firms will lower their greenhouse gas emissions up to the point where the loss of profits from reducing emissions by a further unit – the marginal abatement cost – just starts to get bigger than the price it has to pay for continuing to emit that unit. This approach is considered as the most effective to reach the environmental target.

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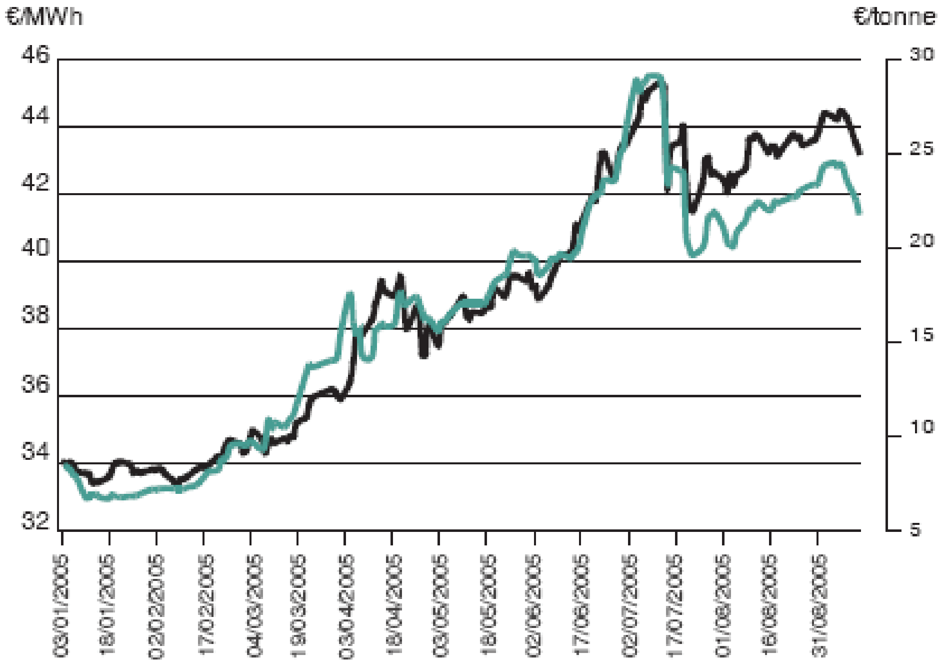
In such a market-based mechanism system, also called a cap-and-trade system, the issue for policy markers is not the trading part, but rather the determination of the cap. This strongly determines the level of the price, which should in theory be set at the marginal damage cost of a unit of emissions. Economically speaking, the price reflects the present value of the economic cost caused by one extra unit of greenhouse gas while it is in the atmosphere known as the social cost of carbon. This is where the emissions reduction objectives set by policy makers determine the level of the price. The main papers debating about the matter are Stern (2007), Nordhaus (2008), Ackerman and Stanton (2010), Dietz (2011), to cite a few.

While the microeconomic representation of a cap-and-trade is easy, the macroeconomic figures and the measurement of its impacts are much more difficult to grasp. Not surprisingly, research and modeling rely on a very small variety of indicators with simple hypothesis.

Energy and emissions: a strong correlation

Combustion of fossil fuels is by far the dominant source of greenhouse gases (IPCC, 2007). When assessing emissions reductions on the economy, energy-related parameters are therefore important in the equation. Interactions between climate change, energy and the economy have been deeply studied during the past decades. For more than twenty years, a particular attention has been paid to the impact of energy use on climate, among others to understand the complex links between economy, energy policy and environmental issues. It is therefore not possible to assess the impacts of any emissions reduction policy on the economy without taking into account and understanding the economy of the energy sector. The literature is rich to have a better understanding of the energy economy, energy markets and linkages with the overall economy (Trieu and al, 2013, IEA, 2013).

The energy-related parameters are mong the most important when assessing emissions reductions on the economy.



Correlation between the price of electricity and the price of a European allowance under the EU ETS (source : *European Energy Exchange*).

Looking at the European Union ETS (EU ETS) is useful: the most significant emitters, and ultimately compliance buyers, are power production companies, and their investment strategy, since the launch of the EU ETS in 2005, is relying on the so -called "triple play": coal, gas and carbon.

For instance, the graph below presents the price of electricity in Europe expressed in € per MWh (dark blue), and the price of an carbon allowance, expressed in € per tone of CO_2 (light blue).

Also, many models assume limited flexibilities and opportunities for substitution in the way emissions reduction are achieved, limited availability of low-carbon technologies, high baseline emissions, or high emissions of non-CO_2 greenhouse gases, or a combination of these factors and thus find it infeasible to achieve low stabilization (Tol, 2009).

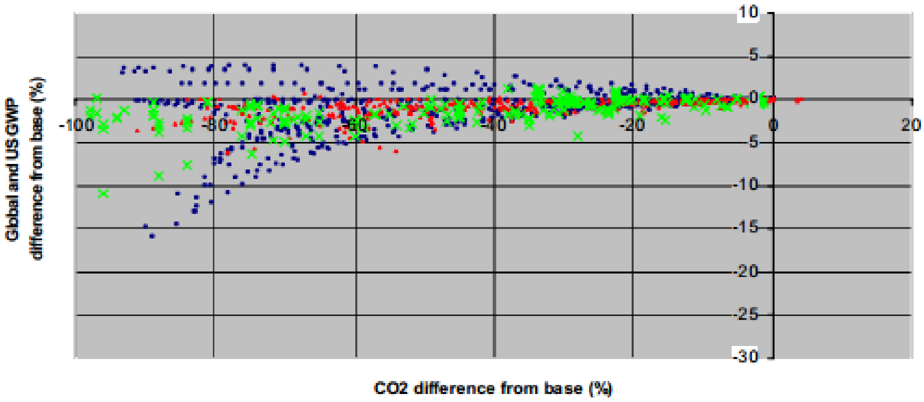
A key research issue in setting a cap-and-trade scheme: what are the economic impacts?

Another important question in designing an ETS for policy makers concerns the expected economic impacts of setting such a system. To evaluate the economic impacts on targeted sectors under different capping scenarios, modeling is a powerful tool giving some quantitative insights for policy decisions.

Different models can be implemented in order to appreciate impacts of the cap-and-trade scheme. The advantage of the modeling is that it can cover various economic sectors selected on greenhouse gas (GHG) emission levels criteria. As far as Shanghai is concerned, the coverage is on production industries such as iron and steel, petrochemical, chemical, non-ferrous, electricity, building materials, textile, paper, rubber, fiber. The ETS could include or already covers service industries like airlines, ports, airports, railways, commercial, hotels and financial.

Since the Kyoto Protocol negotiations and implementation, it is accepted that in the long run the impacts of an ETS are limited to less than 1% of a GDP's country, considering obviously that this depends of the emissions reduction targets. The Stern Report (2007) compares some models, looking among others at the impacts on the GDP of the United States.

At a global level, annual costs of stabilising at around 550ppm CO_2e are likely to be around 1% of global GDP by 2050 according to the Stern Review (2007).



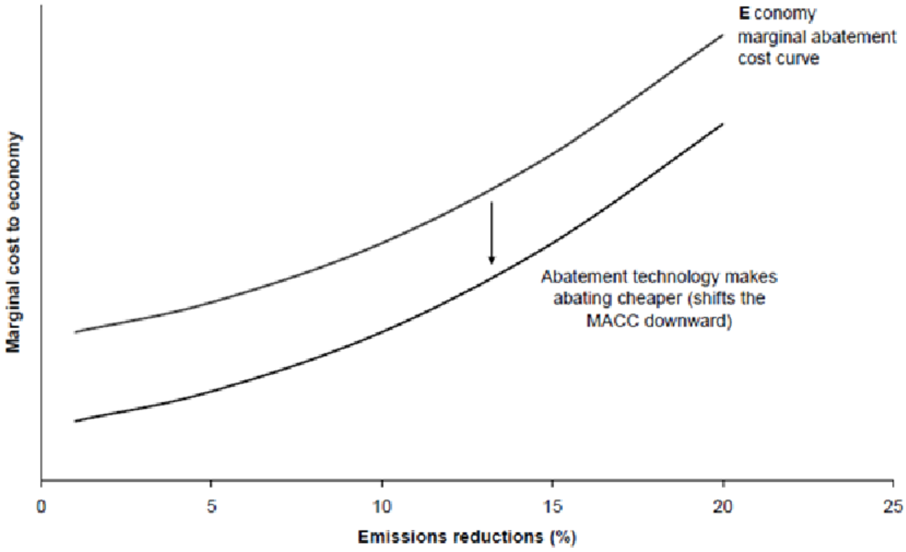
Model cost projections scatter plot, costs of CO_2 reductions as a fraction of world GDP against level of reduction, using three different datasets (IMCP, post-SRES, WRI) (Stern, 2007).

Behind the implication for the economic of GHG emissions reduction, the question of the abatement costs is central.

Literature review: a focus on abatement costs

The costs for each individual sectors of mitigating climate change have to be estimated to run any model. It varies depending on the capacity of firms to reduce their emissions in an economically efficient way. Their capacity to adjust depends strongly on the technical ability of a less emissions-intensive production process. The problem is that it is difficult to estimate how cost-reducing technological advances will be developed. Therefore, effects of technological advances are uncertain and they require the formulation of assumptions. Generally, endogenous technological advances are not modeled. The best is to run a model with different scenarios, each of them with a technological change induced by the carbon price.

Assumptions have to be adapted to the timeframe considered. For example, in the future, major technological breakthroughs could occur (for example finding 'geo-engineering' ways of extracting greenhouse gases from the atmosphere) and the ease with which businesses and households can substitute low-carbon products for currently high-carbon ones can vary over time. These factors have very different impacts depending on time horizon over which one is looking. Depending on the time scale chosen, those potential advances can be taken into account or not in the estimation of abatement costs.



Effect of technology advances on the abatement costs (from NZIER, 2009).

Moreover, each type of industry doing the abating has its own abatement cost. The cost of reducing CO_2 emissions will be different depending on technological characteristics of industries. One can simplify it with a single economy-wide cost of abatement, but it is based on strong assumptions (NZIER, 2009).

Two approaches can been used to estimate abatement opportunities, for combustion and non-combustion emissions. In the first case, improvement in energy efficiency is assessed when energy-saving technological is available. For a given price, the level of abatement is exogenous to the model. The cost of energy-saving abatement is taken into account as an increase in requirement for capital. This method represents quite well how abatement happens in practice: energy-saving technologies require investments.

For non-combustion activities, the assessment relies on the abatement activities dependant on the price of carbon. New technologies are appearing following the estimated abatement cost curves. The cost of abatement is taken into account in the production function via deterioration in inputs, increasing technological change (NZIER, 2001).

The costs to individual sectors (and hence the macroeconomic costs and benefits) of mitigating climate change vary depending on the ability of firms to reduce emissions in an economically efficient way. The ability of firms to adjust is largely dependent on the possibility of substituting towards less emissions-intensive production processes or materials and the development of cost-reducing technological advances. These effects are uncertain and require the use of assumptions. In general, endogenous technological improvements are not modelled, but we examine some scenarios with technological change induced by a carbon price (NZIER, 2009).

III. Modelling analysis: looking at computable general equilibrium models

Introduction to CGE for policy analysis

Back in the 19th century, Augustin Cournot has recognized the role of demand in a general equilibrium framework for the first time. Afterwards, Léon Walras incorporated the demand function into the model and he gave to the demand a central position in the relationships among markets. Today, the Walrasian theory is still applied and it is considered as one of the most useful conceptual tool. Latter, Arrow-Debreu (1954) and McKenzie (1959) have developed a full set of conditions for general equilibrium. Their models demonstrated the existence of equilibrium for a competitive economy without any loss of generality. Today, the standard approach of a CGE model is a simplified version of the Arrow-Debreu model. The continuous development of those models has led to a powerful tool to represent the full economy. Therefore, they are often used by policy makers to analyze the impacts of policies. CGEs contain this mechanism and so are also known as "price endogenous models": "*all prices must adjust until the decisions made in the productive sphere of the economy are consistent with the final demand decisions*" (Dervis, de Melo, Robinson, 1982). In this context CGEs appeared as a "*natural outgrowth of input-output and linear programming models, adding neoclassical substitutability in production and demand, as well as an explicit system of market prices and a complete specification of the income flows in the economy*" (Robinson, 1989) in the early 1970s.

CGE models are essentially structural, capturing market mechanisms explicitly, specifying explicitly demand and supply behaviors with roles for prices and demand and supply elasticities. In order to gain realism, the factor and products equilibrium concepts that come from the Arrow-Debreu general equilibrium theory are sometimes enriched by additional equilibria concepts and ad-hoc elements. Models are set in a continuum going from Walrasian to Keynesian models, and can be classified in different ways, e.g. according to the equilibrium concepts they include, the ad-hoc devises they have, their treatment of expectations, their size, etc. In any case, the Walrasian model is "*an uneasy host for incorporating macro phenomena*", not being still an "*acceptable reconciliation of micro and macro theory*" (Robinson, 1989).

Therefore, CGE models typically consist of a database that represents an economy benchmarked for a particular time period based on input-output tables. The database specifies the interactions and relationships between various economic agents including firms, workers, households, the government and overseas markets.

CGE models typically consist of a database that represents an economy benchmarked for a particular time period based on input-output tables.

The base case model is so-to-say shocked by changing a policy variable or an assumption about one or more parameters outside the model (so-called exogenous variables). Values for all other variables inside the model (so-called endogenous variables) are calculated from equations describing the economy, given numerical values for the parameters and the variables outside the model. The equations describing the relationships between economic agents exhibit a number of common features based on neoclassical economics (Mai and al., 2013).

Producers maximize their profits by buying intermediate goods and inputs and selling outputs to other domestic and international firms, households and government. There is a market for each commodity (goods and intermediates) and in equilibrium market prices are such that demand equals supply in all input and output markets.

In recent past until today, the characteristic of CGE modeling is to represent what happened when a new policy is implemented, i.e. how a new policy induces a change of allocation of resources between stakeholders in an economy. It has direct applications in understanding the consequences of policy changes and provides a better understanding of how policy changes affect economy.

CGE models are particularly well adapted to climate change policy because they can examine adjustments across all sectors of the economy to changes in energy supply and prices through changes in factor proportions and sectoral output levels (NZIER, 2009). In fact, the application of CGE modelling to climate change mitigation policy scenarios is even widespread, but may have understated the cost of meeting the targets by overstating the price elasticity of demand for energy (Beckman and Hertel, 2009).

The next section is reviewing some modeling researches done in various economies for climate mitigation.

A review of CGE modeling for climate change mitigation policies analysis

CGE models are particularly well adapted to climate change policy because they can examine adjustments across all sectors of the economy.

In the framework of an ETS, energy-environment-economy models have been developed by a number of researchers to analyze the impacts of an ETS, under various assumptions, on main economic variables (employment, energy consumption, economic incomes…). The results of these modeling exercises were often different in direction and magnitude.

Top-down models focus on economic relationships and bottom-up models, on technologic aspects.

The results obtained can vary significantly according to the model chosen. Two opposite structure are identifiable: the top-down approach focuses on economic relationships and the bottom-up approach focuses on technologic aspects. The main difference between these two approaches is the way to consider technology. In bottom-up models, technology is modeled through technical description and industrial economic parameters. Technology is considered from the point of view of engineering. Those models emphasize technological details, like technological progress or competition between technologies.

Typically, the effects of a carbon cap will be changes of the technology mix, fuel switching, change in the choice of a vehicle or change in energy consumption. Information concerning effects on economic growth will not be provided by the bottom-up model, nor the distribution of the cost of the cap across the different stakeholders.

On the contrary, in top-down models, the production function, which models the substitution among different production factors, takes into account the technology. The top-down models can cover lot of interactions across regions and sectors, and aspects of market distortions can be integrated through calibration to historical behavior in real economies. It means that the technologies, preferences, and behavioral patterns in the model coefficients are fixed, or at least exogenously defined. Substitution among production factors induces the movement of equilibriums and changes in behavior of economic actors (Fei and al., 2007).

Historically, the two approaches have been developed separately in order to answer to the issues of energy and economics decision making process. In order to fill the gap between the two opposite models, hybrid models have been designed to gather bottom-up and top-down approaches in a single model. It takes into account the technological specificities of the bottom up modems and the microeconomic decision process of the top-down models (Hourcade and al. 2006). Usually, both integrated models are able to be run independently. Many of the models currently used for mitigation policy assessment are hybrid models (Mai and al., 2013).

Most of the models are inspired by both of them, named hybrid structures. The choice of the model depends on the aspects one want to insist on (economic technical or social aspects) but also on the data available (Mai and al., 2013).

Several models developed for climate change mitigation policies under different scenario in Europe are presented and compared. These models were designed to implement for instance the EU ETS or taxation regimes..

Examples of CGE modeling applied for mitigation policies analysis in Europe

Reviewing existing models that have been developed is necessary, but one has to keep in mind that all the models are based on different assumptions, with different baseline scenarios and different policy scenarios. Therefore, the comparison of models is very difficult.

In Europe, effects of European ETS on competitiveness for European business have been studied by many researchers and economic institutes. Peterson (2003) uses for example the Dynamic Applied Regional Trade (DART) model.

The DART model is a global CGE model with regional as well as sectoral details. Within every region household and industry behavior is fully specified based on microeconomic foundations. The evolution of the economies over time is described by a sequence of single-period static equilibria connected through capital accumulation (Springer, 1998)

Another interesting modeling exercise to consider is proposed by the project entitled "Report on Energy a Climate Policy in Europe" (RECIPE). The economic adjustment effects of long-term climate policy are analyzed based on cross-comparison of the inter-temporal optimization models REMIND-R and WITCH, as well as the recursive dynamic computable general equilibrium model IMACLIM-R (Luderer and al., 2011).

IMACLIM-R, is a recursive computable general equilibrium model (Crassous and al., 2006) capturing explicitly the underlying mechanisms driving the dynamics of technical parameters, structural change in demand for goods and services and micro- as well as macro-economic behavioral parameters. The model considers open economies with international trade of all goods and CO_2 permits. A major feature of IMACLIM-R is the partial use of production factors (underused capacities, unemployment) due to sub-optimal investment decisions resulting from the interplay between inertia, imperfect foresight and 'routine' behaviours. This allows distinguishing between potential and real economic growth, and, more specifically, to capture the transitory costs resulting from unexpected shocks affecting the economy. In IMACLIM-R, climate policies can be a means of remedying market failures and implement no-regret options which are profitable in the long term but which are not taken under normal conditions due to myopic behavior. This property can also result in some kind of 'bi-stability' in the sense that initially large efforts are required to move the system from its current path (fossil based) to an alternative one (low-carbon) but little extra effort is required once it is located on this new trajectory.

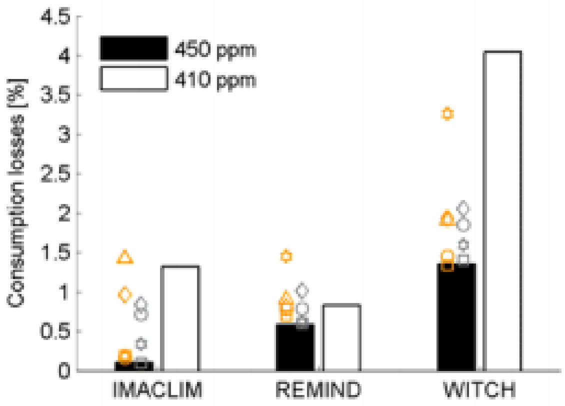
ReMIND - R is a global energy-economy-climate model. This global multi-region model ReMIND-R as introduced by Leimbach and al. (2009) represents an inter-temporal energy economy-environment model which maximizes global welfare based on nested regional macro-economic production functions. ReMIND-R incorporates a detailed description of energy carriers and conversion technologies (including a wide range of carbon free energy sources), and allows for unrestricted inter-temporal trade relations and capital movements between regions. Mitigation costs estimates are based on technological opportunities and constraints in the development of new energy technologies. By embedding technological change in the energy sector into a representation of the macroeconomic environment, ReMIND-R combines the major strengths of bottom-up and top-down models. Economic dynamics are calculated through inter-temporal optimization, assuming perfect foresight by economic actors. This implies that technological options requiring large up-front investments that have long pay-back times (e.g. via technological learning) are taken into account in determining the optimal solution. The ReMIND model is usually run in two modes.

A "business as usual" mode in which the global welfare function is optimized without constraints. This resembles a situation where the occurrence of climate change would have no effect on the economy and the decisions of the representative households in the regions.

A "climate policy" mode where an additional climate policy constraint is imposed on the welfare optimization. The constraint can take the form of a limit on temperature, CO_2 concentration, cumulative carbon budget, or CO_2 emissions over time. The mitigation costs of reaching the policy goal to meet the climate constraint is calculated as percentage reduction of net present value consumption or GDP to the business as usual case. The impact of a prspecified carbon tax can also be studied in ReMIND, although it is less straightforward. For such scenarios, the tax is implemented as a penalty on emissions. This tax as part of each regional budget constraint is counterbalanced by an fixed amount of tax revenues. The model is solved iteratively with adjusted tax revenues until these match the tax payments.

The WITCH model developed by the climate change group at FEEM (Bosetti and al., 2006, Bosetti and al., 2007) is a regional model in which the non-cooperative nature of international relationships is explicitly accounted for. The regional and inter-temporal dimensions of the model make it possible to differentiate climate policies across regions and over time. In this way, several policy scenarios can be considered. WITCH is a truly inter-temporal optimization model, in which perfect foresight prevails over a long term horizon covering the whole century. The model includes a wide range of energy technology options, with different assumptions on their future development, which is also related to the level of innovation effort undertaken by countries. Special emphasis is put on the emergence of carbon-free backstop energy technologies in the electricity as well as the non-electricity sector, and on endogenous improvements in energy efficiency triggered by dedicated R&D investments contributing to a stock of energy efficiency knowledge.

Luderer and al. (2011) compared the three models and conclude that for the default 450 ppm climate policy scenario, the aggregated mitigation costs in terms of consumption losses relative to the baseline aggregated over the period to 2100 and discounted at 3% amount to 0.1% (IMACLIM-R), 0.6% (ReMIND-R), and 1.4% (WITCH).



Aggregated global consumption losses for the three models (Luderer and al., 2011)

Global welfare losses as consumption differences relative to baseline for the first-best default 450 ppm (solid), the 410 ppm (dashed) as well as ranges for second best scenarios with limited availability of technologies (orange shading) or delayed climate policy (grey shading). Aggregated consumption losses are discounted at 3%.

Modelling in Australia: carbon tax versus ETS

Australia has had in the past years various positions regarding climate mitigation, one interesting being the introduction of a carbon tax announced in 2011. CGE modeling was then used to evaluate the effects of such a tax in the economy. Siriwardana, Meng and McNeill (2011), using general equilibrium calculations based on the model ORANI-G, show that an environmentally valuable reduction of carbon dioxide emissions in Australia through a carbon tax is achievable without major disruptions to the Australian economy. They conclude that the Government's target at that time of reducing Australia's emissions to 5% below 2000 levels by 2020 is plausible with an 23 AUD tax with minimum adjustments. Similarly, the MMRF model (Adams et al., 2008) studies the economic impacts of climate change mitigation in Australia. MMRF determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Marginal abatement cost curves were also added to MMRF to capture the response of both fugitive and industrial process emissions in response to emission pricing. The set of industries covered by these curves was expanded from those used previously in MMRF, and the parameterisation of these curves was adjusted.

Impacts of ETS on particular sectors have also been studied in Australia where consequences of ETS on electricity system have been modeled (Yusuf, 2008).

Climate change mitigation and examples of CGE modeling in China

In China, the Development Research Center of State Council has developed a CGE model in order to answer to various questions concerning the future trend of industry structure in China, the environmental impacts of the industrial trend and the impacts of a pollution limitation policy on economic growth and on the structure of industry (Teng and al., 2007).

Research about the link between energy policy and economic growth in China has begun in the end of the 1980s with energy planning models. Afterwards, because of the growing environmental issues linked with greenhouse gas emissions, an environmental component has been introduced in the developed models, aiming at a sustainable development. A significant number of models have therefore taken into account new energy policies, with for instance Clean Development Mechanisms.

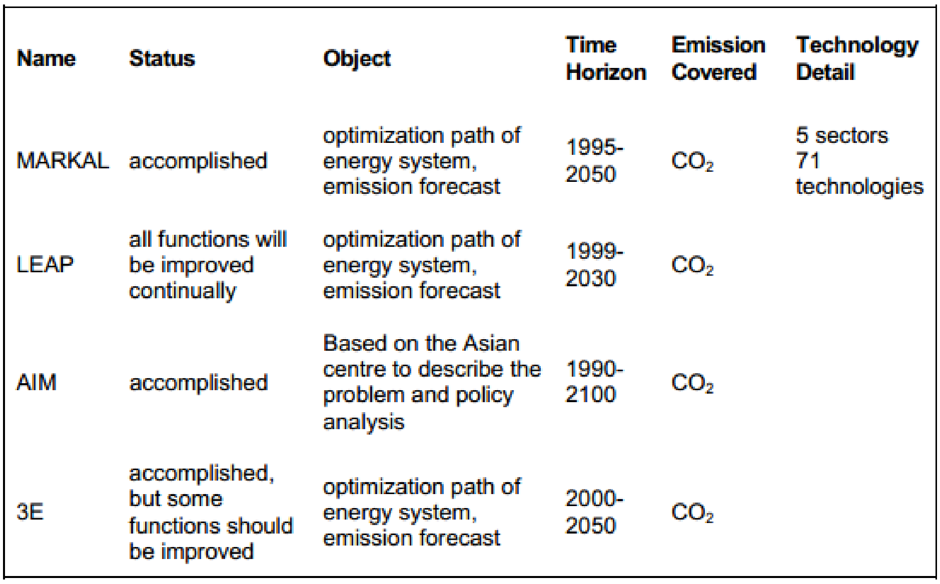
The bottom-up approach has been particularly used to work on interactions between energy, environment and economy. One of the limits of the models developed so far is that they have seldom taken into account some of the characteristics of China, for example rapid technological changes or non-commercial energy use in the rural regions and it seems that those aspects should be more often taken into account in models (Teng and al., 2007).

One of the most well-known models in China is the Integrated Policy Model for China (IPAC). This model relies mainly on a top-down approach. In the business as usual scenario, the economy is the main driving force, with high consumption pattern, significant concern on environmental protection, and with technology progress. In a low carbon scenario, it is more driven by domestic forces and measures, with combined forces such as a new energy technology adoption, energy savings, enhanced technology innovation and development, energy security and economic competitiveness. It includes cost reductions of low carbon technologies and some investment on a low carbon economy.

The general findings from the low-carbon scenario compared to business as usual are that CO_2 emissions are reduced by 44%, and primary energy by 26.8% (Liu, 2009). Models based on a bottom-up approach have also been developed in China, such as the energy-technology AIM/END-use model. In this model, technology selection is based on a linear optimization framework. Total costs are minimized by several constraints, for instance service demands or energy supply (Miyashita, 2006).

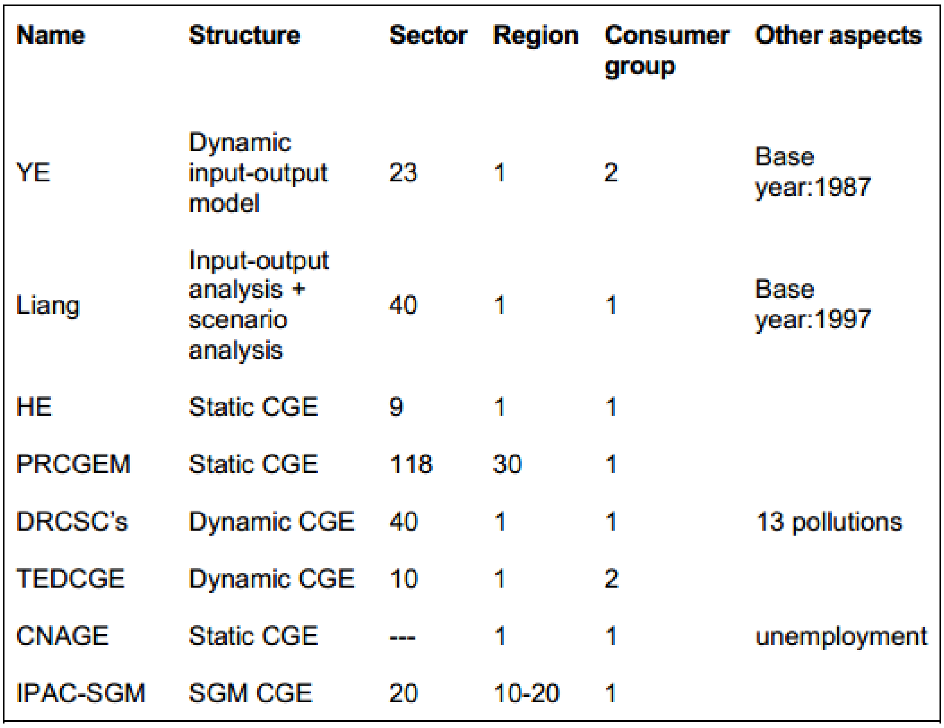
The two tables below show the main bottom-up and top-down models developed in China in the field of climate and energy policies (Teng and al., 2007).

One of the most well-known models in China is the Integrated Policy Model for China (IPAC).



Name	Status	Object	Time Horizon	Emission Covered	Technology Detail
MARKAL	accomplished	optimization path of energy system, emission forecast	1995-2050	CO_2	5 sectors 71 technologies
LEAP	all functions will be improved continually	optimization path of energy system, emission forecast	1999-2030	CO_2	
AIM	accomplished	Based on the Asian centre to describe the problem and policy analysis	1990-2100	CO_2	
3E	accomplished, but some functions should be improved	optimization path of energy system, emission forecast	2000-2050	CO_2	

Examples of bottom-up models (Teng and al., 2007)



Name	Structure	Sector	Region	Consumer group	Other aspects
YE	Dynamic input-output model	23	1	2	Base year:1987
Liang	Input-output analysis + scenario analysis	40	1	1	Base year:1997
HE	Static CGE	9	1	1	
PRCGEM	Static CGE	118	30	1	
DRCSC's	Dynamic CGE	40	1	1	13 pollutions
TEDCGE	Dynamic CGE	10	1	2	
CNAGE	Static CGE	---	1	1	unemployment
IPAC-SGM	SGM CGE	20	10-20	1	

Examples of top-down economy-energy-environment models in China (Teng and al., 2007)

Wu and Tang (2013) establish an Inter-Regional CGE model and simulate economic and welfare effects of climate policies on national and regional levels. The simulation results indicate that the economic and welfare effects are sensitive to policy mechanisms including the allocation of emission permits and whether the permits are tradable. They conclude that the policy make can alter the allocation of emission permits so as to adjust regional income and welfare without causing substantial extra economic losses.

To assess the Shanghai ETS's impacts on targeted sectors and the economy of the city, it is hence best to use a CGE model under key assumptions from the targeted sectors. The model can be run under different scenario of emissions reductions, versus a baseline scenario without any attempt to meet emissions reductions targets. Such an assessment aims to forecast some of the adjustment costs in the economy, incorporate information on abatement costs specific to the economy of Shanghai, and ultimately the hypothetical future state of the economy under the chosen target.

More recent studies have been carried out to model a global Chinese ETS. The authors of a 2013 study (Tang and al., 2013) found that establishing an ETS system improves economic efficiency. Another model (Cong and al., 2010) estimated the impacts of a national ETS system covering the power sector. The authors found that such a system increases the average electricity price by 12% and that emissions-based allocation produces higher electricity and carbon prices relative to an output-based emissions allocation scheme. Finally, a national ETS system model (Yuan and al., 2010) tested a small auction but mostly free allocation. The authors modeled two scenarios that achieve the same level of emissions reduction. The first scenario, in which emissions intensity decreases proportionally across each industry, results in no substantial economic impacts.

Limitations of CGE modeling

One important problem with CGE modeling is related to the dependency of data. The accuracy of CGE modeling results is highly dependent on the quality and suitability of the initial database employed in the base case scenario.

One important problem with CGE modeling is related to the dependency of data. The accuracy of CGE modeling results is highly dependent on the quality and suitability of the initial database employed in the base case scenario. For CGE modeling to assess the impacts of a climate mitigation policy, the data used for the economic impact assessment should include GHG emission data, production data and other relevant economic and technology information of overall ETS pilot and the specific sectors covered by the ETS.

An issue with CGE models is that, given the vast amount of data, parameters, equations and assumptions required to compute outcomes, such models can be somewhat of a "black box" in nature. That is, it is sometimes difficult to identify exactly how certain results were obtained. This is true only to the extent that models are not transparent regarding what data are computed into the model, how the policy changes are modeled, and how the results can be interpreted.

A specific limitation of static CGE models is that they usually assume that economic variables adjust smoothly to policy shocks. Such models do not capture step-wise industry adjustments but assume smooth and continuous changes. In reality, industries with large capital resources face discrete production and investment decisions. Along similar lines, comparative static models report the likely change in the economy at a given point in time; they do not capture the gradual implementation effects of a shock as the economy adjusts over time. This is more of a concern for short run modeling scenarios. In the long run, it is assumed that the economy can adjust to the desired point, although different models use different approaches to the movement of labor and capital to allow this adjustment.

Even if cap trade systems and carbon taxes differ (complexity, impact of prices and quantity certainty, administration costs, linkage to the international market), in CGE models, ETS is modeled as a carbon tax. This is also an approximation to be taken into account (NZIER, 2009).

Finally, CGE model have a smooth responsiveness. It means that the model does not take into account step-wise industry and economy-wide adjustments. It is assumed that changes are smooth and continuous. In reality, in the field of industries with large capital resources, production and investment decisions are discrete (NZIER, 2001).

Aggregation bias and access to accurate data

Given the fact that a model is a simplification of reality, it aggregates the economy into a number of industries and commodities. It is assumed that the level of detail chosen is sufficient to capture the most important economic issues of the economy. Nevertheless, some effects cannot be identified due to the fact that a model is based on a sample of industries. This is the reason why one speaks of an aggregation-bias.

A comparison of detailed policy options is not possible at this stage, given the current lack of firm proposals. It is difficult to model the benefits of adopting policies to control greenhouse gases, most of which are in the form of avoided costs of climate change a long time into the future. But within constraints of necessary simplification, modeling can illustrate economy-wide impacts of broad policy options for greenhouse gas control (NZIER, 2001).

Access to accurate data to undertake CGE modeling to assess the impacts of the Shanghai ETS on the economy is uneasy.

In the case of China for instance, a detailed discussion on the uncertainty in Chinese fuel consumption data is reported by different sources. As a matter of fact, in recent years, the uncertainty in the CO_2 estimates for China was the subject of several studies. The uncertainty estimate by Gregg and al. (2008) was based on revisions of energy data for the transition period of the late 1990s, which may not be fully applicable to more recent energy statistics, since the revisions made by the National Bureau of Statistics of China in 2006 and 2010 (Tu, 2011). Interestingly, a recent study by Guan et al. (2012), continuing the comparison made by Gregg et al. (2008), points out the large difference between total provincial coal consumption statistics and national total statistics. Tu (2011) claims that China's coal statistics have been seriously underreported since 1998. He also mentions that in 2006 the National Bureau of Statistics of China made statistical revisions for the 1999–2004, which were particularly large in the years between 1999 and 2001, and once more in 2010, with smaller revisions for the 1998– 2007 period. There might be discrepencies between estimates based on national statistics and on provincial data, especially regarding coal (Guan and al., 2012).

This discussion, which includes conclusions from recent literature on the accuracy of Chinese CO_2 emissions (Tu, 2011, Andres and al., 2012, Guan and al., 2012), yields an uncertainty in the range of 10% for China. For the current report, accurate data for Shanghai were for instance not made accessible to realize some modeling.

IV. Constructing a CGE model for the Shanghai ETS

Background

The objective of the Government of People's Republic of China is to cut carbon intensity by 40% to 50% by 2020 and to reduce per capita GDP emissions by 17% by 2015 (relative to its 2005 levels). To achieve these goals, the Government decided to gradually build up a national ETS. Around the same time, the General Office of National Development and Reform Commission released the "*Notice on Carrying out Pilot Program of Emissions Trading Scheme*". This document approves seven pilot cities and provinces for emission trading scheme pilots, which are the following ones: Beijing, Tianjin, Shanghai, Chongqing, Shenzhen, Hubei and Guangdong.

These above mentioned seven trial operations started in 2013, thus driving carbon market mechanism development in People's Republic of China, and to achieve the target of reducing greenhouse gas emission at lower cost and speed up the low carbon transformation.

Shanghai being one of the seven pilots, the city is therefore actively involved in the planning and advancing the overall design of its ETS, with Shanghai Municipal Development and Reform Commission in charge of the overall design and implementation work.

Characteristics of the Shanghai Emissions Trading Scheme

This section presents the characteristics of the Shanghai Emissions Trading Scheme. The characteristics are detailed in the Shanghai 12th five-year plan and the annex on specific planning. The Shanghai Draft Rules for Emissions Trading Guidelines first published in 2012 and the Shanghai's Draft Measures on Emissions Trading Pilot in the summer of 2013 provides further information.

The Draft Rules are the working plan for Shanghai's Government on establishing the ETS pilot.

Industries located within the Shanghai Municipality annually emitting CO_2 of more than 20,000 tons during any year between 2010 and 2011 (including both direct and indirect emissions) are participating to the ETS. The sectors covered are the following: steel, petrol, chemicals, ferrous metals, power, construction materials, textiles, paper-making, rubber and chemical fibers industries.

Sectors not covered during this period, but emitting over 10,000 tons annually should establish a carbon emissions reporting system. Hence, non-industrial firms in aviation, ports, airports, railways, commercial enterprises, hotels and financial institutions that are emitting CO_2 annually of more 10,000 tons during any year between 2010 and 2011 may also participate in the future.

Trading includes direct and indirect CO_2 emission rights and "verified cap and trade permit" for voluntary participants. Both direct and indirect emissions are covered. Direct emissions are from energy-related activity and industry production. Indirect emissions stem from purchased electricity and heating power.

Trading takes place in the designated trading platform at the Shanghai Environment Energy Exchange (SEEE).

Trading takes place in the designated trading platform at the Shanghai Environment Energy Exchange (SEEE) establishing trading types, auction procedures, purchase contracts, and the level of transaction fees.

Covered entities are not be allowed to receive forward allowances, but are permitted to bank unused allowances from the previous year. After an entity surrenders its allowances into the registry system, surplus allowances can be banked for future use.

Pilot enterprises receive emissions allowances based on emissions during the period from 2010 to 2011, then receive a "carbon emissions inspection," and assume "carbon emissions control responsibilities" according to the carbon emission reporting mechanism.

One allowance in Shanghai ETS pilot is called SHEA (Shanghai Emissions Allowance), meaning to allow releasing 1 ton of CO_2. Covered entities need to surrender their allowances to the registry system between 1 June and 31 June each year. The allowances for the entire period from 2013-2015 are allocated all at once.

During the pilot ETS, the primary allowances are allocated for free. If needed, an allowance auction may take place.

China Certified Emissions Reductions (CCERs) enable tp offset actual emissions in the place of allowances.

GHG offsets verified by the national or local government will also be included. At present, the Shanghai DRC is actively exploring 'innovative products' related to carbon emissions trading. China Certified Emissions Reductions (CCERs) can be used to offset actual emissions in the place of allowances. The amount of CCERs cannot exceed 5% of a covered entity total allocation amount.

The Shanghai ETS is encouraged to link with other ETS pilots, however provisions to link are not included in the draft rules. The Shanghai DRC is responsible for the allocation plan and for issuing allowances to covered entities via a registry system. In terms of penalties for non compliance, if an entity does not report its emissions, the Shanghai DRC can issue a penalty in the range of 10,000 to 30,000 RMB. If an entity provides false information or hides information during the verification process, the Shanghai DRC can issue a fine in the range of 10,000 to 30,000 RMB. If an entity resists a verifier's work, or provides a fake verification report, the Shanghai DRC can issue a fine in the range of 30,000 to 50,000 RMB. Finally, if an entity cannot surrender enough allowances to the registry compared to its reduction target, the Shanghai DRC can order the entity to surrender the undue amount within a defined period; otherwise, the Shanghai DRC can issue a penalty in the range of 50,000 to 100,000 RMB (IETA, 2013).

Assumptions and scenarii

A model of the Chinese economy adapted to the context of Shanghai can reflect the covered sectors, and the available options for substitution between energy sources, and between energy and capital, to assess the economic consequences of different emissions reductions policy scenarios.

Assumptions should be made on the estimation of the price of greenhouse gas emissions faced by firms under the ETS, GDP forecast and energy demand with or without the ETS.

The extent of free allocation of permits to exposed industries is an important parameter, related to the emissions reductions targets. Hence, any model can be run under different scenarii. The objective is to consider three scenarii:

Reduction of CO_2 intensity (CO_2 emissions per unit of GDP) until	
BAU scenario	40%
LC scenario	45%
ELC scenario	55%

40% and 45% scenarios respectively correspond to China's low and high end Copenhagen pledge. The enhanced scenario of 55% is reviewed and updated to meet the requirements of SEEE.

The consequences of different prices for other Chinese allowances or CCER are not taken into account, but this could be included in the future. The Shanghai market would then be in a position of a price taker in such a scenario, given the limited size of its carbon market compared to the other regional Chinese markets.

Selection of a model

A description of a model used to conduct the quantitative analysis is made under this section. We recommend a static

We recommend a static computable general equilibrium derived from the ORANI-G/PRCGEM model.

computable general equilibrium derived from the ORANI-G/PRCGEM model. This large-scale model can be used for environmental policies. It is based on a CES production function with capital and labor stocks, both remaining stable, in which only the emission caused by fossil fuel combustion is considered. Significant effort has been devoted to augmenting the basic model structure with a detailed depiction of energy use and greenhouse gas emissions, similar to Rutherford and Paltsev (2000).

The model characterizes a small economy with consumers, producers, the government, and a foreign sector. In terms of emissions reductions, the estimates of the abatement costs are derived to the 191 covered enterprises from the industrial and non-industrial sectors for carbon emissions trading.

This model incorporates carbon emissions associated with the use of fossil fuels from these enterprises. Abatement is modelled by requiring the covered enterprises to purchase an allowance in proportion to the quantity of emissions.

In the benchmark case, the permits are costless. The model may be configured such that a specified quantity of abatement is required. In such cases, the permit price is then determined endogenously. Alternatively, the price of permits may be fixed, which in turn causes the model to select abatement opportunities at least cost.

Comparison of existing results

In the current modelling of the Shanghai ETS, the model structure remains limited by the snapshot of the economy. In this document, some data are presented in annex from the energy balance of Shanghai as physical quantities for coal, coke, electricity and petroleum products. But data such as GHG emission, production, energy consumption, economic and technology information of overall ETS pilot and the specific sectors covered by ETS have not been made available.

Instead, a review of various results from research studies is presented. Regarding abatement costs, the cost of CO_2 emissions reduction of conventional thermal power plants in Shanghai is estimated at about 234.2 RMB per ton at average level (Qin, Zhang and Yin, 2011). This is due to the fact that power plants in Shanghai already employed advanced equipments and therefore the potential for carbon reduction is limited. This estimation for Shanghai is slightly higher than the national average level.

The cost of CO_2 emissions reduction of conventional thermal power plants in Shanghai is estimated at about 234.2 RMB per ton at average level (Qin, Zhang and Yin, 2011).

The results of a macroeconomic modeling of a national Chinese emissions trading system (Hubler et al, 2014) shows that a 45% emissions reduction target would bring a 1% loss in GDP and welfare by 2020, and 2% by 2030, against the expected welfare and GDP growth in a business-as-usual scenario. It is based on a 45% goal of reduction in carbon intensity (that is emissions per GDP) by 2020, and a fixed target after 2020.

V. Conclusion

In order for Shanghai to enforce maximum positive economic impact of its ETS, the allowance system needs to be carefully moni-

On November 25, 2013, Shanghai became the second Chinese city to launch a carbon trading scheme to regulate soaring CO_2 emissions from its main power generators and manufacturers, with first trades reported to have gone through at 4 USD per allowance. The city followed newly established market in Shenzhen. Beijing and Guangdong province launched their ETS in December 2013. China now possesses seven distinct ETS systems, working differently but sharing a common context, which is China's socialist market economy.

Shanghai's ETS covers 160 million metric tons of CO_2 emissions and around two hundred entities in the concerned sectors. The allowance price on July 30, 2014 was at 7.68 USD (Munnings and al., 2014).

Resources for the Future's last review of the Chinese ETS pilots confirms that an in-depth analysis of Shanghai ETS economic impact at the sector and city scale, and all the more the running of a computable general equilibrium model, would require further transparency on the cap-setting process, on the business-as-usual emissions, on the emissions impact of complementary policies, and on the electricity sector (consumption, emissions factors, electricity imports, etc.), at least in an aggregative data.

It is hence recommended to assess the economic impacts of the Shanghai ETS through a comparative analysis of the first year of functioning of the Shanghai ETS on one hand, and of similar ETS systems over the world.

In order for Shanghai to enforce maximum positive economic impact of its ETS, the allowance system needs to be carefully monitored. The scientific consensus endorses the idea of starting off with more free allocation and gradually moving toward more auctioning. Authors also agree that the allowance price should be controlled.

In the EU-ETS, impact on companies' performance was negligible, while emission reductions did happen in the second phase of the market (Abrell and al., 2011).

In conclusion profits, employment and added value are not harmed nor improved by the ETS regulation, in comparison with companies of similar sectors which are not subject to the regulations. The impacts are highly variable between sectors. Precisely, the electricity and heat sectors usually do not significantly contribute to emission reductions. On the contrary, non-metallic minerals and basic metals contribute the most to emission reductions. The non-metallic minerals sector are negatively affected as a consequence, but not enough to suffer a loss of competitiveness.

Finally, to meet the intensity reduction target of close to 17% by 2015, relative to 2010, according to the 12th Five Year Plan, China's carbon intensity will need to continue to decrease but at a slightly higher rate (4.6%) for the three years following 2012 (Fung and Peng, 2012).

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ENERGY BALANCE OF SHANGHAI-2011 (PHYSICAL QUANTITY)

	Coal Total	Raw Coal	Cleaned Coal	ther Washed Co	Briquettes	Gangue	Coke	Coke Oven Gas	last Furnace G	Converter Gas	Other Gas	er Coking Prod	oleum Products	Crude Oil	Gasoline	Kerosene	Diesel Oil	Fuel Oil	Naphtha	Lubricants	Petroleum Wax	White Spirit	Bitumen Asphal	Petroleum Cok	LPG	Refinery Gas	Petroleum Pro	Natural Gas	LNG	Heat	Electricity	Other Energy
	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^8 cu.m)	(10^8 cu.m)	(10^8 cu.m)	(10^8 cu.m)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^4 t)	(10^8 cu.m)	(10^4 t)	(10^{10} kJ)	(10^8 kW·h)	(10^4 tce)
Total Primary Energy Supply	**6144,60**	**4938,61**	**1129,06**	**7,59**	**19,54**		**79,01**				**52,10**	**70,96**	**3145,79**	**2194,69**	**197,74**	**250,96**	**-266,60**	**645,04**	**186,25**	**109,99**	**-6,05**	**-0,49**	**10,62**	**-20,24**	**56,44**	**0,22**	**-00,77**	**55,97**	**0,59**		**947,40**	
Indigenous Production													0,12	0,12														3,01			4,10	
Moving In from Other Provinces	8499,52	7996,00	1199,12	4,62	19,50		192,44				52,10	71,44	3629,04	241,44	949,90	191,10	1799,27	100,25	220,06	109,94					50,09		12,77	91,29			972,02	
Import	290,40	290,40											2292,00	1919,74		271,51		99,55							11,64		1,65	21,07				
Domestic Airplanes&Ships Refueling in Abroad													625,02			140,99	9,01	474,20														
Sending Out to Other Provinces(-)	-2541,06	-2541,06					-119,21						-3899,49	-5,50	-744,90	-101,29	-2826,09	-29,42	-90,71		-1,14	-0,42	-10,62	-19,15	-26,97		-102,54				-50,72	
Export(-)													-50,47			-95,64		-1,95			-5,71			-15,17								
Overseas Airplanes&Ships Refueling in China													-242,29			-151,60		-90,61														
Stock Change	-49,14	-42,01	-9,26	2,97	-0,05		-5,42					-1,00	-2,29	-29,11	-7,09	-4,64	16,27	19,74	-9,90	0,59		-0,06		0,00	1,14	0,22	-0,65					
Input(-) & Output(+) of Transformation	**-4990,90**	**4020,55**	**-962,49**				**692,01**	**29,69**			**19,96**	**90,96**	**-94,90**	**-2194,00**	**274,97**	**150,42**	**797,99**	**19,19**	**299,41**	**6,11**	**11,52**	**2,66**	**95,01**	**00,99**	**01,70**	**119,50**	**276,61**	**-15,44**		**7665,90**	**1022,22**	**4,59**
Thermal Power	-5667,60	-5667,60						-0,77			-52,10		-96,76				-0,07	-14,15						-21,22		-0,45	-0,05	-10,24		-10,09	1022,22	-16,94
Heating Supply	-524,02	-524,02											-25,49				-0,05	-2,05						-22,59	-0,09	-0,74	-0,06	-2,09		7975,14		-2,22
Coal Washing																																
Coking	-992,44	-91,12	-961,92				640,62	20,05			-2,00	90,96																				
Petroleum Refineries													50,05	-2194,00	274,97	150,42	790,05	29,99	299,41	6,11	11,52	2,66	95,01	192,14	01,01	120,75	290,97					
Petroleum Products Input (-)													-22,25														-22,25					
Gas Works	-6,92	-5,01	-1,11					-9,65			19,50																	-9,11		-90,11		
Coke Input (-)							-7,01																									
Natural Gas Liquefaction																																
Briquettes																																
Recovery of Energy											0,00																			999,16		29,15
Loss	**4,90**	**4,90**									**0,94**																	**2,06**			**70,49**	
Total Final Consumption	**1146,59**	**950,09**	**161,49**	**7,59**	**19,54**		**706,94**	**29,54**			**11,29**	**100,72**	**3119,65**	**9,69**	**472,07**	**400,50**	**592,05**	**650,04**	**425,06**	**110,09**	**4,94**	**1,27**	**16,99**	**60,15**	**110,90**	**119,54**	**107,09**	**97,06**	**0,59**	**7665,29**	**1269,19**	**4,59**
Farming, Forestry, Animal Husbandry, Fishery Conservancy	1,77	1,77											90,50		17,92		19,24								0,02			0,01			6,97	
Industry	1001,62	019,06	161,49	7,59	19,54		706,94	29,54			1,00	100,72	1054,27	9,69	99,91	4,64	00,19	62,06	425,06	6,22	4,90	1,27	0,50	60,15	69,09	119,54	107,09	29,20	0,59	7454,99	795,27	4,59
Non-Energy Use	0,29				0,29							29,66	599,96		0,00	4,09	7,05	0,27	425,06			1,27		0,04	49,02		110,02					
Construction	12,95	12,95									0,02		05,92		26,10		99,95	9,62		0,29			15,09					0,09		9,79	26,95	
Transport, Storage and Post	2,06	2,06									0,16		1900,71		109,11	995,02	101,59	570,96		29,29					6,60			0,92		69,69	90,97	
Wholesale, Retail Trade and Hotel, Restaurants	99,52	99,52									2,44		155,47		55,52	0.01	75,69	6,14		10,04	0,52				7,62			1,46		40,07	72,04	
Others	45,19	45,19									1,49		241,25		00,94	0,09	106,19	1,06		97,60	0,04				6,57			9,41		69,11	214,91	
Residential Consumption	49,95	49,95									5,90		246,06		142,50		42,04			27,91					54,20			0,69		20,96	175,22	
Urban	95,05	95,05									5,10		177,66		129,12		29,57			20,97					10,61			7,19		20,96	162,00	
Rural	0,90	0,90									0,20		60,99		19,99		10,47			6,94					29,59			1,44			19,22	
Statistical Difference	**0,95**	**-0,94**			**-0,01**		**0,20**	**0,09**			**-0,01**		**-2,25**		**-0,79**	**-0,02**	**0,79**	**0,19**	**0,20**	**0,79**	**-0,27**	**0,91**			**-0,60**	**0,26**		**0,01**				
Total Final Consumption	**6141,95**	**4990,96**	**1129,06**	**7,59**	**19,54**		**714,15**	**27,96**			**46,49**	**100,72**	**3140,04**	**2194,69**	**472,07**	**400,50**	**592,96**	**675,04**	**425,06**	**110,09**	**4,94**	**1,27**	**16,99**	**105,90**	**110,99**	**120,71**	**210,19**	**55,96**	**0,59**	**7714,90**	**1999,62**	**29,15**