Economic Assessment of Cap-and-Trade Schemes

Note on Concepts and Instruments[1,2]

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Introduction:

Countries interested in exploring the possibility of setting a cap-and-trade scheme[5] – or a carbon tax - are first interested in responding to a series of questions that are key to the decision making process, in particular to build a political consensus.

Typically, a central question to which government officials need to get solid response is : "What are the possible economic impacts of setting a cap system, either absolute or intensity-based ?"

Indeed, a critical step before introducing any policy instrument is to understand its potential consequences beforehand. Responding this question is essential to prepare an objective basis for the domestic political debate. Defining and measuring economic impacts also provide a metric to assess how much variations in the design of the instrument can help reduce its cost and maximize its benefits.

This first very legitimate question, immediately triggers a series of more methodological questions: "What are the relevant indicators or variables to measure these economic impacts ?" "Which approaches and instruments would be effective to measure the impact on these variables of the implementation of a cap-and-trade scheme and test variations induced by specific features ?"

1) What kind of instrument and what kind of indicators to consider for evaluating the costs and benefits of policy instruments?

Macroeconomic models, particularly, Computable General Equilibrium (CGE) models, are often used for simulating economic impacts of implementing new policy instruments on national economies.

[1] The views expressed are those of the authors; they do not represent views of the World Bank, including those of the PMR Secretariat.

[2] This note has been prepared in the context of the PMR, in particular as part of the cooperative dialogue between the technical team of the Brazilian Ministry of Finance and the WB team for the Brazil PMR operation.

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[5] Also called Emissions Trading Scheme (ETS).

Depending upon flexibility in model structure, a CGE model is capable of assessing impacts on many economic variables due to a policy shock. These variables include :

- gross domestic product,
- consumption of goods by production sectors,
- household consumption of goods,
- labor demand and supply,
- wage rate,
- prices,
- terms of trade,
- imports and exports of goods and services,
- investment,
- capital income,
- taxes and subsidies,
- total government revenue,
- government debt,
- etc.

All these variables are expressed in monetary terms and therefore their variations can be seen as as many forms of measuring costs and benefits for the whole economy. When properly disaggregated at sector level, CGE models can also assess costs and benefits for a specific sector. If appropriately designed, a dynamic model can capture future impacts on each variable mentioned above. Often, a few key variables such as GDP and employment are used for this purpose. But GDP does not count many essential features that should be accounted for policy setting. For example, it does not account value of leisure or comfort that has a crucial role in supplying labor and also to derive household welfare or utility. Since this is eventually for the government to decide which costs and which benefits, or which combinations of them are relevant for the decision making process, the CGE model should be capable to assess impacts on all these variables.

Since the impacts of policy shocks could be positive or negative on each of these variables, it might be difficult for policy makers to decide which impacts should be eventually considered while making the decisions. To address this difficulty, one single variable that is mostly used in literature in decision making is economic welfare. It is measured in terms of compensating variation (CV), a measure of utility change introduced by British economist Sir John Richard Hicks in 1939. It refers to the amount of additional money an agent would need to reach its initial utility after a change in prices of goods and services due to policy shocks (here introduction of a cap & trade system). This indicator combines all possible variables such as prices of goods and services, labor and capital income, international trade, competitiveness of goods and services across their geographical sources, value of leisure and so on.

2) What would be the impact on competitiveness of covered sectors ?

One of the central issues for both the political debate and the dialogue with the national industry is the impact on competitiveness that setting emissions caps might have on covered sectors. This is an issue on which the government needs to be prepared to respond to the industry and other affected sectors before determining the caps. Moreover, it is also as much important to be able to test the cost-mitigation impacts of trading and of specific features that can be associated to the scheme, for instance the form of recycling the revenues generated from auctioning of allocations if any[6].

Variations in competitiveness can be understood in different ways, for instance as variations in sector-specific trade balances or variations of relative prices of sector-specific exports that would result from imposing different caps levels and different scheme features. While there could be various indicators to measure competitiveness across sectors or across jurisdictions for a given sector; the most comprehensive index in the context of CGE modeling are producers price indices (for exports) and consumer price indices (for domestic consumption): a sector would lose its competitiveness with the same sector located in foreign countries if the aggregated prices of the commodities produced by this sector would become relatively higher compared to those produced by its foreign competitors. In the case of domestic consumption, a sector would lose its competitiveness if the aggregate prices of the commodities it produces would become relatively higher compared to the aggregate prices of the same commodities imported from foreign countries.

The corresponding effect resulting from (i) setting caps and from the modalities of allocation and (ii) proceeds recycling on prices of goods and services that country exports to the international markets or imports from the international markets can be simulated with CGE models. A CGE model can trace changes in prices of every good and service due to a policy shock (here the introduction of a cap & trade system) and thus determine how would a particular sector loose or gain competitiveness in the national as well as in the global market.

3) What are the features required for a CGE model to be able to measure costs and benefits ?

As mentioned above, a CGE model can be designed in different ways, depending on the very specific to policy questions to be answered. As a consequence, the structure of a CGE model to address policy question related to financial or banking sector would be very different from that aimed to address climate change policy analysis.

For analyzing climate policy instruments, such as a carbon cap-and-trade (or a carbon tax), a CGE model should have, at least the following features:

- All energy commodities or fuels should be explicitly represented (e.g., coal, gas, gasoline, diesel, ethanol, biodiesel) as these energy commodities have significantly different coefficients for GHG emissions.
- Emission intensive production sectors should be explicitly represented; these sectors should be further broken down to categories of technologies according to the type of fuel these

[6] For a preliminary application of this approach in the case of Brazil, see in particular : Y.-H. Henry Chen and Govinda R. Timilsina: "Economic Implications of Reducing Carbon Emissions from Energy Use and Industrial Processes in Brazil", 2012, 28p., to be published.

technologies do use. For example, the electricity sector should be split into types of technologies, such as hydro, coal, gas, other renewable, etc.

- Behaviors of agents, such as producers, households, governments, international trade (i.e., foreign sector) should be represented by flexible functional forms so that the trade-off they undertake during their decision making are well captured; normally constant elasticity of substitution (CES) functional forms with in-depth nested structure are used for this purpose.
- The model should be dynamic, if possible perfect foresight, if not recursive dynamic, as the policy instruments would have long-term impacts to an economy.

4) Beyond testing direct impacts of caps, what are the costs and benefits of specific features aimed at mitigating net costs ?

The impact of a cap & trade system to an economy depends upon how it is designed. If designed properly, benefits of a cap & trade system can be increased whereas its costs to an economy can be reduced. Below are a few examples of specific questions, which need to be answered using the CGE model to help design an efficient cap and trade system .

Allocation of Caps: Grandfathering, auctioning or some mix?

Allocation of caps is one of the biggest challenges when setting a cap-and-trade scheme, since it eventually determines most of the results that would derive from the adoption of such an instrument. While experiences from other jurisdictions, such as EU, could be helpful, they may not be replicated in a developing country (i.e. Brazil) because of the differences in economic structures and emission sources. Specific simulations are therefore required for each country, where alternative scenarios would be considered for allocation of caps. The first scenario could consider an allocation based on the grandfathering principle. A second simulation could consider an allocation through auctioning. Multiple other scenarios could be considered for different mix of grandfathering and auctioning.

Under a grandfathering scheme where emission allowances would be freely allocated, the government would need to choose whether allocations would be based on historical emissions, current production levels, carbon intensity or some other formula. Free allocation might eventually translate into a net transfer to the recipient industry, in particular when fuel switch is easy, thus triggering controversies on the legitimacy for such generosity toward a specific segment of the economy; windfall profits have for instance been observed in the power sector in Germany[7].

Allowances can also be partially or totally auctioned. Eligibility to participate to auctions can also be regulated to restrict it to covered sectors or open it to a wider audience of non-regulated sectors or intermediaries the latter can induce very significant variations of the monetary burden eventually supported by regulated sectors.

[7] Beat Hintermann: “Market power and windfall profits in emissions permits markets”, CEPE Working Paper N.62, 2009.

A CGE model helps to explore and decide on such questions by testing consequences on relevant variables.

How to maximize the benefits of recycling revenues from auctioning or taxes ?

If emission allowances are auctioned, the government receives an additional revenue, which is similar to revenue resulting from implementing a carbon tax. The revenue can be used for different purposes, for example to partially offset the negative impacts of the scheme on consumers, businesses or the whole economy. The volume of the revenue resulting from auctioning allocations can be very significant: an OECD study showed that in a scenario of emissions trading with full auctioning aimed at delivering the Copenhagen Accord pledges, revenues in developed countries could be more than USD 400 billion in 2020, that is 1% of GDP [8]. CGE models are often used to assess which revenue recycling scheme would be best for an economy[9].

What would be the optimal scope of a sector-based scheme ?

From a pure theoretical perspective, a narrow sectorial scope (i.e., covering only a few sectors) prevents economic benefits that the cheaper GHG mitigation potentials located within non-covered sectors could bring to the cap & trade system. However, extending the coverage to much atomized sectors might not be feasible. The question of how much benefit for the whole economy and for the cap-regulated sectors would derive from a wider scope can be answered by a CGE model by simulating impacts under alternative coverage scenarios. The scenario with the least cost to the economy would be the one providing the optimal sectorial scope.

Many other features can be tested

Many other specific features have been imagined along the years to try to prevent undesirable situations. Examples are floor prices to prevent too low prices (which would discourage many sectors to adopt less carbon intensive technologies) and reciprocally ceiling prices to prevent too high prices (which can increase exaggeratedly the burden on carbon intensive sectors). The combination of a cap-and-trade scheme with other instruments (i.e. carbon or energy taxes) or the joint-implementation with other market mechanisms, either carbon-based (i.e. offsets-based mechanisms) or non-directly carbon-based (i.e. white certificates and/or a green certificates market, re-forestation obligations, other environmental assets, etc.) and many other features can be translated into specific parameterization of CGE models to assess their virtues to mitigating costs and/or maximizing benefits of a cap-and-trade system, or simply to revealing unpredictable economic results of combining different policies eventually affecting the generation and demand of carbon assets.

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[8] Dellink, R., G. Briner and C. Clapp (2010), “Costs, Revenues and Effectiveness of the Copenhagen Accord Emission Pledges for 2020”, OECD Environment Working Papers, No. 22, OECD Publishing. doi: 10.1787/5km975plmzg6-en

[9] A large volume of literature is available. For example, see Timilsina G.R. and R.M. Shrestha, Effects of Revenue Recycling Schemes in Selecting Tax Instruments for CO2 Emissions Reduction: A CGE Analysis of Thailand, Energy Studies Review, Vol. 15, No. 1, pp. 19-48. 2007.

5) Which sector coverage, technologies and levels of caps would ensure market liquidity ? *Complementary "bottom-up" simulation tools are necessary*.

CGE models are by nature "top-down" models, that is, tools that are aimed at simulating the theoretical equations that relate macro-economic variables to each-other, some of which can be more or less disaggregated in a "top-down" movement from the national economy to sector or sub sector levels. As mentioned above, CGE models can and should be further refined to some extent to represent carbon intensive sectors and thus capture relevant GHG features of an economy; in particular, the representation of such sectors should differentiated among categories of technologies according to the type of fuel these technologies do use.

However, there are limits to such top-down disaggregation. On one hand, transaction cost increase with disaggregation of sectors in many smaller sub-sectors (more data and computer resources are needed). One the other hand, the sectorial nature itself of CGE models does not allow to respond to certain key questions, like which mitigation technology can actually contribute to reduce emissions in which quantity, at which cost and in which sector. First, providing carbon intensities and elasticities at sector or sub-sector level won't be sufficient to establish and/or discuss caps with the industry since stakeholders need to be sure that technologies do exist to realistically allow to change these elasticities and achieve the proposed emissions reduction targets. Second, a variety of technical mitigation potentials do exist within the same industrial activity, including related to the use of the same fuel, but these different potential cannot be harvested at the same costs; for instance, in the cement sector, heat recovery systems would not present the same marginal abatement cost than combustion optimization technologies. Third, many of these GHG abatement technologies are not sector-specific and are indeed (unevenly) available in several sectors at the same time (i.e. heat recovery and combustion optimization technologies can be implemented in the cement sector but also in other sectors like agro-industry, chemistry, power generation, etc.).

Getting an explicit description and quantification of the mitigation potentials and abatement costs associated to these technologies in different sectors is essential to determine how much a specific sector will eventually be able to reduce its own emissions under specific market-price conditions. Said in another way, for a determined carbon market price, how much a sector can abate its emissions beyond its cap and thus supply the market in allowances? Or reciprocally, how much short it would be and would need to purchase additional allowances on the market ? Without pretending to exhaust all possible technical mitigation options that the private sector might be able to develop, being able to explore such questions in a realistic way is essential to test the concrete feasibility of proposed caps levels. Getting the expected benefits from trading supposes that the market resulting from the proposed selection of sectors and caps would be liquid enough. What potential supply of allowances beyond the compliance of caps can be expected from the implementation of the mitigation options available in the covered sectors? Would there be a shortage of low cost abatement options to comply with the caps? That is, would the market actually see a significant demand for carbon credits ? What could be the equilibrium price for the expected supply and demand ? If the market presents no liquidity or the possible equilibrium price is too high, it won't deliver any benefits in terms of reducing the impact neither for the economy nor for the covered sectors. This is then a signal that a different set of caps and/or a different sectorial scope should be considered. If not, the endeavor of setting-up a cap-and-trade system would simply not be worth it.

As a consequence, responding to these more detailed questions requires a “bottom-up” approach, meaning starting from precise technologies, for which associated abatement potentials and costs can be reasonably estimated for every relevant sub-sector and which can be combined and aggregated in a “bottom-up” movement at the sub-sector and then sector levels.

6) Beyond macro-economic impacts on the national economy, what would be the cost and attractiveness of abatement options for the private agents of a covered sector ?

Anticipating market liquidity requires also simulating the criteria that private agents would apply when deciding to invest on technologies in their sectors. These criteria can differ very significantly from the criteria chosen by the government to compare abatement costs from a public planning perspective.

To assess the set of abatement options that would preferably be implemented from a national economy perspective, a government will typically compare corresponding abatement costs that would be calculated using the same discount rate than the government uses for its planning, also called a social discount rate (i.e. 8% in the case of Brazil). These technology-specific abatement costs are called Marginal Abatement Costs (MAC)[10] and are expressed in US$ per tCO2 (or in any other currency). MAC costs have been widely popularized by Mc Kinsey in the format of “MAC Curves”. Such MAC costs correspond to a cost-benefit analysis and reflect a micro-economic approach, which is complementary to the macro-economic approach of CGE models presented above. Under the MAC-based approach, all abatement options that present a negative present value, calculated as the sum of the discounted costs minus the sum of the discounted benefits (i.e. investment and O&M costs minus revenues from the sales of renewable energy), would be considered win-wins for the national economy[11]. However, these technologies might not be attractive for the private sector, the reason being that private agents have expectation of internal rates of return (IRRs) that are usually far higher than the social discount rate adopted by the government. In addition, in the real world, when it comes to investment, all private agents do not behave the same way across different sectors (typically the degree of competition might vary or the opportunity cost of private equity might not be the same across sectors). As a result the

[10] The marginal abatement cost of a GHG abatement technology is defined as the net cost of the option considered in a baseline scenario and the net cost of the mitigation option considered in a low-carbon scenario, discounting both costs and benefits using a social discount rate. Costs are typically investment and O&M costs, while benefits are for instance the revenue from the sales of the energy generated or saved. The baseline scenario is usually the one adopted by the country as the long-term planning scenario for the considered sector. In the case of the energy sector, examples of such models include MARKAL, MESSAGE, LEAP, etc. When no long-term planning is available, simplified planning tools can be used, like the EFFECT model, which was developed by the World Bank and allows for the building of both baseline and low-carbon scenarios for different sectors.

[11] Usually located on the left side of the MAC curves.

expected IRRs change from one sector to another[12]. As a consequence the MAC cost based on a social discount rate cannot be used to determine at which carbon market price a technology would become attractive for a private agent to decide to implement it. A private agent will decide to invest in an abatement technology only if the expected revenues are sufficient to meet the IRR expected by this agent.

To respond to that specific question, at the occasion of the Brazil Low-carbon study that the World Bank coordinated and delivered to the Ministry of Finance, the World Bank developed a complementary concept: the Break-even Carbon Price. The Break-even Carbon Price is defined as the additional revenue that is needed for an investment in an abatement technology to deliver the expected IRR, divided by the volume of emission reductions that this investment will enable. Like the MAC, the Break-even Carbon Price is expressed in US$/tCO2, however, the value is usually much higher than the corresponding MAC. The Break-even carbon price, which can also be displayed by technology in a curve similar to the MAC curve, is fully consistent with a market carbon price: if the market carbon price is higher than the break-even carbon price of a specific technology, the revenue from the sales of the carbon credits generated by this mitigation option will be sufficient to match the expected IRR and thus potentially trigger the decision to implement it.

7) The MACTool developed by the World Bank has been designed to test scope, caps, market response and liquidity of domestic Cap-and-Trade Schemes.

The MAC-Tool, a free, open-code and totally transparent excel-based instrument developed by the World Bank at the occasion of the Brazil and Mexico Low-carbon studies (i) calculates both the **Marginal Abatement Cost** (MAC) and the **Break-even Carbon Price** for GHG abatement technologies both being expressed either in U$/t$CO_2$e or in local currency; (ii) generates both the MAC and the Break-even Carbon Price curves, with a display similar to the one popularized by Mac Kinsey, and ; (iii) includes a series of sensitivity analysis against a series of parameters (i.e. oil price, exchange rates, etc). The parameters and the equations used for calculations are totally transparent and can be adjusted by the user to the specificities of the country and the period considered. The tool comes with a series of technical options already parameterized that can be completed or modified.

The MAC-Tool provides also a series of other quantitative and graphical information, such as the volume of financing needed per technology and sector, emissions and emissions reductions curves for a reference scenario, a low-carbon scenario and for the differential between both. To facilitate the dialogue with sectors experts and authorities, the MAC-Tool also provides a series of usual sectorial indicators (i.e. installed power capacity, total area of pastures and crops, kms of metro, tons of waste managed, etc.) for both the reference and the low-carbon scenario.

[12] In the case of Brazil, at the occasion of the Brazil Low-carbon Study, the World Bank conducted a survey among financial institutions serving different sectors and collected sector specific IRRs; these varied from 0.5% to 35% among the different sectors surveyed.

The MACTool can generate curves that display abatement costs and potential per technology for a country, a province, a municipality, a sector or a sub-sector. The META MAC module of the MACTool has been specially developed to simulate cap-and-trade scheme under a bottom-up approach as described above. It can test different sectorial scopes, different caps, the resulting market liquidity and determine a possible carbon market equilibrium price. The META MAC allows to consolidate the data and the curves (MAC and the Break-even Carbon Price Curves) generated with the MACTool for different sectors/sub-sectors or different countries/provinces into one single cross-sectorial curve (MAC or Break-Even Carbon Price Curve). This is particularly useful to consolidate at the national level the data collected first at the province level or at the sector level. While the primary curves built with the MACTool for a province or a sector display mitigation potentials and marginal abatement costs (i) ***by technology***, the consolidated curves built with META MAC can display the aggregated data either the same way (i.e. displaying abatement potential by technology at the country level) (ii) ***by province*** (i.e. positioning different Brazilian States on the same curve according to their total mitigation potential and average MAC cost or break-even carbon price) or (iii) ***by sector*** (i.e. a positioning different sectors on the same curve according to their total mitigation potential and average MAC cost or break-even carbon price). The META MAC allows the user to select the technologies, the provinces or the sectors to be compared.

The possibility of aggregating “break-even carbon price” results of different sectors at the national level is especially relevant for exploring the possible scope for a cap-and-trade scheme in a country. Caps are usually defined by sectors (i.e. cement industry). The META MAC allows to simulate caps on sectors (or sub-sectors)[13] and thus display on the same curve (i) remaining abatement potentials beyond the caps in sectors whose abatement costs are low, which represent the ***potential supply*** for carbon credits in a cap-and-trade scheme, and (ii) the caps to be complied with by the sectors whose abatement costs are higher, which represent the ***potential demand*** for carbon offsets in the same scheme. The META MAC enables to determine the expected demand and supply under different market price hypothesis - including estimating a possible equilibrium price[14] - and thus market liquidity that would result for the selected set of sectors and caps. A market is considered not liquid if there is no demand (i.e. the caps where set too low) or there is no supply (i.e. the caps were set too high). In both case, setting a trading mechanism will not deliver any benefits to mitigate the costs either for the economy or the covered sectors. The META MAC allows testing alternative sets of caps and sector selection to improve liquidity.

Conclusion

Governments interested in setting cap-and-trade schemes to achieve voluntary GHG emissions targets are facing a chain of successive economic questions, which range from macro-economic ones, to anticipate impacts of caps and flexibilisation features on the economy and the competitiveness of sectors, to micro-economic ones, to determine sectorial scope and caps levels that would make such

[13] The META MAC uses the international ISIC4 four-level sectors nomenclature.

[14] The market equilibrium price is defined as the price for which the domestic supply equals the domestic demand. If the market price is forced above that price (for instance by connecting the national carbon market to the international carbon market), the domestic demand is then higher than the domestic supply and reciprocally.

schemes actually work. Both the theory and the experience provide experience and instruments to help address these questions, which will be at the core of the policy debate and dialogue with the sectors representatives. Ideally, macro-economic “top-down” instruments, like CGE models, and micro-economic “bottom-up” ones, like the MACTool developed by the World Bank, should be used iteratively: CGE models allows to assess macro-economic impacts of both caps and trading features, therefore providing the basis for a general policy decision, while the MACTool allows to test sector scope and caps, relating them to specific abatement technology and associated costs and benefits, to test which scope and caps will actually allow the trade mechanism to work, thus delivering the expected cost reduction benefits. Appropriate scope and caps having been refined with the MACTool, more precise macro-economic impacts associated to the proposed cap-and-trade system can then be simulated again at the national level with a CGE model.