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Article

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Impacts of Carbon Pricing on Developing Economies

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ABSTRACT

Carbon pricing is widely recognized as an effective policy instrument for climate change mitigation. Carbon pricing have been imposed in 39 developed countries and eight middle-income countries. Eight more middle-income countries are considering its implementation. As experiences from industrialized countries may not be relevant to developing countries, this literature review fills a knowledge gap by collating the impacts of carbon pricing in developing economies to facilitate cross-learning. Some developing countries still have distortionary subsidies in place, while others are going through environmental fiscal reforms to nudge their societies and economies towards greenhouse gases emission reduction. Various studies demonstrated that safeguards introduced with carbon pricing could help firms to transition while maintaining the motivation to innovate to stay competitive. At the household level, given different energy consumption patterns, carbon pricing in developing economies is not necessarily regressive, especially for rural population. Aggregate impacts to employment rate and gross domestic product change over time as the economy restructures towards decarbonization. A well-designed carbon pricing policy package with revenue recycling mechanisms tailored to the socioeconomic circumstances of the country could achieve multiple dividends of economic growth, increased employment, improved equality, national debt reduction or accomplishment of other sustainable development goals.

Keywords: Carbon Tax, Emissions Trading System, Developing Countries, Competitiveness, Distributional Impact, Economic Impact
JEL Classifications: H23, Q56, Q58

1. INTRODUCTION

Climate change is an issue of cross-temporal trans-boundary externality. Greenhouse gases (GHG) emitted into the atmosphere decades ago are still lingering, building up in concentration and causing global warming now. Emissions from anybody in the world could affect everyone else on the planet in different ways; industrial processes in the developed countries in the North contribute to shifting of the climate system that results in more frequent droughts and floods in Least Developed Countries, sparking debates on climate justice. The Nobel laureate William Nordhaus viewed climate change as the ultimate challenge of economics (Nordhaus, 2019). Many scholars agree that putting a price on GHG emissions – commonly known as "carbon pricing" as carbon dioxide (CO_2) is the most prevalent GHG emission – is the economically most efficient way to mitigate climate change (Aldy, 2015; Edenhofer et al., 2015; Metcalf and Weisbach, 2009; Schmalensee and Stavins, 2017).

Carbon pricing is a policy instrument based on "polluter pays principle" that shifts the financial burden of externalities back to emitters and thus incentivizes them to reduce emissions. An explicit carbon price, in the strict sense, is a Pigovian tax (Pigou, 1920) based on the global warming potential of emissions that would result in different rates on different types of fossil fuels and processes. In practice, however, socioeconomic political considerations may influence these rates, or mask them under different names. Implicit carbon prices may include fuel tax, energy levy, pollution charge, fossil fuel subsidy removal, etc. The traditional explicit carbon pricing mechanisms are: carbon tax, emissions trading system

(ETS) and their derivatives. Emissions trading systems are cap-and-trade or baseline-and-credit systems that allow market forces to determine the price of carbon by trading emission allowances among participants, hence achieving the most cost effective abatement for sectors regulated by the systems. Rather than using the "stick" of carbon tax or ETS to spur emission reduction, carbon credit or results-based carbon financing (RBCF) is a carrot that incentivizes it. Some carbon pricing schemes allow the use of carbon credits generated from verified projects (e.g. projects under the multilateral Clean Development Mechanism (CDM), national or independent standards) to offset carbon price obligations. RBCF is now recognized by the World Bank as a non-traditional form of carbon pricing. A well-known RBCF mechanism is the Reducing Emissions from Deforestation and Forest Degradation In Developing Countries Program (REDD+) (Table 1).

As of April 2020, 61 explicit carbon pricing initiatives have been implemented or scheduled for implementation at regional, national or sub-national jurisdiction levels. These consisted of 31 ETS and 30 carbon taxes. These carbon pricing initiatives covered 12 gigatonne of carbon dioxide equivalent ($GtCO_2e$), or about 22% of global GHG emissions, with carbon price ranging from less than USD1 to around USD120 per tonne of carbon dioxide equivalent ($/tCO_2e$). In addition to these, there were more than 74 multilateral RBCF programs operating around the world (State and Trends of Carbon Pricing 2020, 2020).

Traditional carbon pricing falls under the purview of individual jurisdiction. Internationally, the United Nations Framework Convention for Climate Change (UNFCCC) was established in 1992 to coordinate global efforts in climate change. A key principle of the UNFCCC is "common but differentiated responsibilities and respective capabilities" (UNFCCC, 1992, Article 3(1)), respecting the priority of developing country parties in socioeconomic development and poverty eradication. Under the UNFCCC, the Kyoto Protocol came into effect in 2005. The Kyoto Protocol gave rise to the first international carbon market via mechanisms such as International Emission Trading, CDM and Joint Implementation. The Paris Agreement came into effect in 2016 and will replace the Kyoto Protocol after the second commitment period expires in 2020 (*UNFCCC*, 2021). Article 6 of the Paris Agreement provides frameworks for international market and non-market approaches to achieve emission reduction goals. As of February 2021, there were 190 parties to the Paris Agreement. Under the agreement, all nation parties are committed to emission reduction targets declared in their Nationally Determined Contributions (NDCs). Out of the 190 parties to the agreement, about 100 countries plan or consider carbon pricing mechanisms in their NDCs (Paris Agreement, 2015).

The literature pool on the economic impact of carbon pricing is vast, albeit heavily skewed towards developed countries. Of the 61 carbon pricing initiatives implemented or scheduled for implementation, only eight middle-income countries (Bulgaria – European Union ETS since 2007, Ukraine – since 2011, Kazakhstan – since 2013, China – pilot since 2013, Mexico – since 2014, Colombia – since 2017, Argentina – since 2018, South Africa – since 2019) and none of the lower-income countries are involved. Eight more middle-income countries (Brazil, Côte d'Ivoire, Indonesia, Montenegro, Senegal, Thailand, Turkey, Vietnam) have announced their intention to work towards the implementation of carbon pricing (State and Trends of Carbon Pricing 2020, 2020; World Bank Country and Lending Groups, 2020). Some of these initiatives have been introduced only recently, with the effect that available data is not sufficient to enable more ex-post studies. Other developing countries or emerging economies may have carried out ex-ante research to model the potential socioeconomic impacts of carbon pricing, thus embarking on environmental fiscal reform journeys that would lead to traditional carbon pricing, or mitigation pathways that would utilize RBCF. This paper reviews applicable literature for both ex-post and ex-ante research, with focus on traditional explicit and implicit carbon pricing in developing economies. With different administrative capacities, economic structures and abilities to adapt to carbon pricing, insights from industrialized economies are not always relevant to developing countries (Pegels, 2016). This literature research addresses the question of "what are the impacts of carbon pricing on developing economies", therefore providing integrative comparison and insights for policy-makers in countries with similar economic status.

Table 1: Types of carbon pricing

Implicit	Fuel tax, energy levy, pollution charge, fuel subsidy removal, etc.	
Explicit	Traditional	Carbon tax, ETS or derivatives
	Non-traditional	Result-based carbon financing or carbon credit

After describing research methods and material in the next section, Section 3 will discuss types of impact and implementation strategies of carbon pricing. The results of literature review will include impacts to (4.1) firms, (4.2) households, and (4.3) macroeconomics. Section 5 will address alternatives and complementary strategies before Section 6 Conclusions.

2. MATERIALS AND METHODS

This paper is a result of a semi-systematic literature review. The focus of this paper is on the non-high income countries that have implemented or are considering the implementation of traditional explicit carbon pricing. The exceptions are: the exclusion of Bulgaria as it is part of the European Union Emissions Trading System (EU ETS); and the inclusion of India even though it has implemented only implicit carbon taxes – since India is among the top three GHG emitters in the world. Names of these 16 countries and the phrases "carbon price", "emission trading", "carbon tax" and "environmental tax" formed the principal search terms in the first phase. After the initial review, the second phase of search was conducted on snowballing basis to fill in data gaps. Significant gaps uncovered in the first phase were "environmental fiscal reform", "RBCF" and countries with insufficient literature coverage such as Montenegro, Côte d'Ivoire and Senegal. The primary database used to search for journal articles and reports was Google Scholar. Google search engine was used to search for generic media. The hierarchy of literature sources are (1) peer-reviewed articles; (2) reports from research institutions and multilateral agencies; (3) government publications; (4) media sources. The third and fourth sources provide data on recent developments that are useful for multifaceted perspectives. The review was conducted primarily in English language; literature in Chinese, Indonesian, French and Spanish languages were included as necessary. This literature review focuses on impacts to the entire country, rather than individual province or sector, with a few exceptions. Literature before 2005 was excluded as the knowledge domain experienced a quantum leap with the introduction of EU ETS in the same year. The selection process of literature to be reviewed was easy for some countries – there are simply not many available. In other countries – especially China – with a plethora of literature, previous literature reviews were relied upon to uncover the trends. Abstracts were screened through to select relevant articles for detailed review. The research method is summarized in Table 2.

The first phase of search yielded 529 articles and reports. 129 were shortlisted after title screening and 44 were selected after abstract reading to seek relevance to the research question. The second phase yielded 2 articles, 12 reports and government publications and 10 media.

3. IMPACTS AND IMPLEMENTATION STRATEGIES

3.1. Types of Impacts

Carbon pricing is a policy instrument with potentially far reaching impacts. Even when imposed only on a small number of products and sectors, the impacts will eventually felt throughout the circular flow of economic activity, affecting firms and households. In the short run, carbon pricing drives up marginal cost of firms. For the manufacturing sectors, it causes elevation of production costs as energy generated from fossil fuels will cost more; for the service sectors, logistics costs will increase due to the higher price of transport fuels. Firms will attempt to pass on the additional costs to their customers, resulting in higher price for products and services. Households may suffer higher energy costs, fuel prices, transportation costs and general inflation of goods and services. For households with low disposable income, this may lead to reduction in consumption. Some firms may have to absorb the additional costs due to competition from goods produced in jurisdictions that do not price in negative environmental externalities sufficiently.

Table 2: Literature search strategy and scope

Parameter	Scope
Search method	1st phase: Systematic search 2nd phase: Snowballing search
Database	Google Scholar and Google search engine
Countries	Argentina, Brazil, China, Colombia, Côte d'Ivoire, India, Indonesia, Kazakhstan, Mexico, Montenegro, Senegal, South Africa, Thailand, Turkey, Ukraine, Vietnam
Search phrases	1st phase: "carbon price", "emission trading", "carbon tax", "environmental tax" 2nd phase: Gaps identified in 1st phase
Languages	English, Chinese, Indonesian, French and Spanish
Source types and hierarchy	(1) peer-reviewed articles; (2) reports from research institutions and multilateral agencies; (3) government publications; (4) media
Exclusion	Literature before 2005, studies on individual province or sector (with a few exceptions)
Selection method	(1) screening of title; (2) screening of abstract; (3) other literature reviews

Higher costs coupled with shrinkage of demand due to reduced households consumption would lead to reduced profitability and potentially cessation of operations. Macroeconomic indicators such as gross domestic product (GDP) and employment rate are likely to be negatively impacted in the short term.

In the long run, the Porter Hypothesis postulates that climate actions are able to generate competitive advantages (Porter and Linde, 1995). Low carbon footprint goods and services will be produced via new processes or new industries. Households will adjust their consumption patterns to these goods and services that would be cheaper compared to those subject to carbon price. Behavioral change induced by carbon pricing spurs demand for abatement technologies, energy saving equipment, fuel efficient vehicles, retrofitting and upgrading of buildings, leading to a growth in GDP and employment rate.

Impact to the competitiveness of firms is a leading indicator of how carbon pricing would affect an economy. If a majority of firms stay competitive, the aggregate export, GDP and employment rate of the jurisdiction would not be weakened. Conversely, if a large proportion of firms lose competitiveness and had to downscale or cease operations, the economy would need to restructure with new industries to sustain growth.

Distributional impact on households could also act as a leading indicator of economic impact. Depending on the wealth distribution and cost structure of an economy, incidence of carbon pricing on households with less disposable income may reduce the consumption not only on carbon-intense goods and services, but also others – which could lead to a reduction in total domestic demand. Besides, this may lead to socioeconomic problems of increased poverty and widened economic inequality that jeopardize human development and destabilise a society.

In order to achieve the objective of GHG emission reduction without causing too much undesirable disruption to the economy and the society, carbon pricing is seldom introduced as a solo policy. It is often introduced as part of environmental policy package, with polices implemented in stages to counter negative effects with different latencies and to ease the transition of the economy. Some countries even introduce environmental fiscal reforms that change other taxes or subsidies over a period of time.

3.2. Environmental Policy Package

The optimal design of environmental policy package depends on many factors such as energy sources, key industries, government budget, expenditure pattern, income level and welfare distribution of households, not forgetting political will of leaders as reshaping of an economy could take longer than an average term of a government.

Safeguard policies are often put in place to protect emission-intensive trade-exposed industries while maintaining the signal of decarbonization. These include allocation of free emission allowances, lower tax rate, or potential imposition of border tax on imports and rebate on exports to trading partners without carbon pricing. These often time-bound measures help firms to transition their processes – thus retaining jobs and wealth within the jurisdiction – or to transform the business should existing operations proved to be incompatible with the green economy.

An important element of environmental policy package is revenue recycling policies. Revenue from carbon tax and auction of emission allowance, or budget freed up from removal of subsidies could be explicitly "recycled" into the economy, thus yielding multiple benefits. It is an on-going debate among economists whether the double-benefit hypothesis for environmental taxes, first proposed by Pearce (1991), is valid (Freire-González, 2018). Proponents of the hypothesis believe that an environmental tax package not only would benefit the environment (first dividend), but would also contribute to economic growth (second dividend). On that basis, one may consider other associated potential benefits – employment growth, equality improvement, national debt reduction, poverty eradication and achievement of other sustainable development goals – as further dividends.

The World Bank analyzed how carbon revenue was used around the world and found a variety of models, each suited to the circumstances of the jurisdiction. British Columbia, Canada designed its broad-based carbon tax to be revenue neutral – all revenue generated is recycled back to households and industries via reduction of corporate and personal income taxes and lump sum transfers to lower-income households, making it a progressive tax (Beck et al., 2015). The EU ETS and Japanese carbon tax earmark some of the revenues for climate change-related projects and green spending. Colombia, which implemented a carbon tax as part of environmental fiscal reform in 2016, channels the revenue to the Colombia In Peace (Colombia en Paz) Fund to finance environmental projects for post-conflict zones, supporting long term development goals. Both India and Indonesia recycled part of the freed up budget from removal of fossil fuel subsidies as direct money transfers to poorer households (*Using* Carbon Revenues, 2019).

3.3. Environmental Fiscal Reform

Environmental fiscal reforms involve more extensive changes on taxes or subsidies with the purpose of nudging behavioral change of the society, safeguarding competitiveness of domestic firms, improving welfare distribution of households and stimulating growth of a low-carbon economy (Withana et al., 2013). Gutman (2019) described the prerequisites of carbon pricing in a "road map": with macroeconomic stability, climate and energy policy consistency, the fiscal reform could start with fossil fuel subsidies removal, followed by renewable energy stimuli, regulations and tariffs modification and finally introduction of carbon pricing mechanism. Some industrialized countries, for example Sweden (Shmelev and Speck, 2018), have gone through the reform journey successfully. Many developing countries are still struggling with climate and energy policies alignment, while a few have gone through fossil fuel subsidies removal and are embarking on the introduction of carbon pricing mechanisms.

As an example, Mexico spent 1.95% of GDP on distortionary fuel subsidies in 2011. The country started the process of fiscal reform in 2014 by introducing a carbon tax in 2014. In 2016, it removed fuel subsidies that disproportionately benefited the rich while simultaneously deregulating the oil and gas exploitation, production and retail sectors. With these, fossil fuels consumption was turned from a fiscal expenditure to a revenue stream that made up approximately 10% of total Mexico's tax income in 2017 (Arlinghaus and van Dender, 2017). Parallel to its carbon tax, Mexico has also launched a pilot ETS for 2020-2023 with target of a full implementation in 2024 (Prat, 2020).

Indonesia is right behind in this process. Indonesia spent 3% of it GDP or 10% to 20% of the central government's budget on such subsidies during the period of 2000 to 2014 (Indonesia's Effort to Phase Out and Rationalise Its Fossil-Fuel Subsidies, 2019). The country started significant energy reform in 2005 to remove fuel subsidies gradually over several years. The government is now working towards the full implementation of ETS by 2024 (Indonesia Eyes Pilot for Carbon Trading in 2020, 2020).

4. LITERATURE REVIEW RESULTS AND DISCUSSIONS

4.1. Impact on Firms

Carbon pricing affects the competitiveness of firms in many ways. A firm that need to bear abatement costs or pay carbon price would be disadvantaged compared to its competitors that do not have similar burden. Other firms in the same economy may be indirectly affected as costs of carbon pricing are passed down the value chain as higher energy tariff, increased material prices and dearer services. In response, firms could modify their processes to be less emission- and energy-intensive, optimize their cost structure or employ other innovative means to stay competitive (Ellis et al., 2019).

A jurisdiction that shows negligible impact on firms' competitiveness is India. Currently, India imposes only implicit carbon pricing by the way of clean environmental cess on coal and excise tax on diesel and petrol. Goldar and Bhalla (2015) simulated an explicit carbon price of USD4/tCO_2e to USD15/tCO_2e and found that even with the resultant increase in cost, only 2-3% manufacturing firms in India would suffer reduction in exports due to loss of competitiveness. Subsequent study by Goldar et al. (2017) found an inverse correlation between emission intensity and export volumes when they surveyed Indian manufacturing firms' performance in 2009-2012. During this period, the sector reduced CO_2 emission intensity by 11%. They concluded that internalizing GHG emission cost would not result in a loss of competitiveness.

China has introduced pilot ETS in five cities and three provinces (Beijing, Shanghai, Tianjin, Chongqing, and Shenzhen, as well as in Guangdong, Hubei and Fujian province) since 2013. Lessons learned from these separate pilot programs were used to design a nation-wide ETS that is scheduled to launch in mid-2021 ('China's National Emissions Trading May Launch in Mid-2021', 2021). Mixed outcomes were found on the impact of ETS on competitiveness. Zhang and Duan (2020) summarized that many ex-post studies using aggregated provincial or sectorial data found the impact to be insignificant in the short term, while studies using firm-level data of listed enterprises turned out negative impact. Zhang et al. (2019) discovered that emission reduction achieved by regulated firms during the study period (2005-2015) was mostly due to capacity reduction rather than emission intensity reduction, which in turn, impaired the competitiveness of firms. Dong et al. (2019) compared the effect of pilot ETS with the command-and-control regime in the "Eleventh Five-year Plan" (2006-2010) and noted that emission reduction achieved during this period was contributed by tight control measures that included throttling of power supply. Dai et al. (2018) analyzed firm-level data in 2011-2015 and found remnants of this behavior, in that the productivity of state-owned enterprises was reduced and ETS trading volume was not as high as anticipated. They concluded that state-owned enterprises bore the burden of compliance cost without effectuating competitiveness boosting measures in the early phase of pilot ETS. However, firms' behavior in pilot ETS with transient nature may not be representative of their long term conducts.

Another way to investigate the impact of carbon price on firms' competitiveness is by looking at research, development and innovation outcomes. Zhu et al. (2019) investigated the patent filing frequency at the China's State Intellectual Property Office and found evidence that the pilot ETS increased low-carbon patent filing by 5–10% among the regulated firms, with spillover effects on some large non-regulated firms that might have been preparing for the regulation. The authors believed that the pilot ETS had directly contributed to around 0.4% to 2% low-carbon patents filed in pilot ETS regions during 2014-2015.

The observations on patent filing support Porter's Hypotheses that stringent environmental policy would encourage innovation that in turn, could enhance competitiveness (Porter and Linde, 1995). In order to further stimulate research and development (R&D) activities, revenue from carbon pricing could be recycled to subsidize R&D on emission reduction or low carbon technologies as carbon pricing and R&D incentives would complement each other towards the goals of climate change mitigation and green growth (Acemoglu et al., 2012; Stavins, 2010).

The empirical findings gathered here (as summarized in Table 3) does not give a conclusive view on whether carbon pricing affects competitiveness of firms in developing countries. However, it can be concluded that disadvantages due to additional costs of carbon pricing can be overcome, especially when firms take a long term view of carbon pricing and invest in R&D to improve competitiveness.

Table 3: Impacts of carbon pricing on firms' competitiveness in developing countries

Country	Research	Method and data	Carbon Price (USD/ tCO_2e)	Findings: Impacts on firms
China	Zhang and Duan (2020)	Various ex-post studies	Pilot ETS	Insignificant impact on aggregated provincial or sectorial results, negative impact with listed enterprises firm-level results.
	Zhang et al. (2019), Dong et al. (2019) and Dai et al. (2018)	Difference-in-difference	Command-and-control (2006-2010), Pilot ETS (2013-2015)	Emission reduction achieved via capacity reduction rather than emission intensity reduction. Competitiveness of firms, especially state-owned enterprises, was impaired.
	Zhu et al. (2019)	Ex-post analysis 2001-2015 data	Pilot ETS	Pilot ETS increased low-carbon patent filing by 5–10% among the regulated firms.
India	Goldar and Bhalla (2015)	ASI 2007-2008 data	4 to 15	Only 2-3% manufacturing firms would suffer reduction in exports.
	Goldar et al. (2017)	Ex-post firm-level 2009-2013 data	--	Inverse correlation between emission intensity and export volumes.

4.2. Impact on Households

The movement of consumer price index and the incidence of carbon price depends on how the environmental policy package is designed. Ex-ante simulations on households of different income levels and dwelling locations were used to derive revenue recycling policies to ease the burden of carbon pricing on domestic demand while maintaining the signal to shift behavior towards emission reduction. Revenue recycling strategies were also used to achieve other socioeconomic dividends such as equality improvement and poverty eradication. Wang et al. (2016) provided a good list of studies performed around the world. This section builds on their review with new and updated literature. A summary is provided in Table 4.

Many studies found that isolated carbon pricing mechanism in developed countries has negative Suits Index – they regressively burden lower-income households more than higher-income households. In most developed countries, the rich spend more on energy than the poor; but energy expenditures make up a higher proportion of disposable income for the poor. The poor may face limitations in behavioral shifting for emission reduction as they can ill-afford the upgrade of their poorly insulated homes, less energy efficient appliances or low fuel economy vehicles.

In developing countries, however, the picture is quite different. Dorband et al. (2019) modeled a USD30/tCO_2e carbon price on 87 low- and middle-income countries and found strong evidence that it would be progressive for lower-income countries and regressive for richer countries. A key contributing factor to this observation is the different pattern of energy expenditure between urban and rural households. Higher-income developing countries are more urbanized than the lower-income countries. Unlike rural households, urban households typically use more transportation and do not have the options of energy sources that are not taxable

Table 4: Distributional impacts of carbon pricing on households in developing countries

Country	Research	Method and Data	Carbon Price (USD/tCO_2e)	Findings: Impacts on households
China	Brenner et al. (2007)	CASS 1995 data	11.8	Without revenue recycling, progressive for country aggregate.
	Jiang and Shao (2014)	Input-output model	2.9	Metropolitan Shanghai's Suits Index = −0.078
	Liang and Wei (2012) and Liang et al. (2013)	CEEPA model SAM 2007 data	1.6	Without revenue recycling, Gini coefficient impacts are: −0.0029% to −0.005% rural, +0.019% to +0.024% urban, +0.086% to +0.090% in aggregate.
Colombia	Romero et al. (2018)	Micro-simulation model	10 and 50	Higher-income households most affected, middle-class households least affected.
India	Rathore and Bansal (2013)	competitive and partial equilibrium model 2009-2010 data	--	Regressive for urban, progressive for rural, almost proportional in aggregate.
	Ojha et al. (2020)	CGE model (2021-2040)	0.9 to 6.7	With revenue recycled to households, −0.27% Gini coefficient, With revenue recycled to industries, +0.01% to +0.02% Gini coefficient
Indonesia	Yusuf and Resosudarmo (2015)	ORANI-G model	30	Income side progressive, expenditure side regressive for urban households, progressive for rural households up to the eighth decile.
	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	With revenue recycling to government budget, households and industries, +0.4%, +0.03%, +0.6% rural poverty, +0.3%, +0.1%, +0.4% urban poverty.
Mexico	Renner (2018)	Input-output model	3.5, 20, 50	Progressive in aggregate up to the sixth decile. Rural poverty increase more than urban poverty.
	Gonzalez (2012)	Analytical general equilibrium model	--	Regressive if revenue recycled to manufacturing tax cut, progressive if recycled to subsidies for food.
South Africa	Devarajan et al. (2011)	CGE model, SAM	12.7	Regressive in general, -0.33% welfare
	Alton et al. (2014)	CGE (2010-2025)	3 rising to 30	With revenue recycled to: Reduce corporate tax: regressive Reduce sales tax: proportional Transfer to households: Progressive
Thailand	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	With revenue recycling to government budget, households and industries, +0.4%, -0.5%, +2.2% rural poverty, +1.3%, +1.3%, +1.4% urban poverty.
	Wattanakuljarus (2019)	CGE model, SAM EPPO 2010 data	1.37 to 1.43	Progressive up to the sixth or seventh decile with and without revenue recycled to households.
	Saelim (2019)	Micro-simulation model, 2013 data	37	Progressive. Household welfare: -2.59% lowest quintile, -2.91% highest quintile.
Vietnam	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	With revenue recycling to government budget, households and industries, +.4.1%, -0.6%, +4.2% rural poverty, +0.3%, +0.2%, +0.6% urban poverty.
	Coxhead et al. (2013)	ORANI-G, AGE models	0.7 on coal, 20 on diesel, 47 on gasoline	With revenue recycled to households, progressive for the first three quintiles.

(i.e. biomass). The urban poor suffers the incidence of carbon pricing if no reprieve is provided.

Such was the case in China. Brenner et al. (2007) found that a carbon charge of CNY81.7/tCO_2e (USD11.8/tCO_2e) on the whole of China (with less than 35% urbanization then) would be progressive even without revenue recycling. On the other hand, Jiang and Shao (2014) focused on metropolitan Shanghai and found a carbon tax of CNY20/tCO_2e (USD2.9/tCO_2e) to be regressive, with a Suits Index of -0.078. (Liang et al., 2013; Liang and Wei, 2012) calculated that at a carbon tax of CNY10/tCO_2e (USD1.6/tCO_2e), income inequality would be widened in the urban population and narrowed in the rural population if revenue were not recycled.

Studying the other major emitter in Asia, Rathore and Bansal (2013) found from India's 2009–2010 national sample survey data that a carbon tax on all fossil fuels would have almost proportionate impact in aggregate, consisting of clear regressiveness for the urban dwellers and mild progressiveness for rural population, as 87% of the rural population still used traditional fuels such as firewood and biomass. Ojha et al. (2020) found that a gradually increasing carbon tax of USD0.9/tCO_2e to USD6.7/tCO_2e for 2021-2040 would decrease the Gini coefficient by 0.27% if the carbon revenue was recycled back to households, and would increase it by 0.01% to 0.02% if it was recycled back to industries. Policy makers would have to balance between closing the income equality gap of households or improving the competitiveness of industries.

Using data from Indonesia, Yusuf and Resosudarmo (2015) compared urban and rural households separately and found that a carbon tax at USD30/tCO_2e without revenue recycling would result in factor reallocation away from energy- and capital-intensive sectors to sectors such as services and agriculture, making the tax progressive from the income side. From the expenditure side, the tax was found to be regressive for urban households, but not so for rural households up to the eighth decile. Even at a lower rate of USD10/tCO_2e with various revenue recycling options, carbon tax is found to increase poverty rate in Indonesia (Nurdianto and Resosudarmo, 2016).

The other two countries in Asia that contemplate the implementation of carbon pricing are Thailand and Vietnam. In Thailand, Saelim (2019) did not analyze the urban-rural effect; the author found that a carbon tax at USD37/tCO_2e would be mildly progressive with impact to household welfare at −2.59% at the lowest quintile, widening to −2.91% at the highest quintile. Wattanakuljarus (2019) agreed with the progressiveness, albeit a lower tax rate at around USD1.4/tCO_2e. The author noted that the poorer households received a larger portion of government transfers and government transfers made up a large portion of their income. Indeed, Nurdianto and Resosudarmo (2016) found that poverty rate would decrease among the rural population but increase in the urban areas if a carbon tax of USD10/tCO_2e is imposed with revenue recycled back to households. If the revenue is recycled to government budget or industries, poverty incidence for both rural and urban areas would increase.

Analyzed against labor skill profile, urban versus rural dwelling, income source and level, the environmental taxes introduced by the Vietnamese government in 2012 were found to be regressive in general, only turning progressive for the first three quintiles of households if revenue was recycled back as direct transfers (Coxhead et al., 2013). Similar to Indonesia, rural poverty in Vietnam would decrease while urban poverty would increase if the revenue from a carbon tax of USD10/tCO_2e is recycled back to households; and both would increase if revenue is recycled to government budget and industries (Nurdianto and Resosudarmo, 2016).

In Latin America, similar urban-rural consumption patterns were used to explain the findings in Mexico that carbon tax scenarios of USD3.5/tCO_2e (current effective rate), USD20/tCO_2e and USD50/tCO_2e would be progressive in aggregate up to the sixth decile household income level, although rural poverty would increase more than urban poverty (Renner, 2018). Similar to Ojha et al. (2020)'s finding in India, Gonzalez (2012) found carbon pricing would be regressive if the revenue was recycled as a manufacturing tax cut but progressive if it was recycled as subsidies for food.

In Colombia, a carbon tax simulated at USD10/tCO_2e and USD50/tCO_2e would cause price increase and lower consumption across the population, with higher-income households being the most affected and middle-class households the least (Romero et al., 2018).

In South Africa, while Devarajan et al. (2011) found carbon tax to be regressive in general, Alton et al. (2014) examined revenue recycling options and found that recycling carbon revenue by reducing corporate tax would result in regressiveness, reducing sales tax would make it proportional, and transferring it to households would make it progressive.

Although many findings gathered here point toward progressive impact on households in developing economies, the regressive impact of carbon pricing on urban households cannot be ignored because increased urbanization is an inevitable path in economic growth. A few studies showed that widened economic inequality and incidence of poverty caused by carbon pricing can be averted by recycling the revenue back to households. However, policy makers need to find the right balance among various priorities in the environmental policy package: helping firms to regain competitiveness, easing burden of poorer households, building infrastructure in urban areas, stimulating growth of low-emission industries, etc.

4.3. Impact on Macroeconomics

The Stern Review proposed that 1% of the world GDP should be spent on climate change every year. This figure was later revised to 2% following new evidence of faster GHG build up in the atmosphere (Jowi and Wintour, 2008; "The Stern Review on the Economic Effects of Climate Change," 2006). While this amount may seem large especially for developing countries, it could be raised using carbon pricing mechanisms. The International Monetary Fund calculated that a USD35/tCO_2e carbon price could raise 1-2% of GDP for many countries (Parry, 2019). Spending carbon revenue on climate change mitigation and adaptation activities leads to the creation of jobs and wealth in many sectors such as renewable energy, infrastructure, etc.

On the other hand, a broad-based carbon price causes an upward shift of cost base of an economy, as GHG is emitted in almost every part of modern life, from energy generation to transportation and industrial processes. As firms adjust to a higher cost base, job losses may result due to cost-cutting measures or even operations cessations.

In developed countries with more structured employment and social development systems, the impact on employment could be improved by recycling the carbon revenue to reduce labor costs such as payroll taxes, social security contributions, employment insurance premiums, etc. In developing countries where informal activities make up a larger share of the economy, this option may not be effective (Pegels, 2016). However, the flexibility to return to informal employment may reduce the negative impact on households and improve the income distributional effects (Yusuf and Resosudarmo, 2015). In a populous and labor-abundant economy like India, heavy investment in clean energy sparks worries as it may encourage energy intensive industries that could cause adverse impact to employment (Ojha et al., 2020).

As it is very difficult to isolate the effect of carbon pricing from other factors that shape an economy like interest rates, foreign exchange, global commodity prices, technological changes or other government policies, models are used to study its impact on GDP either on ex-ante or ex-post basis. Computable General Equilibrium (CGE) models have been used in many studies. Freire-González (2018) analyzed 69 CGE simulations from 40 studies around the world and found that 55% of simulations have achieved a double dividend of economic growth. He summarized that although the environmental dividend can be achieved most of the time, the economic dividend is not a certainty.

Mexico, an oil and gas exporter, legislated ambitious emission targets of -30% compared to business-as-usual (BAU) by 2030 and -50% compared to 2000 level by 2050. In order to achieve these targets, Landa Rivera et al. (2016) simulated a few scenarios using Three-ME models at a carbon tax of USD100/tCO_2e by 2030, rising to USD700/tCO_2e by 2050 – albeit the initial rate introduced in 2014 was at a cautious level of MXN5.80/tCO_2e to MXN46.42/tCO_2e for different fuel types or around USD3.5/tCO_2e effective weighted average rate. Even at these hypothetical high tax rates, positive impacts on GDP, consumption and employment were found to be attainable if the tax revenue were fully recycled and renewable energy were to replace a large part of fossil fuel in the electricity generation mix. Without revenue recycling, Octaviano et al. (2016) agreed with Landa Rivera et al. (2016) that meeting the emission reduction target could cost as much as 9% of GDP cumulatively by 2050.

Argentina implemented a carbon tax of USD10/tCO_2e as part of environmental tax reform in 2017. The tax reform, which included lowering of corporate income tax by 10% and reduction of employer's mandatory social contributions, was expected to result in at least 0.5% GDP growth (Ministerio de Hacienda Argentina, 2018). Unfortunately, various exogenous and endogenous factors sent Argentina into financial turbulence in 2018 and the real impact of carbon tax is yet to be seen (Gutman, 2019).

Colombia introduced a carbon tax from 2016 at a modest rate of COP15,000/tCO_2e (USD4/tCO_2e). It is one of the measures to meet the country's NDC target of 20% GHG emission reduction compared to BAU by 2030. The combination of all mitigation measures to meet the NDC target implemented since 2015 would result in a short term negative impact to GDP in the first ten years, but would turn positive to reach a +2.3% impact in 2040 compared to the BAU scenario (Álvarez-Espinosa et al., 2017). Calderón et al. (2016) simulated a more aggressive carbon tax at USD50/tCO_2e annually inflated by 4% for 2020-2050 and found that the impact to be -2% to -3% of GDP if the carbon revenue was recycled back via direct transfer to consumers.

Brazil does not have a carbon tax in place yet. Voluntary ETS simulation exercises have been carried out and the Brazilian government has announced its intention to use carbon pricing instruments to meet the country's NDC target of -37% emissions by 2025 (Karpavicius, 2020). Grottera et al. (2017) simulated carbon tax scenarios at BRL25/tCO_2e (USD4.7/tCO_2e) and BRL50/tCO_2e (USD9.5/tCO_2e), and found the GDP impact to be -3.1% to -5.4% respectively without revenue recycling. When revenue was recycled to households, the impact would reduce to -1.5% and -2.5% respectively. The case would improve to +0.3% and -2.1% if revenue was recycled to industries to cut labor taxes. Pereda et al., (2019) found a smaller impact of -0.2% at USD10/tCO_2e, and -1% at USD50/tCO_2e, if the carbon revenue was not recycled. However, if the carbon tax was designed to be revenue neutral with simultaneous reform of the distortionary PIS/Cofins taxes, a carbon price level of USD35.68/tCO_2e would be required, and it would yield +0.47% in GDP.

Besides explicit traditional carbon pricing, many developing countries in Latin America employs RBCF as part of their climate change strategy. All the aforementioned countries – Mexico, Chile, Argentina, Colombia, Brazil – are participants of the REDD+ (REDD+, 2021). In 2019, Brazil became the first country to receive payment from UNFCCC's Green Climate Fund for the results of reducing GHG emissions from deforestation. The payment of USD96 million was based on a carbon price of USD5/tCO_2e (Camila, 2019).

Acknowledging that Ukraine has the one of the highest CO_2 emission levels per unit GDP in the world, the government introduced a carbon tax on this lower middle-income economy in 2011. The tax started at an extremely low level of UAH0.1/tCO_2e (USD0.01/tCO_2e), gradually increasing to the current level of UAH10/tCO_2e (USD0.4/tCO_2e), which is still too low to stimulate much emission reduction action. Frey (2017) found that at UAH40/tCO_2e (USD3.5/tCO_2e then), the level proposed to the parliament in 2019, the tax would result in 21% emission reduction. With carbon revenue recycled back to enable a reduction in the indirect tax rate, a slight growth in GDP (+0.1%) could be observed.

Kazakhstan is another country with a very high level of CO_2 emission per unit GDP. An ETS was implemented in 2013, covering 55% of its CO_2 emission. In 2019, the average unit price of allowance is USD1.1/tCO_2e. Modeling carbon price scenarios at USD2/tCO_2e, USD5/tCO_2e and USD10/tCO_2e, Nugumanova (2016) found negative impacts on most industrial sectors at all price levels, and negative impacts on overall welfare except in the lowest carbon price scenario. As the Kazakh ETS was temporarily suspended in 2016-2017 to tackle operational issues and reform allocation rules, more study is needed to find out its actual impact.

China is a large economy in the middle stages of industrialization and hence highly energy intensive. The NDC target for China is to reduce GDP-linked carbon intensity by 60% to 65% compared to 2005 level by 2030. In order to meet the lower target, CGE simulations by Cao et al. (2016) and Timilsina et al. (2018) showed that a gradually rising carbon price of USD0.3/tCO_2e in 2016 to USD3.7/tCO_2e in 2030 would be needed, and the impact to GDP would only be -0.1%. The 65% reduction target requires a higher carbon price at USD1.4/tCO_2e rising to USD22.6/tCO_2e, and it would change GDP by -0.7%. These low level impacts to GDP were results of a revenue recycling scenario where the entire carbon revenue was recycled back to the economy by cutting the rates of value-added tax and capital tax. Another simulation using carbon price of USD3.6/tCO_2e with scenarios for ETS, carbon tax and hybrid model for 2020-2030 resulted in negative impacts to the economy in the first couple of years, slowly recovering to a -0.13% to +0.02% impact on GDP, -0.06% to +0.04% impact on employment rate in 2030 (Bi et al., 2019). Yet another simulation yielding similar impact is from Guo et al. (2014), who found that carbon prices of USD2.4/tCO_2e, USD5.2/tCO_2e, USD11.7/tCO_2e and USD19.0/tCO_2e are needed to effectuate emission reductions of 5%, 10%, 20% and 30% respectively, resulting -0.15%, -0.32%, -0.75%, -1.33% impact to the real GDP of China. In comparison, the pilot ETS have been trading at USD1/tCO_2e to USD12/tCO_2e in different locations with Beijing ETS almost always on the high side. The pilot ETS are likely to continue alongside the national ETS for a few years ("Regional Pilot ETS likely to continue until 2025," 2019).

Simulating the effects of an explicit carbon tax of INR66/tCO_2e to INR502/tCO_2e (USD1/tCO_2e to USD7/tCO_2e) on all fossil fuels for years 2020-2040 in India, Ojha et al. (2020) found that emission reduction objectives could be achieved with minimal impact to GDP (0.0% to -0.2%) if the carbon revenue was totally recycled back to households. On the other hand, if the tax revenue was recycled to industries, there would be slight GDP gain. The research also found that at this low rate, carbon tax alone would not be sufficient to promote inclusive green industries development that would spur economic growth. Mittal et al. (2018) calculated that India's NDC was not sufficient to meet the Paris Agreement's target of stabilizing the average global temperature rise to "well below 2°C" compared to the pre-industrial level. In order to achieve the 2°C target, India would need to have a carbon price from year 2020 onward, rising to USD74/tCO_2e in 2030 and USD187/tCO_2e in 2050. If the carbon revenue was entirely recycled back to households, the impact to GDP would be -0.7% in 2020, -3.0% in 2035 and -3.2% in 2050. As coal is the main energy source for India and firmly entrenched in the economy of India (Tongia and Gross, 2019), Ghosh (2016) took a different approach and simulated the impact of a higher coal cess from USD0.42/tCO_2e rising to USD76.80/tCO_2e over the period 2010-2030. He found a slight negative impact (-0.33%) on GDP if the revenue was totally recycled to the wind and solar energy sectors, but +0.11% if half of it was recycled to the agriculture sector. For comparison, the rate of clean environment cess on coal is INR400 per tonne of coal or around USD3.4/tCO_2e in 2020.

For Southeast Asia, a carbon price of USD10/tCO_2e imposed on Thailand and Vietnam would contract the real GDP by -0.14% and -0.33% respectively according to Nurdianto and Resosudarmo (2016). A few Southeast Asian countries have distortionary mechanisms, such as fuel price subsidies, in place. Carbon pricing, in these cases, would conversely bring a positive impact to GDP. An example is Indonesia that would yield +0.25% real GDP in the same study. Ayu (2018) argued that a carbon tax in Indonesia would reduce GDP not only of the country itself but also that of other countries in the region. Besides the pilot ETS scheduled to be launched by end 2020, Indonesia is also active in RBCF, with the first REDD+ payment received in 2020 (Lubis, 2020).

Thailand has spent some time preparing for carbon pricing. The Thailand Voluntary Emissions Trading Scheme was introduced in 2013. Systems were set up and tested for various industrial sectors during the first two pilot phases from 2015 to 2020 ("ETS Detailed Information: Thailand," 2020). Studies based on carbon tax rates at USD6.3/tCO_2e to USD19.0/tCO_2e found modest negative impacts on Thailand's GDP at -0.6% to -1.6% (Puttanapong et al., 2015).

Vietnam has been considering an ETS since 2012 when an implicit carbon tax (in the form of environmental protection tax) was implemented on top of consumption taxes. Simulations were carried on both instruments. A narrow based ETS would result in -4.6% real GDP (only energy, transport and agricultural sectors), while an all-sector ETS could reduce the negative impact to -1.8% real GDP. Increasing the consumption tax by 33.3% on petroleum products would result in -2.0% real GDP, and a 50% increased rate on coal would result in -0.5% real GDP (Nong, 2018; Nong et al., 2020). The rates of the environmental protection tax were increased in 2018 and an explicit carbon tax on coal was introduced to the cement sector in 2020 as a pilot scheme ("Vietnam to increase environment tax on fuel," 2018; "Vietnamese cement producers in four provinces to run carbon tax pilot," 2019). Vietnam also participates in REDD+ program, but has yet received payment from this RBCF.

South Africa finally implemented a carbon tax of ZAR120/tCO_2e (USD8.48/tCO_2e) in June 2019, after a four-and-a-half year delay. An ex-ante analysis based on the design of carbon tax and revenue recycling proposed in the 2013 policy paper found the impact on GDP growth to be slightly negative – from a baseline growth rate of 3.5% to 3.3–3.4% percent per year. Employment, consumption and real wage were similarly impacted (Ward and de Battista, 2016). The belated legislation differs only slightly from this policy paper. It does not earmark revenue for recycling but ensures a neutral impact on electricity tariffs until 2022 when the policy will be reviewed.

Montenegro and Turkey are two countries that are introducing carbon pricing as part of accession negotiations with the EU. Montenegro enacted a regulation in February 2020 to operationalize an ETS. The start date of the ETS has yet to be announced.

Various studies have been performed on the impact of a carbon price on Turkey. In order to achieve the Intended NDC target of -21% emissions compared to BAU by 2030, Kolsuz and Yeldan (2017) estimated that the carbon price in Turkey ought to be around USD30/tCO_2e. If the carbon revenue was recycled to reduce firms' labor tax burden, a +9.2% gain in employment rate could be achieved with +1.6% increase in GDP. Kat et al. (2018) simulated the same target on the energy sector and found the carbon price to be USD50/tCO_2e to USD70/tCO_2e, cumulatively equivalent to 0.8% to 1.1% of its GDP in 2030.

Table 5 lists the findings on macroeconomic impacts of carbon pricing in developing countries. Various carbon pricing levels were used in these studies in order to simulate desired emission reduction outcomes. The resultant macroeconomic impacts were optimized with revenue recycling options to minimized aggregate negative impacts. The wide range of input parameters and outcomes, suited to socioeconomic circumstances of each country, demonstrates the complexity in designing and implementing a carbon pricing policy package.

5. ALTERNATIVE AND COMPLEMENTARY STRATEGIES

Stringent carbon pricing works well in industrialized countries to change behavior and phase out stranded assets such as coal-fired power plants, emission intensive logistics and skills specific to fossil fuel industries. In resource-rich developing countries, however, the challenge is to restrain the exploitation of resources (e.g. conversion of forests, development of coal mines) and thus prevent emission lock-in. The opportunity loss of stranded

Table 5: Macroeconomic impacts of carbon pricing in developing countries

Country	Research	Method and Data	Carbon Price (USD/tCO_2e)	Findings: Impacts on GDP, employment and GHG emissions
Argentina	Government policy paper 2017	--	10	With revenue recycled to reduce corporate income tax and labor costs, expected +0.5% GDP.
Brazil	Grottera et al. (2017)	SAM 2002-2003 data	4.7 and 9.5	Without revenue recycling, −3.1% and −5.4% GDP. With revenue recycled to households, −1.5% and −2.5% GDP. With revenue recycled to industries, +0.3% and −2.1% GDP.
	Pereda et al. (2019)	Input-Output model	10 and 50; 35.68	Without revenue recycling, −0.2% and −1% GDP; with revenue recycled to reform of the distortionary PIS/Cofins taxes +0.47% GDP.
China	Cao et al. (2016) and Timilsina et al. (2018)	CGE model (2010-2030)	0.3 rising to 3.7 1.4 rising to 22.6	With revenue recycled to reduce VAT and capital tax, −0.1% GDP, -3.3% emissions −0.7% GDP, -16% emissions
	Bi et al. (2019)	MCHUGE model (2020-2030)	3.6 carbon tax and ETS	−0.13%, +0.02% GDP, +0.04%, −0.06% employment, −0.3%, −0.1% emissions compared to BAU.
	Guo et al. (2014)	CGE model, SAM 2011 data	2.4, 5.2, 11.7, 19.0	GDP: −0.15%, −0.32%, −0.75%, −1.33% Emissions: −5%, −10%, −20%-30%
Columbia	Álvarez-Espinosa et al. (2017)	MEG4C, Micro-simulation models (2015-2040)	4	Negative impact to GDP in the first ten years, 0.0% to +2.3% in the next fifteen years compared to BAU.
	Calderón et al. (2016)	TIAM-ECN, GCAM, Phoenix, MEG4C models (2020-2050)	50 (+4% annually)	With revenue recycled to consumers, −2% to −3% GDP.
India	Ojha et al. (2020)	CGE model (2021-2040)	0.9 to 6.7	With revenue recycled to households, 0.0% to −0.2% GDP. With revenue recycled to industries, slight gain in GDP.
	Mittal et al. (2018)	AIM/CGE model	74 in 2030 rising to 187 in 2050	With revenue recycled to households, GDP −3.0% in 2035 and −3.2% in 2050.
	Ghosh (2016)	CGE model (2010-2030)	Coal cess 0.42 rising to 76.80	With revenue totally recycled to the wind and solar energy sectors, −0.33% GDP. With revenue half recycled to agriculture sectors, +0.11% GDP.
Indonesia	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	With revenue recycling to government budget, households and industries, +0.25%, +0.27%, +0.26% GDP, +0.4%, +0.03%.
	Ayu (2018)	CGE model, GTAP-E	1, 7.5, 20	0%, −0.02%, −0.07% GDP, −1%, −4.2%, −9.6% emissions. Would also impact GDP of other countries in the region.
Kazakhstan	Nugumanova (2016)	CGE model, GTAP-E 2011 data	2, 5 and 10	Negative industrial output on most sectors, negative overall welfare except at USD2/tCO2e scenario; −4%, −9% and −16% emissions.
Mexico	Landa Rivera et al. (2016)	Three-ME model (2014-2050)	100 in 2030 rising to 700 by 2050	With revenue fully recycled, positive impacts on GDP, consumption and employment. Emissions from energy consumption: −40% by 2030, −75% by 2050 compared to BAU.
	Octaviano et al. (2016)	MIT EPPA model (2005 to 2050)	10, 50 (+4% annually); 17 rising to 437	Cumulative GDP: −1.5%, −4%, −9% Emissions: +35%, +8%, −50% compared to 2010 level by 2050.
South Africa	Alton et al. (2014)	CGE (2010-2025)	3 rising to 30	GDP: −1.07% to −1.23% Employment: −0.5% to -0.6% Emissions: −36% to −41%
	Ward and de Battista (2016)	UPGEM model (2015-2035)	8.5	−0.1 to −0.2% GDP, −1.4% employment, −26% to −33% emissions compared to BAU by 2035.
Thailand	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	With revenue recycling to government budget, households and industries, −0.14%, −0.08%, −0.14% GDP.
	Wattanakuljarus (2019)	CGE model, SAM EPPO 2010 data	1.37 to 1.43	−0.85% to −0.99% GDP, −20% emissions by 2030 compared to BAU.
	Puttanapong et al. (2015)	Monte-Carlo CGE model (2010-2019)	6.2, 12.6, 18.9	−0.3%, −0.9%, −1.2% GDP, −0.6%, −1.3%, −2.1% employment, −0.7%, −1.5%, −2.4% emissions.
Turkey	Kolsuz and Yeldan (2017)	CGE model, 2010 data (2015-2030)	30	With revenue recycled to reduce labor tax, +9.2% employment, +1.6% GDP, −19.7% emissions.
	Kat et al. (2018)	TR-EDGE model (2010-2030)	50 to 70	−0.8% to −1.1% cumulative GDP by 2030
Vietnam	Nurdianto and Resosudarmo (2016)	IRSA-ASEAN model	10	With revenue recycling to government budget, households and industries, −0.33%, −0.22%, −0.22% GDP.

(Contd...)

Table 5: ***(Continued)***

Country	Research	Method and Data	Carbon Price (USD/tCO_2e)	Findings: Impacts on GDP, employment and GHG emissions
	Coxhead et al. (2013)	ORANI-G, AGE models	0.7 on coal, 20 on diesel, 47 on gasoline	With revenue recycled to households, −0.35% to −0.63% GDP.
	Nong et al. (2020)	GTAP-E model	ETS	Only energy, transport and agricultural sectors, −4.6% GDP. All-sector ETS, -1.8% GDP.
	Nong (2018)	GTAP-E model	0.7 on coal, 41 on diesel, 96 on gasoline	Tax on coal +50%, −0.5% GDP, −10% emissions. Tax on petroleum products +33.3%, −2.0% GDP, −7% emissions.
Ukraine	Frey (2017)	CGE model, SAM 2007 data	0.02 to 4.3	With revenue recycled to reduce indirect tax rate, 0.0 to +0.14% GDP, −0.2% to −25% emissions

resources needs to be countervailed by phasing in renewable energies and green technologies to meet development needs (Bos and Gupta, 2019).

At the Africa Climate Week 2019 in Ghana, mitigation was not given priority as it was recognized that the entire continent contributes to just 3% of global GHG emissions. The priority was to make financial resources available for sustainable development (Carbon Pricing in Sub-Saharan Africa, 2020). In order to meet Paris Agreement's target of limiting global average temperature rise to 2°C, Africa will have to leave 26%, 34% and 90% of gas, oil and coal reserves undeveloped (McGlade and Ekins, 2015). Stringent traditional carbon pricing in many African countries would not generate a far-reaching signaling effect, and would need to settle at a low level to be economically affordable and politically acceptable. However, a low level carbon price could not amass sufficient revenue needed to phase in green growth and may not be adequate to prevent emission lock-in given the sizable stranded resources. Carefully targeted policy packages with non-price instruments (Finon, 2019) and multilateral RBCF would work better in many cases.

Senegal and Côte d'Ivoire are members of the West African Alliance on Carbon Markets and Climate Finance, which has recently started consultation on a sub-regional joint carbon pricing initiative. Senegal has stated its intention to launch a national carbon pricing mechanism by 2025 (Michaelowa et al., 2019). Senegal targets to start producing oil by 2022 while commercializing major gas discoveries (Africa Energy Outlook 2019 | Overview: Senegal, 2019) in order to meet the rapidly growing energy demand. As of 2016, 58% of primary energy consumption came from biomass while fossil fuel was used to generate 88% of electricity supply that was accessible to 65% of the population. 43% of Senegal's land mass is covered by forest and 87% of GHG emissions were sequestered by forest and land use ("The World Bank: Data," 2020; Troisieme Communication Nationale Du Sénégal, 2015).

Côte d'Ivoire has also announced its intention on a national carbon pricing mechanism. Côte d'Ivoire is an oil and gas producer and energy exporter with very little presence of coal. As of 2018, more than half of primary energy consumption came from biomass while natural gas was the main source for electricity generation that was accessible to 67% of the population. With savanna landscape at the north of the country, Côte d'Ivoire has 33% forest cover and 40% of GHG emissions were sequestered by forest and land use ("The World Bank: Data," 2020; Troisième Communication Nationale (TCN) De La Côte d'Ivoire Dans Le Cadre De La Convention Cadre Des Nations Unies Sur Les Changements Climatiques (CCNUCC), 2017).

There is clear room for REDD+ and other RBCF (e.g. grants for distribution of clean cook stoves, solar rural electrification) in the environmental policy package for both countries. Both countries have successfully established frameworks for CDM and participate in international carbon trading. As of August 2020, there are eight and seven carbon credit generating projects in Senegal and Côte d'Ivoire respectively. Participation in the market and non-market approaches under the Paris Agreement should be given priority in the policy packages too.

6. CONCLUSIONS

Carbon pricing mechanisms could stimulate innovation that would help firms to stay competitive – even though it is difficult to quantify in ex-ante modeling. When introduced with time-bound safeguards, most firms would adjust to higher cost base while some would cease operations due to their incompatibility with the low-emission economy. In developing countries, carbon pricing mechanisms were found to be mostly progressive for rural populations but regressive for city dwellers. Revenue recycling policies could change the Suits Index and the Gini Coefficient impact of a carbon pricing policy. Even as simulations at different carbon price levels led to ranges of results, most studies demonstrated that revenue recycling could also reduce the negative impacts to employment and GDP. In developing countries, multi-year environmental fiscal reforms are often required to implement carbon pricing. The higher proportion of informal economy in developing countries requires revenue recycling strategies that are different from that of developed countries. In many developing countries, multiple carbon pricing and non-price instruments should be considered in parallel to achieved climate change and sustainable development objectives.

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