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Energy Models for Analyzing the Economic Wide Impact of the Environmental Policies

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***Abstract*—**Different countries have introduced different schemes and policies to counter global warming. The rationale behind the proposed policies and the potential barriers to successful implementation of the policies adopted by the countries were analyzed and estimated based on different models. It is argued that these models enhance the transparency and provide a better understanding to the policy makers. However, these models are underpinned with several structural and baseline assumptions. These assumptions, modeling features and future prediction of emission reductions and other implication such as cost and benefits of a transition to a low-carbon economy and its economy wide impacts were discussed. On the other hand, there are potential barriers in the form political, financial, and cultural and many others that pose a threat to the mitigation options.

***Keywords*—**Economic wide impact, energy models, environmental policy instruments, mitigating CO_2 emission.

I. Introduction

DIFFERENT countries have adapted different schemes and policies to counter global warming, based upon the developments levels, the social and political structure and the cultural beliefs prevalent in the countries. The policies are primarily based on resolution of the issue, by mitigating CO_2 emission of the countries. Some countries have developed market based policies, while others have more autocratic command and control policy [1]. Furthermore, various countries chose to employ different economic energy models like G-CUBED, G-TEM, MMRF according to each country's requirement and structure [2]. These are based on various assumptions which include scenarios such as business as usual, high, low, etc. For these models different production functions are needed based on Neoclassical or Keynesian principles such as COBB-DOUGLUS, TRANSLOG, etc [2]. These models are important for policy maker and used for policies and schemes such as Carbon Tax, Emission Trading Scheme (ETS) and other schemes implemented by different countries. Also they are useful tool for short and long term analysis. There in depth study is very useful to address this paper and its economy wide impact.

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II. Methodological Framework and Modeling Assumptions Used in Analyzing the Economy Wide Impacts

Initially, significant efforts have been made by the scientists and environmentalist in analysing the change in climate patterns owing to carbon emissions and its environmental impacts. In recent times, collective efforts of several nation governments joined hands in this war against global warming and their impacts to limit the amounts of GHG released into the atmosphere. Against this backdrop this section of the study presents several policies measures that have been adopted since 1997 to provide a comparative assessment of the mitigation potential of major economies. A country adopts the policy best suiting its current economic situation.

Different policies are being implemented across these countries on the basis of the country structure and modelling assumptions. These policies have several benefits and impacts and are effective on the basis of the modelling assumptions. Thus, the following section will look into these aspects of policies and their potential barriers. The mitigation options adopted in economies provide the level of GHG emission reduction that can be realised. It is relative to the projected emission baseline in a given year, for a given carbon price [3], [4]. To end up with a good comparative policy analysis, these estimates differ on the basis of modelling used, data applied, and underlying modelling assumptions and present the potential barrier to implementation.

In 1997, the Kyoto Protocol was adopted in Kyoto, Japan which is an international agreement linked to UNFCC. "The major feature of the Kyoto Protocol is that it sets binding targets for 37 industrialized countries and the European community for GHG emissions .These amount to an average of five per cent against 1990 levels over the five-year period 2008-2012" [5]. Under this protocol, the countries have committed to reduce its emissions as signed for. This protocol has been entered into force since 2005 and in present times has been ratified by 192 countries including India and China but not by USA [6]. Protocol also recognizes the principal responsibility of developed nations in current level of emission, places a heavier burden of reduction on them, under the principle of 'common but differentiated responsibilities'. The convention divides the countries into two major groups Annex I which consists of industrialized countries and economies in transition countries and Non-Annex-I parties which includes developing economies respectively.

TABLE I
ENVIRONMENTAL POLICIES ADOPTED BY VARIOUS COUNTRIES

Name of country	Name of policy or measure	Objective and/or activity affected	Kyoto Protocol Mechanism (planned)	Greenhouse gas/es affected	Assumptions	Model	Status	Estimated contribution to mitigation impact in 2020 & 2050
AUSTRALIA	•Carbon Pollution Reduction Scheme (CPRS) •Emission Trading Scheme (ETS) •Greenhouse Gas Abatement Scheme (GGAS) •Carbon tax	Reduce emissions and transition to low carbon economy.	Emissions Trading Scheme (ETS) or Carbon Tax	CO_2	BAU (Business as Usual).	CGE models GTEM G-Cubed model (MMRF) model.	In process	30% -2020 60%-2050
EUROPEAN UNION	•Kyoto Protocol. • Emission Trading Scheme •Energy Efficiency •CCS, •Renewable Programs • Audit Programs •Kyoto Protocol.	Reduce emissions and carbon neutral.	ETS.	CO_2, Methane hydroxyl radical.	BAU	(GEM-E3) and POLES.	In process	20%-2020 30%-2050
USA	ETS •Energy Efficiency •Renewable •Climate change programs •Cap and trade •Kyoto Protocol.	Reduce emissions, zero carbon.	Clean Development Mechanism (CDM-Host Country)	CO_2	BAU	EPPA, SGM, ADAGE, MERGE	In process	17%-2020 80%-2030
BRAZIL	Efficiency Enhancement •Reduce Deforestation •Renewable.	Reduce emissions (without sacrificing growth).	CDM Clean Development Mechanism (CDM-Host Country)	CO_2	BAU	World Bank's Environmental ENVISAGE	In process	30%-2020 40%-2030
INDIA	•Energy Efficiency Renewable, •Incentive Based Schemes •Voluntary Measures •Kyoto Protocol.	Reduce emissions (without sacrificing growth).	CDM (Host Country)	CO_2	BAU	ENVISAGE	In process	20%-2020 25%-2030
RUSSIA	•Energy Efficiency •Expansion of renewable and nuclear reserves, • Voluntary Measures •Kyoto Protocol	Reduce emissions (without sacrificing growth).	Joint Implementation (JI)	CO_2	BAU	ENVISAGE	In process	15%-2020 25%-2030
CHINA	•Energy Efficiency Renewable •Nuclear reserves •Kyoto Protocol.	Reduce emissions (without sacrificing growth).	CDM (Host Country), Possibly ETS	CO_2	BAU	ENVISAGE	In process	9%-2020

TABLE II
METHODOLOGICAL FRAMEWORK VARIOUS MODELS USED IN ENVIRONMENT POLICY MAKING

Model	Structure	Methodology	Time	Countries
MMRF	Hybrid	Recursive-Dynamic	2050	Australia
GTEM	Hybrid	Recursive-Dynamic	2050	Global
G-Cubed	Top-down	Forward-Looking	2050	Global
GEM-E3	Top-down	Recursive-Dynamic	2050	Global
EPPA	Top-down	Forward-Looking	2100	Global
SGM	Top-down	Recursive-Dynamic	2100	Global
ADAGE	Top-down	Forward-Looking	2050	Global
MERGE	Hybrid	Forward-looking	2100	Global
ENVISAGE	Top-Down	Recursive-Dynamic	2050	Global
POLES	Bottom-Up/Hybrid	Recursive-Dynamic	2050 OR 2100	Global

Global: Include OECD and BRICS NATIONS

Currently the debate is to meet the ambitious goal of stabilizing levels of greenhouse gases in the atmosphere at 450 ppm CO_2-eq or lower by 2020 and keep the global temperatures around 2^{o}C, which is the quantified economy-wide emissions target.

III. KEY POLICY INSTRUMENTS, THEIR POTENTIALS SAVINGS AND METHODOLOGICAL

Environmental policies governments may use a number of different types of instruments. For example, economic incentives and market-based instruments such as taxes and tax exemptions, tradable permits, and fees can be effective to encourage compliance with environmental policy.

ETS is preferred option by other countries [7] as well as it is effective in the long run, when the cost of abatement are likely to be less as the production has adapted to the higher relative prices of fossil fuels. The benefits of the abatement would be greater as the cost of climate change would increase sharply, thus increasing the benefits from a cap and trade [2], [4]. In the short run carbon tax is more effective than the regulator would levy a fee for each ton of CO_2 emitted. However, the total amount of CO_2 emitted in any given year would be highly uncertain and also maintaining an international consistency would be essential to avoid double taxing or exempting certain goods [8]. Voluntary measures, such as bilateral agreements negotiated between the government and private firms and commitments made by firms independent of government pressure, are other instruments used in environmental policy. Another instrument is the implementation of greener public purchasing programs. Brazil and India are focusing on deforestation and renewable sources of energy in order to reduce CO_2 emission. China has a major share in global emissions but the argument is that its contribution to the world GDP and population is more than the emission share as in the case with other developing countries. Russia has reduced its emissions in the period from 1990 to 2010, and it is in a position of surplus carbon emission permit. It can choose to sell the permits or use it in future. This is predominantly due to the instability of the economic activity, seen over the same period in the Russian Economy. Hence, further review of these instruments with their methodological framework and modeling assumptions used in analysing the economic wide impact as shown in Table II.

	Share of emissions (%)		
	2005	2030	2100
United States	18.3	11.1	5.1
European Union	12.6	7.1	3.6
Former Soviet Union	8.4	6.9	4.5
Japan	3.5	1.8	0.7
Canada	2.0	1.3	1.0
Australia	1.5	1.1	1.0
China	18.3	33.0	21.2
India	4.6	8.0	16.8
Indonesia	2.0	1.8	2.4
Other Southeast Asia and Korea	4.3	2.9	3.3
South Africa	1.3	1.3	1.4
OPEC	4.7	5.4	7.8
Rest of world	18.5	18.2	31.3
World	100	100	100

Fig. 1 Emission from top emitters in 2005, 2030 and 2100

IV. Key Features of the Methodological Frameworks

Modeling has a large number of processes underlying change invariably requires consideration of a large number of parameters. The parameters included in models simulating energy policy are selected from a wide-ranging set of potential data sources, including econometric estimation, "best guesses" or consensus and calibration. The data to support these parameters represent a major source of uncertainty in estimates of the energy policy. Another source of modeling uncertainty is the aggregation involved in keeping such potentially large models tractable. Aggregation is often necessary in both partial and general equilibrium models. However, in some cases aggregation may affect simulation results significantly and needs to be accounted for in such cases. The economic and policy environments as well as the quantity, quality and resolution (temporal and spatial scales) of data needed to specify models at the global level varies by locality, nation and region and represents another major source of uncertainty [9]. Much of the data required for modeling the policy such as high-resolution datasets that document historic land use changes and the corresponding changes in carbon stocks and GHG fluxes over time simply do not exist.

V. Modeling Assumptions and Production Functions Analysis

From Garnaut's report [10] it can be seen that GDP and population assumptions up to 2030 are broadly consistent for the projections. Population projections from the United Nations are 'medium variant' for Australia. Based on Australian Treasury (2007) projections [11], by the end of the century the world's population is over 40% larger than at the start.

Population growth is above 1% per year in the current decade, and then steadily falls to zero annual growth around 2080, when global population peaks. After 2080, population falls by 0.1% a year on average, with nearly all regions showing zero or negative growth. Many developing countries including India gain in population share over the century. Australia, Canada and the United States hold a broadly constant share as a result of immigration; and the shares of China, Europe, Russia and Japan drop (the Garnaut's climate change review).

Assumptions on nearer-term GDP per capita growth rates [1] are based on growth accounting and judgments informed by recent experience, both of which suggest the continuation of high growth, albeit falling over time, in the developing world. Longer term, GDP per capita is assumed to converge over time towards that of the United States, which is assumed in the long term to grow at 1.5% a year. Growth slows in developing countries as the income gap with the United States diminishes. Countries are assumed not to close the gap completely by the end of the century, with average world per capita incomes around half US levels at 2100. The global annual per capita GDP growth peaks at just over 3% in the middle of the 2020s, then falls to 2% by the end of the century. Global annual GDP growth peaks around 4% in the early 2020s, then falls to just below 2% by the end of the century as shown in Fig. 2.

Growth in greenhouse gas emissions in the reference case are a function of changes in production and consumption structures in different countries, changes relative prices including for different sources of energy, and improvements energy efficiency and the efficiency of intermediate input use. The reference projections also include emissions of methane, nitrous oxide and various industrial gases, as well as a subset of forestry-related emissions and sequestration.

With various assumptions such as (greenhouse gas benchmark rules, cost–curve, GHG base calculations, market demand and supply, base year economic data, economic growth, population growth, energy use) any country's future emissions can be predicted. Also these models with various assumptions help to forecast long term and short term effect on the economy. But these can be fulfilled with proper analysis and in depth study of various production functions. These functions are important because they give a base for the policy making, taxes and other important schemes or programs in the climate change scenario [12].

The two approaches for modeling have different level of focus such as top-down modeling which is based on macroeconomic principles thus intends to include all important economic interactions in the society on contrary, bottom-up modeling which is based on disaggregation and technical parameters. Thus the different approaches have led to different results in recent studies to integrate the approaches. It is argued that the approaches are more complementary than substituting in nature; others suggest that the two approaches are incompatible.

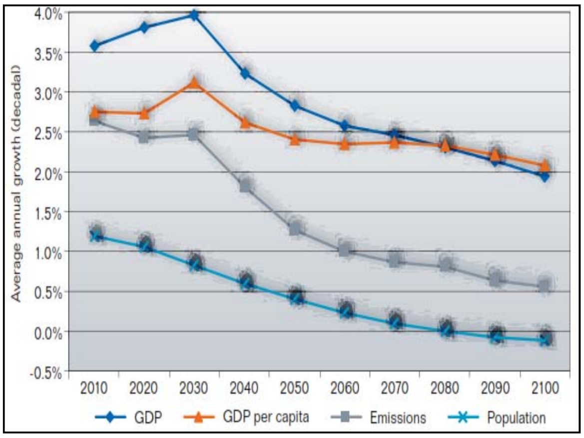

Fig. 2 Average annual growth for GDP, GDP per capita, emissions and population [10]

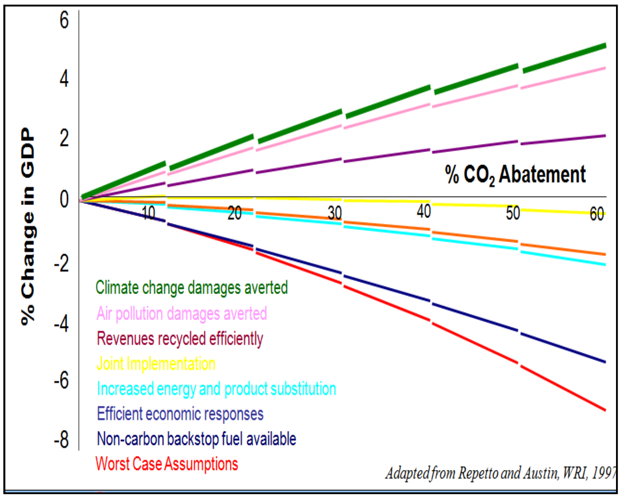

Fig. 3 Percentage change in GDP and CO_2 abatement for different model assumptions [8]

A top-down integration principle implies, energy demand is based on relative prices, income and exogenous energy efficiency are quantified from bottom-up calculations. Problems of consistency arise in such an approach, if the technological improvements in energy efficiency in bottom-up models is not autonomous but a function of investments in production capacity and this cannot be transferred to the macro model setup through exogenous parameters because it involves a re- specification of important relations in the macroeconomic model.

Bottom-up integration principles suggest that the macroeconomic specification of energy demand in which the inputs are dependent on each other should be replaced by bottom-up determined energy demand which is independent of other factor inputs. This difference can influence the total factor demand relation in production sector. It is not practically feasible to adjust these factor inputs if the bottom-up relation yields a result other than top-down relation. Also the revisiting and re-estimating can weaken the basis of factor-demand specification. A mixed integration model is more beneficial as it reduces the need for re-specification and re-estimation work, but suffers with complexity of nested production functions. Even though this challenge can be avoided using soft link approach. It will pose a problem in achieving overall consistency and convergence of iterative solution algorithms. Using hard link would be easier but it would result in distorted energy demand, thus effecting supply which will be implicated on the policy analysis, thus reducing is very objective. With the help of such integration based models, these costs of emissions are converted to benefits which are shown in Fig. 3.

Differences and comparative analysis of Production Functions are discussed in Table III. Different countries of world have started taking some serious action to cut down the emission of green gases in the atmosphere. Every individual country has defined their policies and targets to minimize the emission from their countries. Some countries have adopted command and control approach and other have adopted market based incentive approach. Many countries are now optioning for the tax on emission. Accordingly countries will be less energy intensive and will move toward low energy areas for economic growth. Pricing carbon if it is not done in an effective way, it can lead to dangerous failure [13].

Both Top-Down and Bottom-up models can yield useful insights on mitigation. Top-down models are most useful for studying broad macroeconomic and fiscal policies for mitigation such as carbon or other environmental taxes. Bottom-up models are the most useful for studying options that have specific sectoral and technological implications.

In microeconomics and macroeconomics, a production function is a function that specifies the output of a firm, an industry, or an entire economy for all combinations of inputs. This function is an assumed technological relationship, based on the current state of engineering knowledge. It does not represent the result of economic choices, but rather is an externally given entity that influences economic decision-making. Almost all economic theories presuppose a production function, either on the firm level or the aggregate level.

Neoclassical production function is the best one as compared with Keynesian which means the Cobb-Douglas, CES, and Translog, etc. As there are useful for implementing various policies, carbon tax by various countries as it offers for substitution and the production functions are flexible and can be twice differentiated. In addition to this the stability of the model which is determined by extent of substitution between factor inputs, main types of production functions are-Cobb-Douglas, Constant Elasticity of Substitution and Transcendental Logarithmic (Translog) production function and it is good for long term analysis.

TABLE III
DIFFERENCES AND COMPARATIVE ANALYSIS OF PRODUCTION FUNCTIONS

Features	Leontief Model	Cobb-Douglas Model	Constant Elasticity of Substitution (CES) model	Translog model
Type	Keynesian	Neo - Classical	Neo - Classical	Neo - Classical
Production Functions	$\mathrm{Yt} = \min(\mathrm{Kt/v}, \mathrm{Lt/b})$ Y_t = Output (production) in period t. K_t=capital input in period t L_t=labor input in period t v=(fixed) capital–output ratio. b = (fixed) labor–output ratio.	$\mathrm{Y} = \mathrm{F(K, L)}$ $\mathrm{Y} = \mathrm{aK}^{\alpha}\,\mathrm{L}^{1-\alpha}$ $\alpha > 0$ $0 < \alpha < 1$ Y- aggregate output, K- aggregate capitol input, L- aggregate labour input a- coefficients α - cost shares.	$\mathrm{Y} = \mathrm{F(K, L)}$ $\mathrm{Y} = (\mathrm{aK}^{\delta} + \mathrm{bL}^{\delta})$ $\delta < 1$ δ - value added factors	$\mathrm{Y} = \mathrm{F(K, L, E, M)}$ $\ln P = \alpha + \sum_{i}^{n} \alpha i \ln Pi + \frac{1}{2}(\sum_{i}^{n}\sum_{j}^{n} \gamma ij \ln Pi \ln Pj$ $\sum_i^n \alpha i = 1, \gamma ij = \gamma ji,\ \sum_i^n \gamma ij = 0$ P- overall prices, E – aggregate energy inputs, M- aggregate machinery inputs, *i-j* – vary between K, L,E,M γij- determine the price response of the model.
Basic Assumptions	1. Production Function has fixed capital–output and labor–output ratios. 2. Output is function of capital stock. 3. Capital is the limiting factor. 4. The marginal product of capital is constant. 5. Production function exhibits constant returns to scale. 6. Saving is investment, (calculated as product of the savings rate and output) which equals investment. 7. For long term equilibrium.	There are some common assumptions for the three models: 1. Production Functions of each is twice differentiable. 2. Marginal Productivities of production factors are positive and equal to their prices. 3. Capital and labor inputs are substitutable, and prices flexible of both. 4. Law of diminishing returns holds true. 5. Production functions are linear homogeneous, thus exhibit constant returns to scale. 6. Two elasticities exist, production and substitution. COBB – DOUGLAS → Constant elasticity of substitution, independent of other factors of the production function. → Both labour and capital are needed for production to sustain. → Input factors are in a mix relative to their prices. → The marginal productivity of labour (or capitol) is proportional to the amount of production per unit of labour (or capitol). CES → Substitution among factor inputs. → Industry specific Constant elasticity of substitution. TRANSLOG → Based on Minimising Cost. → Holds Duality theorem: develop the cost structure and then develop the production function.			
Substitution	Does not allow Substitution	Elasticity of Substitution is Allowed	Elasticity of Substitution is Allowed	Elasticity of Substitution is Allowed

VI. CONCLUSIONS

Climate change is a complex and multi-dimensional problem which carries important implications for environmental, social, cultural, economic, and political sustainability. It can be concluded that technologist focuses on technology, climatologist on atmospheric stabilization, economist on market instruments along with social and political institutions; but in fact all of these are critical factors required simultaneously for an integral climate change response.

Australia's relatively poor position has become substantially worse over the last two decades. Over the 1987-1992 period, Australia's energy-related CO_2 emissions grew much more than the OECD average more than 13% compared to less than 5% for the OECD as a whole (OECD). Analysis reveals that the growth in emissions in Australia has been due principally to population growth and growth in output per capita. Economic growth was also high in OECD countries but the effect on emissions was offset by a large fall in fuel consumption per unit of output.

CO2 is a consistently mixing pollutant, which means that the location of the pollution sources is not relevant. However, the role of transaction costs may still be an important consideration in the justification of a policy mix. Hence, the evaluation of any policy mix requires careful analysis and is dependent on the many contextual factors, including the source of emissions and the type of investment or behavioral changes that is being targeted.

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