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Fuel Switching Impacts of the Industry Sector under the Clean Development Mechanism: A General Equilibrium Analysis of Iran

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ABSTRACT

The importance of international cooperation in reducing the green house gas has been widely recognized. The primary tool for involving developing countries in carbon reduction without hindering their development is the clean development mechanism (CDM). In order to simulate numerically the impact of the Iran clean energy development of the industrial sector under the CDM, a computable general equilibrium model is used. The numerical simulations reveal the growth potential and sustainable development benefits that represent the CDM for Iran, though the environmental impact in terms of carbon emission of sectors appears broadly mixed. Based on results some sectors benefit from these clean investment flows - including industry - other sectors show carbon emission increases, but the overall emission of the economy decrease and results in lower environmental costs in gross domestic product.

Keywords: Clean Development Mechanism, Computable General Equilibrium, Industry Sector, Iran
JEL Classifications: D58, O13, Q56

1. INTRODUCTION

The importance of international cooperation in reducing the green house gas (GHG) has been widely recognized. The Kyoto protocol as the largest ever international effort to combat the global environmental problem, introduced three mechanisms that allow for flexibility in achieving GHG emission reductions, namely international emissions trading, joint implementation (JI) and the clean development mechanism (CDM).

The CDM is a market-based flexible mechanism that allows industrialized countries to reduce the cost of complying with their emissions obligations at lower costs by funding climate mitigation projects in the developing world (UNFCCC, 2012). Furthermore, CDM constitutes the primary tool for involving developing countries (non-Annex1 countries) in carbon reduction without hindering their development. Therefore, the CDM is supposed to achieve dual goals: Lowering abatement costs and promoting sustainable development.

The question of the effects of this additional development funding source and the related strategies for using it by host countries seems insufficiently explored by economic literature. Decision makers need clear and consistent information concerning the impact of energy and climate policies on the economy, as well as the cost-effective technology portfolio to achieve their goals.

The mechanism has saved at least USD 3.6 billion in emissions reduction costs. It has mobilized USD 215 billion of investment in developing countries. Of this amount, USD 92.2 billion is already invested (UNFCCC, 2012).

Reducing GHG emissions in the most economical way and promoting sustainable development are the main goals of CDM. CO_2 emission mitigation can take place via fuel switching (inter-fuel substitution) or energy savings (either by fuel-non-fuel substitution or a scale reduction of production and final demand activities). The bulk of these emission reductions may come from industrial gas mitigation projects (Lokey, 2012). Therefore, the industrial sector is one of the opportunities in GHG mitigation. One of the main applied projects under the CDM has been switching from heavy oil (residual fuel oil) to natural gas, as a less carbon intensive energy carrier and an available source of energy. The project activity will result in GHGs reduction and finally will provide financial resources, making the project economically feasible and attractive. Successful implementation of this project, will promote local and related high energy consuming industries to follow that and thus leads to sustainable development.

The aim of this study is to assess the effects of the CDM strategy implementation on a single host country, using the specific case of Iran industry sectors, where this mechanism had been a funding source for investments. In order to simulate numerically the impact of the clean energy implementation and the CDM revenues, we use a computable general equilibrium (CGE) model.

The remainder of this article is as follows. Section 2 provides a review of literature. Section 3 deals with the model. Section 4 presents the data for Iran and lays out alternative policy scenarios to investigate clean development strategy and then provides the results of the model simulations. Section 5 summarizes and concludes.

2. LITERATURE REVIEW

The CDM was originally defined as a bilateral instrument with where an entity from an industrialized country invests in a project in a developing country. The slow process of implementation for industrialized country companies and low carbon prices led to a unilateral mechanism. Consequently, the industrialized countries incentives alternate to buy certified emission reductions (CERs) instead of investing in projects. Thus the unilateral option gained prominence where the project development is planned and financed within the developing countries.

Some primary forward-looking research investigated CDM by quantitative approach (Banuri and Gupta, 2000; Mathy et al., 2001) followed by researches focused on empirical quantitative analysis (Han and Han, 2011; Zhang and Wang, 2011; Huang and Barker, 2012; Jia et al., 2013).

Some other research analyzed CDM from sustainable development perspectives using qualitative multi-criteria approach (Kolshus et al., 2001; Huq, 2002; Begg et al., 2003; Sutter, 2003; Anagnostopoulos et al., 2004; Olhoff et al., 2004; Olsen, 2007). The majority considered environmental or technical transfer aspects focusing on different indicators of development (Castro and Benecke, 2008; Olsen and Fenhann, 2008; Boyd et al., 2009; Karakosta et al., 2009; Alexeew et al., 2010; Bumpus and Cole, 2010; Subbarao and Lloyd, 2011).

Using CGE models, macroeconomic impact of the CDM implementation is studied at global (Nijkamp et al., 2005; Anger et al., 2007) or country level (Montaud and Pécastaing, 2013; Montaud and Pécastaing, 2015). Montaud and Pécastaing (2013) present a quantitative assessment of the economic and environmental impacts of CDM investments in the specific case of Mexico. The numerical simulation of macroeconomic shocks generated by current and future CDM projects by Montaud and Pécastaing (2015) reveals the significant potential impact of such investments in terms of employment, growth.

This paper adds a country study of Iran to the applied economic literature on impact assessment of the CDM application. The specific methodological contribution of the CGE analysis is the focus on economic and environmental impacts of scenarios to reduce GHG emissions under the CDM. The economic costs of clean development can be substantially reduced if an assessment is made of new policies and technological options. The costs of new policies and technological change are determined by the direct costs of implementation and the indirect effects induced by these strategies, such as sectoral shifts in production and consumption.

The reason for participating developing countries in GHG mitigation activities such as CDM is the availability of low-cost, emissions reduction projects based on the high potential of clean energy in economic activities. Developing countries are particularly important to long-term decarbonisation of the global industrial sector (IEA, 2015). Number of CDM registered projects by Iran as of 01/07/2014 amount to 25 projects, equivalent to nearly US$2.918 billion investment.

In the medium term, the most effective measures for reducing industrial emissions include implementing best available technologies and energy efficiency measures, switching to low-carbon fuel mixes, and recycling materials. Fuel switching from heavy oil (residual fuel oil) to natural gas, applied as a strategy towards a less carbon intensive energy source. This project activity will result in reduction of GHGs, and will provide financial resources, making the project economically feasible and attractive. Successful implementation of this project, will promote local and related high energy consuming industries to follow that. Fuel oil consumption by industry sector of Iran in 2006 equals to 5853 million liter, which emits 17431 million ton CO_2. While value added of this sector amount to 9.1 billion dollars, the emission intensity index of CO_2 is 741.2 (Energy Balance, 2006). In this regard, the industrial sector is one of the opportunities of GHG mitigation. The focus of this study is to assess the cleaner technology implementation in the industry sector accompanied by CDM revenues.

3. THE CGE MODEL

This section, presents the main hypotheses of the CGE model built for Iran and its economic and environmental databases. General equilibrium models have been widely applied to support energy and climate policies, helping to explore alternative new energy and carbon mitigation strategies. Based on the circular flow of the economy the model includes the main agents (firms, households, and government), flows of goods and services, payments to factors, international trade and relationships with the environment.

The model includes a representative agent, who is endowed by labor and capital as primary factors and maximizes profits of the activity. Producer behavior is specified through a nested constant elasticity-of-substitution (CES) production function for domestic supply and through a zero-profit condition. Production of commodities is captured by a cost function for primary factors and a Leontief function of intermediate materials.

All goods used in the domestic market in intermediate and final demand (Armington, 1964) correspond to a CES composite. The Armington assumptions applied in combining domestic production and imports, using a CES function. The resulting homogeneous 'Armington commodities' are either sold domestically or exported. A constant elasticity transformation function determines the scope for choice between domestic supply and export. All international trade links with other countries is aggregated into one additional sector, namely "rest of the world" (RoW).

On the demand side, household consumption is based on a linear expenditure system function. Nominal demand from the government and firms is proportional to total government demand assumed to be exogenous. Intermediate demand is driven by a fixed technical coefficient in each production process.

Primary incomes are distributed to different agents on the basis of their factor endowments and access to transfer and foreign incomes. The private households have income from the sale of their endowments of capital goods and labor, with lump sum transfers from other institutions (government, firms and ROW).

The government has two sources of income: The lump sum transfer from institutions and tax revenues. The lump sum transfers are endogenously adjusted to ensure budget balance for the government. The savings of the institutions are the residual of the income subtracted by their consumption and transfer to other institutions. The total savings are made up of the household savings, the enterprise savings, the government savings, and the savings from the ROW.

This standard CGE model reaches equilibrium according to Walras law to clear goods and factor markets, and thus determining prices and quantities. The model is closed by the market balances for producing goods, domestic demand, and the capital and labor market. We assume capital is fixed and immobile among sectors, but there is unemployment in the economy and labor is intersectorally mobile. Similar to a number of existing general equilibrium models such as Dervis et al. (1982) and Benjamin (1994) nominal exchange rate is kept fixed. The volume of investment demand (CDM and others) is assumed to be exogenous and constituted the main variable for the simulations.

Moreover, because of the aim of this study, we also extend this standard CGE analysis by two modifications, including an environmental perspective, which can reveal the consequences of these economic changes, in terms of carbon emission reductions and the relative foreign revenues. CO_2 emissions are linked in fixed proportions to the fossil fuel consumption with CO_2 coefficients differentiated by the specific carbon content of fuels. CO_2 emission mitigation will take place via fuel switching (inter-fuel substitution). The environmental costs are then considered as the monetary value of the CO_2 amount emitted in the production process subtracted from the value of gross domestic product (GDP) to show green GDP. The descriptions of the equations are presented in the appendix.

A social accounting matrix (SAM) of Iran for the year 2006 was constructed for this study on the basis of energy Input-Output (I/O) Table (Power Ministry, 2006) and the statistical foundations of SAM of Iran (Islamic Parliament Research Center, 2011). The economy is aggregated into 9 productive activities (agriculture, industry and mining, oil and gas extraction, coal, oil products, electricity, gas distribution, construction, and services) and four institutions (households, government, firms and the RoW).

Most of the parameters in the economic equations and the initial level of the variables were calibrated from Iran's 2006 (SAM-2006). Base year data together with exogenous elasticities determine the free parameters of the functional forms.

4. SIMULATION RESULTS

We use CGE model to quantify the economic impacts of the applying clean energy in the industry sector. This section presents the obtained quantitative results of the numerical simulations. The scheme assumes Iran has no mandatory obligation to reduce GHG emissions and sells the resulted emission mitigation credits to Annex I countries as units (CERs). The scheme is termed as a unilateral CDM scheme, as the Non-Annex I countries can implement it without involving an Annex I country and sell granted credits of CERs. The CERs being equal to one metric ton of CO_2, consistently sell to the European Union Allowances (EUAs). The CER prices varying from US$2 per unit (i.e., per ton of CO_2) to US$ 20 per unit are considered to compare CDM revenues of the projects under different market CER prices. The CER revenue is recycled into the economy through a lump-sum transfer.

Simulation results are reported as percentage changes in key economic variables from their business-as-usual (BAU) levels. Exogenous domestic investments constituted the main variables for the simulations. It affects the Iranian economy by two channels. First, they generate a demand shock for the activities producing the required fixed capital goods. Second, they generate a supply shock which changes the nature of the production process of sector activities. We deduced the nature and the level of these shocks from data of registered projects detailed in the CDM pipeline (Fenhann, 2013). These data confirm the importance of CDM investments in Iran since 2009 (Table 1).

A group of "registered projects", such that they already have been validated by the executive board supervising the Kyoto Protocol's CDM, represent US$118.3 million. Projects involving fuel switching are the most numerous, but there are also the energy efficiency supply side and renewable energy projects - that is, 95.6% of registered investments. The efficiency supply side and renewable energy projects appear to offer a sustainable alternative to the highly polluting thermal generation of electricity (Fenhann, 2013).

In this context, we consider just registered projects of the fuel switching types of the CDM projects in the industrial sector of Iran. We assume that the generation of this clean production will replace the use of fossil fuels and reduce the demand for intermediate consumption of industry activity. The effect of this environmentally friendly technology is included in each simulation, as a reduction of the technical coefficient for the industrial activity.

The simulations differ by the magnitudes of the shocks experienced by the Iranian economy. The shocks are determined by analyzing the project design document (PDD) of each project and Iran Energy Balance sheet. Thereby the range of the parameter change of fuels in the industry subject to capital demand is obtained.

It is assumed that the reduction of fuel oil consumption in Sugarcane Plant based on registered projects in the CDM pipeline would be nearly 0.02% of the 2006 coefficient (SC1). The other scenarios (SC2, SC3, SC4) are assumed based on 100%, 200% and 400 investment increases to fuel switch of the industry sector. It also should appear in the environmental equations, as a reduction of the CO_2 emission calculating by emission coefficients of each energy carrier.

Table 2 shows the contribution of each scenario to GDP and Green GDP changes. According to these simulations, the investments for using a cleaner energy in industry contribute significantly to economic growth, mainly through a demand effect for activities. In four scenarios, GDP increases by 0.01%, 0.02%, 0.04%, and 0.06%.

Despite increasing production, environmental costs decrease. The environmental impact of this economic growth appears positive. Based on the environmental Kuznets curve (EKC) it is believed that growth in developing countries is accompanied by parallel increases of social emission cost (Shafik and Bandyopadhyay, 1992; Seldon and Song, 1994; Holtz-Eakin and Selden, 1995; de Bruyn and Opschoor, 1997; Panayotou, 1997). In this case study economic growth happens with emission reduction and consequently it doesn't decrease green GDP. Finally, we find an increase in the share of labor in the economy (0.06-0.32%). Because of the closure rule of the labor market in the model contributions to employment can be obtained which is induced by a demand shock for activities.

With the nature of the related projects, the industry and refinery sector are logically the one most affected by the shocks. At this stage, the supply effects in the model (i.e., reduced use of fossil fuels and associated effects on the carbon emission by industrial activity) exert a substantial influence. Despite increasing production, total carbon emission decreases in all scenarios because the share of fuel oil in the energy mix decreases, and oppositely gas has a higher share in the energy mix. The intermediate demand of fuel oil in industry decreases by 1.96%, 3.93, 5.89%, and 7.85% in four scenarios. The intermediate demand of gas increases by 3.3%, 5.07%, 7.12%, and 9.18%.

The sectoral changes that CDM investments generate for the economy is presented in Table 3. The impact of the scenarios and numerical simulations on sectoral domestic output is mixed. Services sector is negatively affected and oil and gas extract is not affected by CDM investments. While other sectors benefited from these investments and the most effects appears in coal, electricity and refinery products. The refinery products increase ranges from 0.13% in the first scenario to 0.57 in the last. The contribution of the investment strategy to the electricity sector activity rises by 0.23% in the first scenario and generates more effects in the last scenario by 1.0%. The index for industry grows by 0.03% in the first scenario (0.16% in the last).

Table 4 indicates the impact of scenarios on each sector in terms of Carbon emission. These trends are varied among different sectors. Although in all sectors the emission index increases except industry and services, the different magnitude of sectors in carbon emission results in total carbon emission reduction of the economy. In this case, the emission index in industry and services decreases by 1.3% and 0.12% in the first scenario and 5.16% and 0.54% in the last.

Table 1: The nature of the CDM projects in industry of Iran

Title	Sub-type	Investment MUS$
Fuel switching of amirkabir sugarcane plant	Oil to natural gas	0.7
Fuel switching of salman farsi sugarcane plant	Oil to natural gas	0.9
Fuel switching of imam khomeini sugarcane plant	Oil to natural gas	1.1
Fuel switching of mirza kuchak khan sugarcane plant	Oil to natural gas	0.7
Fuel switching of debal khazaei sugarcane plant	Oil to natural gas	0.3
Fuel switching of hakim farabi sugarcane plant	Oil to natural gas	1.3

Registered projects only, CDM: Clean development mechanism
Source: Fenhann, 2014

Table 2: Main Macroeconomic results of simulations (Variation in %)

Variables	SC1	SC2	SC3	SC4
GDP	0.012	0.025	0.04	0.057
Green GDP	0.012	0.025	0.04	0.057
Labor	0.06	0.14	0.22	0.32
Industry fuel oil demand	−1.96	−3.93	−5.89	−7.85
Industry gas demand	3.03	5.07	7.12	9.18

GDP: Gross domestic product

Table 3: The impacts of simulations on domestic output (variation in %)

Sectors	SC1	SC2	SC3	SC4
Agriculture	0.03	0.06	0.09	0.14
Industry and mining	0.03	0.07	0.11	0.16
Transport	0.06	0.12	0.19	0.27
Services	−0.12	−0.24	−0.38	−0.54
Construction	0.036	0.07	0.11	0.16
Oil and Gas extract	0	0	0	0
Coal	1.24	2.44	3.67	4.86
Refinery products	0.13	0.27	0.42	0.57
Gas distribution	0.08	0.16	0.24	0.33
Electricity	0.23	0.47	0.73	1.02

Revenues of carbon reduction in each scenario based on different CER prices are presented in the Table 5. The CERs being equal to one metric ton of CO_2e, consistently sell to the EUAs. The CER prices varying from US$2 per unit (i.e., per ton of CO_2) to US$ 20 per unit are considered to compare CDM revenues of the projects. The CDM projects would further increase the foreign transfers. As expected, foreign transfers increases along with the CER price as the country gets higher CER revenue at higher CER prices. This CER revenue is recycled into the economy through a lump-sum transfer.

The implementation of this carbon reduction policy will have a positive impact on environmental indicator, the CO_2 emission as well as energy intensity. The stronger macroeconomic impact can be achieved by the phasing out fuel oil consumption in other sectors; the use of the fuel oil decrease and export increase of this product will result the most preferable impact on domestic environment indicator.

The carbon reduction policies (either end-of-pipe technologies or cleaner production) in developing countries in the absence of the CDM scheme may cause welfare loss depending on the policy implemented. Such a loss would be avoided under the projects with excess revenue. The effects of the CDM depending on two factors: (i) The scheme of recycling the CER revenue to the economy and (ii) the price of CERs. The CDM may cause a welfare gain even at a very low CER price (US$2/$tCO_2$) when the revenue is recycled into the economy (Timilsina, 2009). In very low prices of CER, the revenue earns decrease, but still implementation of such projects has positive effects because of the social cost decrease of carbon emissions.

Table 4: The carbon emission index (variation in %)

Sectors	SC1	SC2	SC3	SC4
Agriculture	0.03	0.06	0.09	0.13
Industry and mining	−1.3	−2.58	−3.87	−5.16
Transport	0.06	0.12	0.19	0.27
Services	−0.12	−0.24	−0.38	−0.54
Construction	0.036	0.07	0.11	0.16
Oil and gas extract	0	0	0	0
Coal	1.24	2.46	3.67	4.86
Refinery	0.13	0.27	0.42	0.57
Gas distribution	0.08	0.16	0.24	0.33
Electricity	0.23	0.47	0.73	1.02

Table 5: CDM revenues in different CER prices (million US$)

CDM revenue	2	10	15	20
SC1	3810	19425	29137.5	38850
SC2	7471	38150	57225	76300
SC3	10928	55915	83872.5	111830
SC4	14104	72350	108525	144700

CDM: Clean development mechanism, CERs: Certified emission reduction

5. CONCLUSION

This study has explored the quantitative impact of investments on the Iran economy in terms of fuel switching of the industrial sector to a cleaner energy. A static CGE model of Iran was developed to simulate this CDM strategy. The carbon reduction policies (end-of-pipe technologies or cleaner production) in developing countries in the absence of the CDM scheme may cause welfare loss depending on the policy implemented. Such a loss would be avoided under the projects with excess revenue.

The numerical simulations show that these investments partially meet their development and environmental objectives. Implementation of the carbon reduction strategies in industry as fuel switching has a positive impact on GDP, real output, and employment relative to the BAU condition. In four scenarios, GDP increases by 0.01%, 0.02%, 0.04%, and 0.06%. Despite increasing production, the environmental costs decrease because economic growth happens with emission reduction and it doesn't show a decrease of green GDP.

Almost all sectors are expected to receive a positive impact in terms of output due to clean strategy in the industry. The most affected sectors include coal, electricity and refinery products. They also reveal the growth potential and the revenue earned by the CDM. However, its environmental impact in terms of carbon emission appears mixed, even though some sectors benefit from these clean investment flows -including industry, the target of CDM projects in this study. Other sectors, such as refinery, gas distribution, and electricity show carbon emission increases, but the overall emission of the economy decrease and may make carbon revenues.

The economic costs of clean development can be substantially reduced if an assessment is made of new policies and technological options. The costs of new policies and technological change are determined by the direct costs of implementation and the indirect effects induced by these strategies, such as sectoral shifts in production and consumption. Therefore, the stronger macroeconomic impact can be achieved by the phasing out fuel oil consumption in other sectors; the use of the fuel oil decrease and export increase of this product will result the most preferable impact on domestic environment indicator. The analysis of such reduction strategies for different sectors and their impacts can limit the costs of environmental policy and help to know the most effective ones. Yet, due to the lack of detailed technology information, assessing such technology policies is difficult.

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APPENDIX

Algebraic model summary

SETS

$a \in$ A activities
$c \in$ C commodities
$c \in$ CE ($\subset$C) exported commodities
$c \in$ CEN ($\subset$C) commodities not in CE
$c \in$ CM ($\subset$C) imported commodities
$c \in$ CMN ($\subset$C) commodities not in CM
$c \in$ EC ($\subset$C) energy commodities
$c \in$ NEC ($\subset$C) non-energy commodities
$f \in$ F factors
$i \in$ INS institutions (domestic and RoW)
$i \in$ INSD ($\subset$INS) domestic institutions
$i \in$ INSDNG ($\subset$ INSD) domestic nongovernment institutions
$h \in$ H ($\subset$INSDNG) households

PARAMETERS

ad_a: Production function shift parameter
α_{fa}: Share of value-added for factor fin activity a
aq_c: Armington function shift parameter
at_c: CET function shift parameter
β_{ch}: Marginal share of consumption spending on marketed commodity c for household h
cpi: Consumer price index
$cwts_c$: Weight of commodity c in the CPI
δ_c^q : Armington function share parameter
δ_c^t : CET function share parameter
ica_{ca}: Quantity of c as intermediate input per unit of activity a
pwm_c: World market price of imports
pwe_c: World market price of exports
$gles_c$: Government consumption shares
$eles_c$: Firm consumption shares
$qinvbar_c$: base-year quantity of private investment demand
ρ_c^q : Armington function exponent
ρ_c^t : CET function exponent
$shry_{insf}$: Share for domestic institution in income of factor
fte_c: Export duty rates
θ_{ac}: Yield of output c per unit of activity a
tm_c: Tariff rates on imports
ta_a: Activity tax rate
tq_c: Sale tax rate
ty_h: Income tax rate
$tr_{insinsp}$: Transfers from institution ií to I (both in the set INSDNG)
trr_f: Transfer from ROW to factor f
trf_f: Transfer from factor f to ROW
sh_h: Share for institution in disposable income of household
ef_{ec}: Pollution emission factor
cf_{eca}: Energy conversion coefficients
φ: Share of pollution cost in the economy

VARIABLES

ER: Real exchange rate
EG: Government expenditure
YG: Government revenue
EENR: Firm expenditure
YE: Firm revenue

GDTOT: Total volume of government consumption
FDTOT: Total volume of firm consumption
HSAV: Total household savings
GSAV: Government savings
ESAV: Firm savings
FSAV: Foreign saving
IADJ: Investment adjustment factor
OCAP: Outflow of capital
MPS: Marginal propensity to save for domestic nongovernment institution
PA_a: Activity prices
PD_c: Domestic prices
PM_c: Domestic price of imports
PE_c: Domestic price of exports
PQ_c: Composite commodity price
PVA_a: Value added price by sector
PX_c: Aggregate producer price for commodity
QA_a: Level of activity a
QD_c: Quantity sold domestically of domestic output
QE_c: Quantity of exports
QM_c: Quantity of imports
QQ_c: Composite goods supply
QX_c: Aggregated marketed quantity of domestic output of commodity
QF_{fa}: Quantity demanded of factor f from activity a
QFS_f: Labor supply by labor category (1000 persons)
QH_{ch}: Final demand for private consumption
$QINT_{ca}$: Quantity of commodity c as intermediate input to activity a
$QINV_c$: Final demand for productive investment
WF_f: Average wage rate by labor category
$WDIST_{fa}$: Wage distortion factor for factor f in activity a
YF_{hf}: Income to household from factor f
YH_h: Household income
YFE_f: Income to firms from factor f
EM_a: Emission of CO_2 from activity
GDP0: Gross domestic product
GGDP: Green gross domestic product
CDMI: Investment for clean development
CDMR: Revenues of clean development
PCER: CO_2 price ($/ton)

EQUATIONS

1. $PM_c = pwm_c.ER.(1+tm_c)$
2. $PE_c = pwe_c.ER.(1+te_c)$
3. $PQ_c.QQ_c = (PD_c.QD_c + PM_c.QM_c)(1+tq_c)$
4. $PX_c.QX_c = (PD_c.QD_c + PE_c.QE_c)$
5. $PA_a = \sum_c PX_c.\theta_{ac}$
6. $PVA_a = PA_a.(1-ta_a) - \sum_c ica_{ac}.PQ_c$
7. $QA_a = ad_a.\prod_f QF_{fa}^{\alpha_{fa}}$
8. $WF_f.WDIST_{fa}.QF_{fa} = QA_a.PVA_a.\alpha_{fa}$
9. $QINT_{ca} = ica_{ca}.QA_a$
10. $QX_c = \sum_a \theta_{ac} QA_a$
11. $QQ_c = aq_c(\delta_c^q.QM_c^{\rho^q} + (1-\delta_c^q).QD_c^{\rho^q})^{\frac{-1}{\rho^q}} \in CM$
12. $\frac{QM_c}{QD_c} = (\frac{PD_c}{PM_c}.\frac{\delta_c^q}{(1-\delta_c^q)})^{\frac{1}{1+\rho^q}}$

13. $QQ_c = QD_c \quad c \in CNM$

14. $QX_c = at_c(\delta_c^t.QE_c^{\rho^t} + (1-\delta_c^t).QD_c^{\rho^t})^{\frac{1}{\rho^t}} \quad c \in CE$

15. $\frac{QE_c}{QD_c} = (\frac{PE_c}{PD_c}.\frac{1-\delta_c^{qt}}{\delta_c^t})^{\frac{1}{\rho^t-1}}$

16. $QX_c = QD_c \quad c \in CNE$

17. $YF_{hf} = shry_{hf}.(\sum_f WF_f.WDIST_{fa}.QF_{fa} + trr_f.ER)$

18. $YH_h = \sum_f YF_{hf} + \sum_{ins} tr_{h,ins}$

19. $QH_{ch} = \frac{\beta_{ch}.(1-MPS_h).(1-ty_h).(1.sh_h).Y_h}{PQ_c}$

20. $YG = \sum_h ty_h.Y_h + \sum_{cm} tq_c.(PD_c.QD_c + PM_c.QM_c) + \sum_{cm} tm_c.ER.pwm_c QM_c + \sum_{ce} te_c.ER.pwe_c Qe_c + tr_{gov,row}.er + tr_{gov,insd}$

21. $YENT = \sum_f shry_{ent,f}.(\sum_f WF_f WDIST_{fa}.QF_{fa} + trr_f.ER) + \sum_{insd} tr_{ent,insd} + tr_{ent,row}.ER$

22. $HSAV = \sum_h MPS_h.(1-ty_{h)}).(1-sh_h).YH_h$

23. $GSAV = YG - \sum_c PQ_c.gles_c.gddtot + \sum_{ins} tr_{ins,gov}$

24. $ENTAV = YG - \sum_c PQ_c.e.entddtot + \sum_{ins} tr_{ins,ent}$

25. $QFS_f = \sum_a QF_{fa}$

26. $EM_a = \sum_{ec} QINT_{eca}.ef_{ec}.\frac{1}{CF_{eca}}$

27. $CDMR = PCER.(\sum_a EM0_a - \sum_a EM_a)$

28. $QQ_c = \sum_a QINT_{ca} - \sum_h qh_{ch} + PQ_c.gles_c.GDTOT + PQ_c.eles_c.entdtot + qinv_c + CDMI$

29. $\sum_{cm} pwm_c.QM_c + \sum_f trf_f + \sum_{ins} tr_{row,ins} + OCAP = \sum_{ce} pwe_c.QE_c + \sum_f trr_f + \sum_{ins} tr_{ins,row} + FSAV$

30. $\sum_c QINV_c.PQ_c + CDMI + OCAP + WALRAS = HSAV + GSAV + ENTSAV + FSAV.ER$

31. $\sum_c PQ_c.cwts_c = cpi$

32. $GDP = \sum_a QA_a.PA_a$

33. $GGDP = GDP - \varphi \sum_a EM_a$