Environment and Development Economics 21: 226–248 © Cambridge University Press 2015
doi:10.1017/S1355770X15000169

Does Mexico benefit from the Clean Development Mechanism? A model-based scenario general equilibrium analysis

JEAN-MARC MONTAUD
Center for the Theoretical Analysis and Handling of Economic Data, University of Pau and Pays de l'Adour, Pau, France.
Email: jean-marc.montaud@univ-pau.fr

NICOLAS PECASTAING
Center for the Theoretical Analysis and Handling of Economic Data, University of Pau and Pays de l'Adour, Avenue du Doyen Poplawski, B.P. 1633 64016, Pau Cedex, France.
Email: nicolas.pecastaing@univ-pau.fr

Submitted 11 September 2013; revised 4 September 2014, 25 January 2015; accepted 20 April 2015; first published online 2 June 2015

ABSTRACT. Since 2000, the Clean Development Mechanism (CDM) under the Kyoto Protocol has included southern countries in the fight against climate change by encouraging northern countries to make environmentally friendly direct investments at the lowest cost in these developing nations. Although CDM investments have enjoyed great success, the question of the contribution of these investments to the development of the host countries remains insufficiently explored. This paper offers a computable general equilibrium model-based scenario, describing the potential economic and environmental impacts of CDM investments for Mexico. As modelled in this study, these investments should generate both additional demand for activities that produce the fixed capital goods required for their implementation and environmentally friendly technological changes in the production process for the electricity sector. The numerical simulations reveal the growth potential and important fund of development represented by the CDM for Mexico; however, they show that the environmental impact also appears broadly mixed and dependent on both the nature of the sectors it affects and the intensity of the technological change it generates.

1. Introduction

Involving southern countries in the fight against climate change, without hindering their development, is a major challenge for the international community. The Clean Development Mechanism (CDM), under the Kyoto Protocol, currently constitutes the primary tool for enabling northern countries (Annex I countries) to make environmentally friendly direct investments at low costs in developing countries (Non-Annex I countries),[1] through the carbon credit granted in proportion to the greenhouse gas reductions achieved. The CDM has enjoyed great success since its introduction in November 2004. As of April 2013, 6,600 CDM projects had been registered worldwide, for a total investment of approximately US$215.4 billion (UNFCCC, 2012; Fenhann, 2013). However, despite extensive studies of the CDM in economic literature, mainly to assess the costs of climate policy, its impact on the development of host countries remains insufficiently explored.

The main objective of this study is to assess the impact of CDM on a host country, using the specific case of Mexico, where CDM has been a significant funding source since its ratification of the Kyoto Protocol in September 2002. At the start of 2013, 215 CDM projects had been registered or planned in Mexico, equivalent to nearly US$13.2 billion, making it the fifth largest recipient of such funds. Using the data from the CDM pipeline (Fenhann, 2013), we numerically simulate the economic impacts of these foreign CDM investments on the Mexican economy, using a computable general equilibrium (CGE) model that includes environmental variables, which reveal the ecological consequences of these economic changes.

In the next section, we outline some limitations of extant CDM assessments in economic literature, before we detail our main hypotheses and present the CGE model for Mexico. Next, we describe our model-based scenario of the impact of CDM investments in Mexico and our quantitative results. Finally, we consider some alternative scenarios, to test the sensitivity of our results.

2. Assessing the CDM in economic literature

Since the establishment of the Kyoto Protocol, the goal of assessing the CDM has emerged progressively as a critical research area for economic literature, focusing on two complementary issues: how CDM achieves its environmental objective in terms of climate policy; and how it achieves its development objective in southern countries.

The analyses in the first group are more numerous, because there are strong incentives to analyze the effect of CDM on greenhouse gas emission reductions in order to quantify the revenues generated by each project in the carbon market. Most studies in this tradition either estimate marginal abatement cost curves or use microeconomic CGE models (for a review, see Böhringer *et al.*, 2013). For example, Klepper and Peterson (2005) use a multi-region, multi-sector, recursive, dynamic CGE model of the world economy to compare the costs for investors stemming from the different flexibility mechanisms provided by the Kyoto Protocol. Jotzo and Michaelowa (2002) and Michaelowa and Jotzo (2005) apply a numerical partial equilibrium approach to assess how transaction costs

[1] To receive CDM, these non-Annex I countries must have adopted the Kyoto Protocol and appointed a designed national authority (DNA), responsible for validating each project.

https://doi.org/10.1017/S1355770X15000169 Published online by Cambridge University Press

and institutional rigidities influence the market size of a CDM. Finally, Anger *et al.* (2007) use a large-scale CGE model of international trade and thereby quantify the macroeconomic impact of CDM, while accounting for the relative importance of investment barriers and risks and CDM regulations.

The second group of analyses assessing the CDM's potential impact on southern countries is smaller, perhaps because its contributions to development appear de facto less important than its environmental impacts. Development is just one objective required in the project design documents (PDD)[2] that each CDM must submit to the DNA of a host country. One group of econometric studies attempts to classify the types of CDM projects according to their technology transfer contributions (Haites *et al.*, 2006; Dechezleprêtre *et al.*, 2008; Seres and Haites, 2008). Another group focuses on more global development issues. Early studies in this tradition tended to adopt prospective quantitative approaches (Banuri and Gupta, 2000; Mathy *et al.*, 2001), although most research features qualitative analyses with multiple criteria (Kolshus *et al.*, 2001; Huq, 2002; Begg *et al.*, 2003; Sutter, 2003; Anagnostopoulos *et al.*, 2004; Olhoff *et al.*, 2004; Olsen, 2007; UNFCCC, 2012). However, these heterogeneous studies are sometimes controversial (Olsen, 2007; Olsen and Fenhann, 2008; Boyd *et al.*, 2009; Alexeew *et al.*, 2010; Bumpus and Cole, 2010; Subbarao and Lloyd, 2011. Their relevance appears limited by the arbitrary weight studies granted to the different development indicators and, in many cases, they depend on criteria specified by the DNA of each host country to select projects. Without *ex post* verification by independent studies, these selections usually reflect national priorities and conceptualizations of development or even are guided by competition with other DNAs that also are trying to attract CDM investments. Thus several studies call for an international standard for rating CDM projects, according to their contributions to various development dimensions (Cosbey *et al.*, 2005; Schlup, 2005; Cosbey, 2006; Sutter and Parreño, 2007; Olsen and Fenhann, 2008).[3]

Our study can be included in this second research stream. In an effort to assess the potential impact of CDM on Mexico's development, we adopt a quantitative approach and simulate numerically the impact of foreign CDM investments on the Mexican economy. With this perspective, we use a CGE model to reveal the various interdependencies that generate exogenous shocks on demand, supply, income and prices in the economy. Noting criticisms of the use of CGE models (e.g., Böhringer and Löschel, 2006) – especially their inability to estimate social and environmental dimensions of development accurately (Scrieciu, 2007) or assess the fundamental challenge of establishing a monetary valuation of natural resources – we extend

[2] The mandatory PDD provides information about the project's legislative aspects, implementation, baseline scenarios adopted, funding sources, and local political operators affected. It should also describe the potential impact in terms of infrastructure, jobs, social project funding or environmental quality improvements.

[3] Olsen and Fenhann (2008) suggest that the potential benefits of CDM projects reflect five criteria: job creation, growth, air quality, access to energy and the wellbeing of the people.

the standard CGE analysis by including an environmental perspective that reveals the ecological consequences of economic changes, in accordance with the system of environmental accounting used in Mexico.

3. CGE model

The model, as detailed in the Appendix, encompasses eight main productive activities (agriculture, mining, electricity, energy, construction, industry, transport, services) and three domestic institutions (households, government and firms).

3.1. Main economic features

Because we adopt a developmental perspective, the internal economic logic of the model is fairly standard to CGE modelling for a developing country (see Dervis *et al.*, 1982; Bourguignon *et al.*, 1989; Robinson, 1989). On the supply side, activities maximize profit by combining fixed capital with labour (equations (1)–(3)). Their products may be sold locally or to the rest of the world, given a *constant elasticity transformation* specification (equations (6)–(9)), and they are imperfectly substitutable with imported products, given an Armington (1969) specification (equations (10)–(13)). Primary incomes generated by the activities are distributed to the different agents, on the basis of their factor endowments and access to transfer and foreign incomes (equations (14)–(28)). On the demand side, households' consumption is a linear expenditure system function; nominal demand from the government is assumed to be exogenous (equations (29)–(31)). Intermediate consumption is driven by fixed technical coefficients in each production process. The volume of investment demand (including foreign CDM investments addressed to each activity, $\overline{CDMQ_i}$) is assumed to be exogenous (equations (33)–(34)).

Prices, nominal investments and row saving ensure the closure mechanisms for product markets, the capital market and the external accounts market, respectively (equations (35)–(38)). However, the closure rule for the labour market (equations (39)–(40)) deserves more attention, in that it reflects the dual nature of the Mexican economy, as is often assumed for developing economies. That is, the inefficient social insurance system in Mexico leads us to assume that unemployment might not be an option for workers excluded from activities. If the overall labour supply is fixed in volume and a real wage is assumed to be rigid, labour market balance can be achieved through the presence of an informal sector that serves as a shelter for 'unemployed' workers. This informal sector is composed of individual, non-capitalistic microenterprises (equations (4)–(5)), whose products are only sold in domestic markets for final household consumption (equation (30)) and whose value added is fully distributed to individual entrepreneurs (equation (16)).

3.2. Environmental features

Some additional equations link existing economic variables to some environmental variables, following the logic of the international System of Environmental and Economic Accounting (SEEA) used by the Mexican

https://doi.org/10.1017/S1355770X15000169 Published online by Cambridge University Press

Environmental Accounts System.[4] Two environmental costs can be associated with the production of each (formal) activity. First, depletion costs represent the monetary valuation of the depreciation of natural resources used in the production process. For Mexico, these costs mainly refer to hydrocarbons, forest resources and underground water. Their valuation relies on a market value approach, which covers natural assets using the economic value indicated by current or potential market transactions (United Nations, 2000).[5] Secondly, degradation costs represent monetary assessments of the cost of restoring environmental damages caused by each economic activity. For Mexico, these costs mainly involve the pollution of water, air and soil. Their valuation is more difficult and relies mainly on a maintenance cost valuation method (i.e., estimate the costs of restoring an environmental asset to its original or a tolerable level of degradation) and a contingent valuation method for environmental services.

In the model, each environmental cost is assumed to be proportional to the volume of production of each activity (equations (45)–(46)). Subtracted from the value added of each activity, these overall environmental costs indicate the ecological gross domestic product, or green GDP (Boyd, 2007), of the Mexican economy (equations (43)–(44)).

3.3. Model databases and initial equilibrium

Most of the parameters and the initial level of the economic variables in the model were calibrated from Mexico's 2004 Social Accounting Matrix (2004 SAM), as built by Barboza-Carrasco *et al.* (2009), adjusted to the needs and objectives of our analysis. First, we reduced the number of activities in the 2004 SAM to match those in the SEEA environmental accounting. Secondly, considering the nature of the CDM projects, we isolated a fossil energy sector (*Fossil energy*), to specify energies responsible for emissions of a greenhouse gas (gas, oil, coal), which are the main target of CDM projects in Mexico. Thirdly, because of the closure rule chosen for the labour market, we included the informal sector in the 2004 SAM, using data from Mexican employment surveys (INEGI, 2006), so that we could estimate the contributions of informal activities to employment and value added.[6] The parameters and initial levels for the environmental variables came from the Mexican Environmental Accounts System (INEGI, 2010). For 2005–2009, these costs accounted for an average of 8 per cent of Mexico's GDP: 6 per cent for degradation costs and 2 per cent for depletion costs (INEGI, 2010).

[4] In 2012, the UN decided to adopt an integrated SEEA, as an initial version of an international standard for environmental and economic accounting (European Commission *et al.*, 2012).

[5] Other methods also exist to estimate the market value of the stocks of scarce natural resources (e.g., net present value of natural resources, net price method, users' cost allowance).

[6] We use a restricted definition of informal employment, as proposed by INEGI, that corresponds to individual entrepreneurs and assumes that informal microentrepreneurs receive the full value added they generate.

Table 1. *Economic and environmental contributions of each activity at initial equilibrium (share in %)*

		GDP	*Depletion costs*	*Degradation costs*	*Green GDP*	*Total costs/GDP*
Initial equilibrium	Agriculture	4.0	26.9	18.9	2.5	38.8
	Mining	3.6	71.4	0.2	1.9	44.2
	Industry	17.2	1.0	2.9	16.8	1.0
	Electricity	1.3	–	1.4	1.2	5.4
	Construction	5.2	0.2	0.2	5.4	0.2
	Transport	8.3	–	49.9	6.1	30.6
	Services	59.8	0.6	26.4	65.4	5.5
	Fossil energy	0.6	0.0	0.2	0.6	1.5
	Total economy	**100.0**	**100.0**	**100.0**	**100.0**	**7.3**

Source: Own calculations, based on 2004 SAM and INEGI, 2010.

Table 1 describes the contribution of each activity to GDP, green GDP and environmental cost at the initial equilibrium. Nearly 60 per cent of the Mexican national value added is generated by *Services* activity, with 17 per cent by the *Industry*. Depletion costs come mainly from *Agriculture* and *Mining*, whereas the degradation costs are generated by *Transport*, *Services* and *Agriculture* activities. Globally, these environmental costs represent 7.3 per cent of Mexico's GDP.

4. Model-based scenario of the impact of CDM investments in Mexico

4.1. Scenario 1: Main hypotheses and empirical database

The main objective of our first model-based simulation is to evaluate the potential impact of the CDM projects registered for Mexico – that is, projects that have been validated since 2005 by the CDM Executive Board supervising the Kyoto Protocol's CDM. Data from the CDM pipeline (Fenhann, 2013), supplemented by data from the UNFCCC (2012) about the type, location, amount and stage of completion of each project, confirm the importance of these investments (table 2). As of April 2013, 171 registered projects represented US$11,532.1 million (nearly 1.25 per cent of Mexico's GDP). Projects involving methane avoidance were the most numerous, but the data also indicate a preponderance of wind, hydro and transport projects, equivalent to 98.2 per cent of investments. These projects, and renewable energy projects more particularly, appear to offer a sustainable alternative to the highly polluting thermal generation of electricity, which currently accounts for nearly 71 per cent of installed electricity capacity in Mexico (SENER, 2010).

In our model-based scenario, these CDM investments should have three main impacts on the Mexican economy. First, on the demand side, they should generate additional demand for activities that produce the fixed

Table 2. *Registered CDM projects in Mexico*

Type	*Number of projects*	*Amount of investment (million US$)*
Biomass energy	6	30.9
Energy efficiency industry	4	1.8
Energy efficiency own generation	1	43.9
Fugitive	1	14.5
Hydrofluorocarbon	1	–
Hydro	5	141.1
Landfill gas	23	90.8
Methane avoidance	98	21.5
N_2O	1	0.3
Transport	5	3,713.3
Wind	26	7,474.0
Total	**171**	**11,532.1**

Notes: This table refers to CDM projects registered between 2005 and 2013.
Source: CDM pipeline, April 2013; UNFCCC (2012).

capital goods required for their implementation. Therefore, in the CGE model, exogenous foreign CDM investments addressed to each activity ($\overline{CDMQ_i}$) constitute the first critical variable for this demand shock (equation (34)). Second, on the supply side, the CDM investments should generate a technological shock, by changing the nature of the production process for *Electricity* activity toward more environmentally friendly technology. Relying on the principle of additionality from the Kyoto Protocol,[7] we assume that the generation of 'clean' electricity replaces the use of fossil fuels and reduces the value of the technical coefficient parameter between *Electricity* and *Fossil energy* activities. Thus in the CGE model, the parameter $ica_{ener,elec}$ constitutes the second critical simulation variable. *Ceteris paribus*, a reduction of this parameter should generate an increase in the *Electricity* value added (equation (3)) and decreased demand in the *Fossil energy* sector (equation (32)). Thirdly, we introduce another environmental effect of CDM investments in the simulation. Mexican environmental accounting rules link the pollution costs of *Electricity* activity proportionally to its production level, given the initial technology process used. Because this technology process should have been modified by the previous technological effect, we assume that the environmental impact of *Electricity* activity also is affected. In this case, the parameters θp_{elec} and θg_{elec} constitute the third critical variable for our simulation (equations (45) and (46)). Their values should decrease with the same magnitude as that of the previous technological shock.

[7] This principle states that projects would not have happened in the absence of the CDM.

Table 3. *Scenario 1*

Demand shock for activities[a] ($\Delta CDMQ_i$)	
Industry	+6,808.5
Transport	+390.2
Construction	+3,217.1
Services	+1,116.6
Total	+**11,532.1**
Technological shock ($\Delta ica_{ener,elec}$)	−8.1%
Environmental shock ($\Delta \theta_{elec}$)	−8.1%

Notes: [a]Million US$.
Source: Own calculations, based on CDM pipeline, April 2013.

To determine the nature and magnitude of these shocks, we analyze the data in each PDD detailed in the CDM pipeline (Fenhann, 2013), as well as data from the UNFCCC (2012). For demand shock, it appears that wind, hydro and transport[8] projects largely determine the allocation of CDM investments. For example, for a wind project, 64 per cent of investments go to the *Industry* branch (e.g., purchase of wind turbines), 24 per cent to the *Construction* branch (e.g., engineering and electrical installations), 9 per cent to the *Services* branch (e.g., legal fees, project engineering, control systems, financial and import costs), and 3 per cent to the *Transport* branch (e.g., transportation costs). For the technological and the environmental shocks, the CDM pipeline indicates that the additional production of electricity expected from registered projects would be nearly 8.1 per cent (4,142 MW) of 2004 total production (EIA, 2004).[9] Using these elements, we present the first simulated scenario from the CGE model in table 3.

4.2. Simulation results for Scenario 1

Table 4 shows the results of the simulation of this first scenario. As defined in the CGE model, the CDM investments would contribute significantly to Mexican economic growth (+0.50 per cent), mainly due to the demand effect generated by these additional investments for different activities. However, the overall environmental impact of CDM investments appears negative, such that green GDP grows at a slower pace than economic growth (0.45 per cent vs. 0.50 per cent). Economic growth is accompanied by parallel increases of depletion (+3.02 per cent) and degradation (+0.53 per cent) costs. This global effect would stem essentially from the contributions of *Agriculture* and *Mining* activities to overall depletion costs (nearly 98.3 per cent) and of *Transport*, *Services* and *Agriculture* activities to overall

[8] Branch allocation for transport projects is more difficult to estimate, because of the importance of the Metro Line 12 (Mexico City) and Metrobus 2-1 projects, which together account for an estimated total investment of US$3.4 billion.

[9] We used 2004 Mexican electricity sector data for two reasons: to maintain consistency with SAM 2004 and to avoid double-counting the impact of CDM in this sector during 2004–2012.

Table 4. *Scenario 1: simulations of economic and environmental impacts of registered CDM investments in Mexico (percentage variation)*

	GDP	*Depletion costs*	*Degradation costs*	*Green GDP*	*Total costs/GDP*
Agriculture	0.98	0.87	0.87	1.09	−0.11
Mining	4.31	3.90	3.90	4.84	−0.40
Industry	0.77	0.62	0.62	0.81	−0.15
Electricity	9.73	–	−5.72	10.59	−14.08
Construction	−3.30	−2.98	−2.98	−3.34	0.33
Transport	0.77	–	0.68	0.83	−0.09
Services	0.28	0.30	0.30	0.28	0.02
Fossil energy	−1.74	1.53	1.53	−1.84	3.33
Total economy	**0.50**	**3.02**	**0.53**	**0.45**	**0.78**

Source: Own calculations, using GAMS software.

degradation costs (nearly 95.2 per cent). Finally, the sectors would increase their activity and thus the environmental degradation, which explains the increase (+0.78 per cent) in the share of GDP represented by environmental costs.

With value added growth rates of 9.73 per cent, *Electricity* activity would be logically the one most affected by the shocks, considering both the nature of the CDM projects and the close links of this activity with other sectors. However, the supply effects of the reduced use of fossil fuels would lead to substantial decreases in the degradation costs generated by this activity, by −5.72 per cent, such that the share of its environmental costs as a proportion of total GDP would decrease by −14.08 per cent. For the other activities, the simulation shows that variations in sectoral production induced by CDM investments would modify their respective contributions to the environment. They would help slightly reduce the environmental impacts generated by *Agriculture*, *Mining*, *Industry* and *Transportation*. In contrast, *Construction* and *Energy* sectors would exert stronger environmental impacts.

5. Alternative scenarios and sensitivity analyses

The model-based Scenario 1 shows that even if CDM investments would contribute positively to economic growth, they would also have negative environmental impacts in Mexico. However, these results may be difficult to interpret in isolation, considering the circular causalities that drive our equilibrium general analysis. Moreover, the validity of the results also depends strongly on our scenario assumptions about the nature and the intensity of the potential effects of CDM projects in the CGE model. To provide points of comparison and gain further insights into the results, we thus change some key elements of Scenario 1. First, with the same empirical and theoretical methodology, we simulate alternative scenarios based on other CDM project portfolios, which should generate different

Table 5. *Scenarios 2 and 3*

	Scenario 2 Registered and awaiting validation projects	*Scenario 3 Only renewable energy projects*[a]
Demand shock for activities[b] ($\Delta CDMQ_i$)		
Industry	+7,777.9	+4,821.5
Transport	+493.2	+235.5
Construction	+3,948.6	+1,868.5
Services	+1,323.3	+689.6
Total	**+13,543.0**	**+7,615.1**
Technological ($\Delta ica_{ener,elec}$)	−11.5%	−7.9%
Environmental shock ($\Delta\theta_{elec}$)	−11.5%	−7.9%

Notes: [a]CDM projects registered between 2005–2013. [b]Million US$.
Source: Own calculations, based on CDM pipeline, April 2013.

magnitudes of shocks. Secondly, we simulate a hypothetical scenario, 'business as usual', for which investments in the power sector should not have any technological effect in terms of electricity generation. Thirdly, we test the sensitivity of the scenarios' results to various magnitudes of the technological effect included in the numerical simulations.

5.1. Scenarios 2 and 3: Changes to the CDM projects' portfolios

Scenario 1 reflected the potential impact of all registered CDM projects validated by Mexico's Executive Board since 2005. However, many other CDM projects remain awaiting validation; as of April 2013, 44 such projects in Mexico accounted for US$2,010.9 million, or nearly 0.22 per cent of Mexico's GDP, which could represent additional electricity production of 1,757.8 MW (+3.4 per cent of current capacity) (UNFCCC, 2012; Fenhann, 2013). Scenario 2 integrates at-validation projects together with the registered ones and thus envisages broader demand and supply effects on the Mexican economy. In addition, noting their prominence in the CDM project portfolio, we sought to isolate the impact of renewable energy projects, biomass, wind and hydro; as of April 2013, these projects accounted for US$7,615.1 million (0.83 per cent of Mexico's GDP) and could potentially increase electricity production of 4,080 MW (+7.9 per cent of current capacity). Scenario 3 features only these renewable energy projects and thus envisages smaller effects on the Mexican economy. Table 5 describes the main assumptions of Scenarios 2 and 3; table 6 contains the simulation results obtained with the CGE model.

As we might have predicted, the impact of CDM projects gets amplified when we include projects awaiting validation, along with registered projects. Because of the stronger demand effect of CDM investments (+US$2,010.9 million vs. Scenario 1), expected economic growth would increase to about 0.70 per cent (vs. 0.50 per cent in Scenario 1). The negative overall environmental impact would also appear stronger, such that green GDP grows at a slower pace than economic growth (0.65 per cent). As

Table 6. *Scenarios 2 and 3: simulations of economic and environmental impacts of different CDM project portfolios in Mexico (percentage variation)*

	GDP	*Depletion costs*	*Degradation costs*	*Green GDP*	*Total costs/GDP*
(a) Scenario 2: registered and awaiting validation projects					
Agriculture	−0.25	−0.03	−0.03	−0.46	0.22
Mining	6.12	5.56	5.56	6.60	−0.53
Industry	0.97	0.70	0.70	1.04	−0.27
Electricity	38.28	–	1.34	40.40	−26.71
Construction	−4.78	−4.56	−4.56	−4.82	0.23
Transport	0.80	–	0.70	0.87	−0.11
Services	0.00	0.20	0.20	0.10	0.20
Fossil energy	−1.16	2.73	2.73	−1.20	3.94
Total economy	**0.70**	**3.96**	**0.46**	**0.65**	**0.82**
(b) Scenario 3: renewable energy projects					
Agriculture	−0.16	−0.04	−0.04	−0.28	0.13
Mining	2.97	2.70	2.70	3.20	−0.26
Industry	0.63	0.44	0.44	0.68	−0.19
Electricity	18.92	–	−1.01	20.10	−16.77
Construction	−2.54	−2.41	−2.41	−2.56	0.13
Transport	0.37	–	0.33	0.39	0.04
Services	0.00	0.11	0.11	0.10	0.10
Fossil energy	−0.25	1.62	1.62	−0.30	1.88
Total economy	**0.36**	**1.92**	**0.19**	**0.35**	**0.37**

Source: Own calculations, using GAMS software.

in Scenario 1, this environmental negative impact occurs because growth would be accompanied by parallel increases of depletion costs (3.96 per cent) and degradation costs (0.46 per cent). Ultimately, the share of GDP represented by these environmental costs would increase by 0.82 per cent for both scenarios. The supply effects on *Electricity* activity, such as reduced use of fossil fuels and the associated effects on degradation costs, would exert a substantial influence. Furthermore, *Electricity* activity appears most affected, relative to Scenario 1, such that its value added grows by 38.28 per cent (vs. 9.73 per cent in Scenario 1). Despite this increasing production, environmental costs would increase only slightly by +1.34 per cent (vs. −5.72 per cent in Scenario 1), and the share of environmental costs from the *Electricity sector*, as a proportion of total GDP, would decrease by −26.71 per cent (vs. −14.08 per cent in Scenario 1). This shift relates strongly to the nature of the projects awaiting validation, 88 per cent of which are dedicated to deriving new electric capacity (+1,758 MW) through biomass, hydro and wind projects.

Table 7. *Scenario 4: Simulation of economic and environmental impacts of conventional investments in Mexico (percentage variation)*

	GDP	*Depletion costs*	*Degradation costs*	*Green GDP*	*Total costs/GDP*
Agriculture	0.58	0.60	0.60	0.55	0.03
Mining	3.82	3.51	3.51	4.21	−0.30
Industry	0.63	0.59	0.59	0.64	−0.04
Electricity	7.26	–	5.39	7.73	−1.74
Construction	−2.89	−2.56	−2.56	−2.95	0.34
Transport	0.73	–	0.67	0.77	−0.06
Services	0.24	0.28	0.28	0.23	0.04
Fossil energy	2.96	3.94	3.94	2.78	0.95
Total economy	**0.43**	**2.67**	**0.63**	**0.36**	**0.82**

Source: Own calculations, using GAMS software.

These trends are also confirmed by the numerical simulation of Scenario 3, although the magnitude of change is smaller. With a smaller demand shock than Scenario 1 (−US$3,917.0 million), the impact on economic growth would appear positive (+0.36 per cent) but attenuated compared with the other scenarios. Green GDP would increase by 0.35 per cent. The depletion costs would increase by 1.92 per cent, and degradation costs would increase by 0.19 per cent; their total share of the GDP would increase to 0.37 per cent. Because of the nature of renewable energy projects, the technological shock is particularly strong (proportional to the demand shock) compared with the other scenarios. In this context, the contribution to GDP of *Electricity* activity would rise by 18.92 per cent and generate lower degradation costs of −1.01 per cent. Finally, we find a decrease in the share of environmental degradation in GDP due to the electric sector (−16.77 per cent).

5.2. Scenario 4: Business-as-usual scenario

Because the technological effect is a critical variable in our analysis, we also simulated a 'business-as-usual' scenario, in which we assume that investments in the power sector are 'conventional', that is, without any technological effect on electricity generation. To facilitate the comparison with Scenario 1 and ensure some level of consistency and equivalency across the scenarios in our general equilibrium framework, we assume that these conventional investments generate the same additional demand as in Scenario 1. Table 7 contains the simulation results for this Scenario 4.

Two notable main differences arise between Scenario 1 and this business-as-usual scenario. First, the technological shock appears to induce a growth effect that was not captured in the previous simulations. That is, CDM projects are likely to have stronger growth effects than conventional investments, in terms of both economic growth rate (0.50 per cent vs. 0.43 per cent) and Green GDP growth rate (0.45 per cent vs. 0.36 per cent). Secondly, the business-as-usual scenario reveals that the technological effect

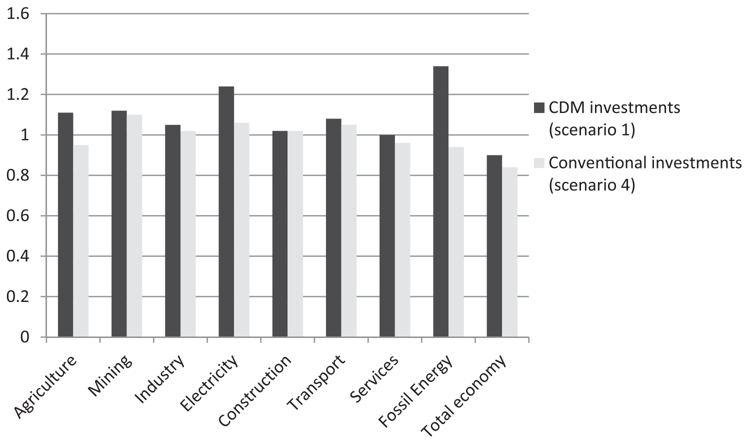

Figure 1. *Percentage change in green growth in response to a 1 per cent change in economic growth in Scenario 1 vs. Scenario 4* $\left(\frac{\Delta \text{Green GDP}/\text{Green GDP}}{\Delta \text{GDP}/\text{GDP}}\right)$

associated with the CDM investments mitigates the negative impact of the demand effect on the environment. If both types of investments would degrade the environmental performance of growth, the growth process generated in Scenario 1 would be of comparatively better environmental quality than the one obtained in the scenario with conventional investments. For example, the share of GDP represented by environmental costs would increase by 0.82 per cent in the business-as-usual scenario and 0.78 per cent in Scenario 1. Furthermore, CDM investments show a greater capacity to generate green growth than do more conventional investments. As figure 1 shows, when global economic growth increases by one point, green growth increases by 0.90 points in the case of the CDM scenario and 0.84 points in the case of a conventional investment scenario. This differentiated effect is particularly strong for the *Electricity* sector and the *Fossil energy* sector, the two areas most affected by the technological shock in terms of environmental costs.

5.3. Technological shock sensitivity results

One of the main insights from Scenarios 1–4 is that the overall impact of CDM investments on the environment and the Mexican economy depends on the respective magnitude of the demand and technological shocks included. Demand shock always has a negative environmental impact, through the growth effect it generates. The impact of the technological shock appears more ambiguous; it generates a growth effect too, but also invokes positive environmental effects that can mitigate the latter. Yet in every scenario, the negative environmental impacts surpass the environmentally friendly technological shock.

To better understand the balance of these opposing forces, we test the sensitivity of the simulations' results to various magnitudes of the technological effect. We repeat Scenarios 1, 2 and 3 with different values for

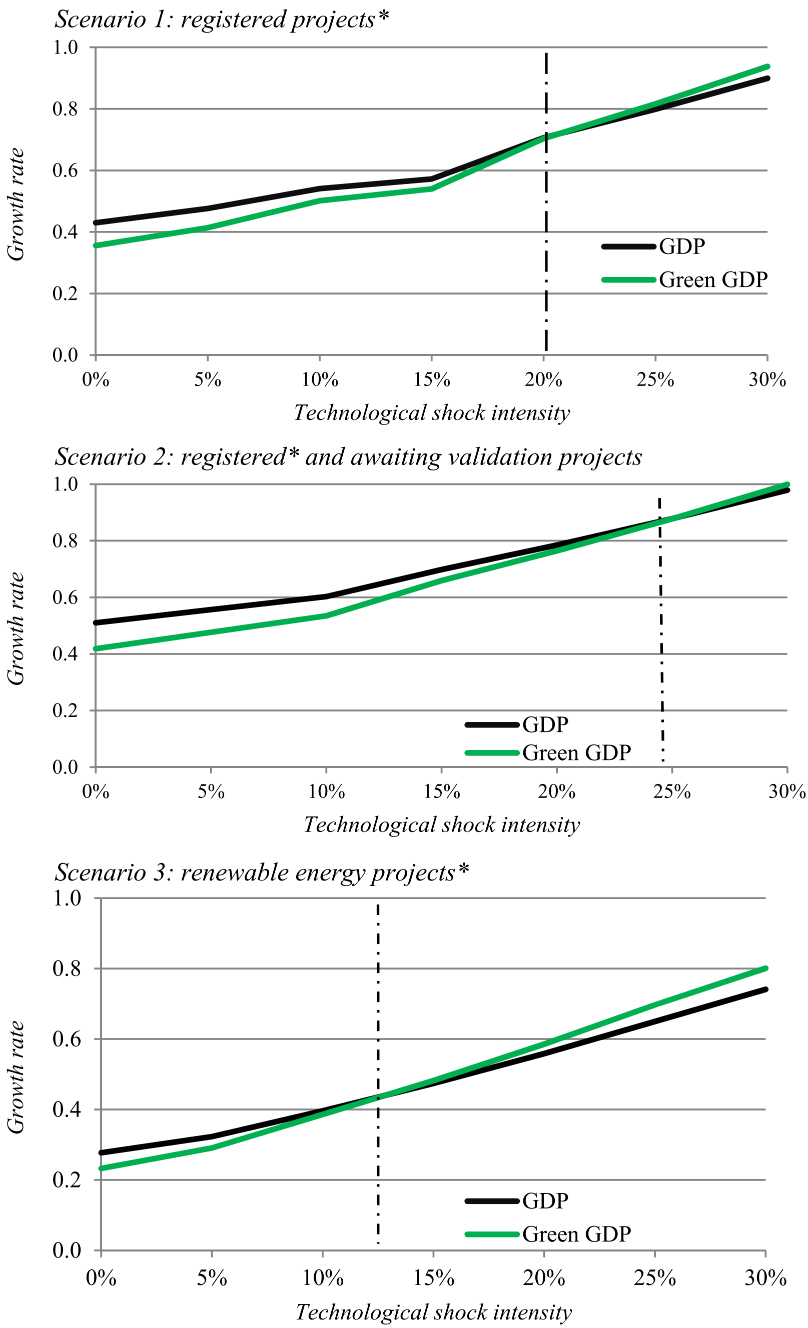

Figure 2. *Impacts of CDM investments on GDP and green GDP growth rates in Mexico for different technological shock levels*
*Notes: *CDM projects registered between 2005 and 2013.*
Source: Own calculations, using GAMS software.

https://doi.org/10.1017/S1355770X15000169 Published online by Cambridge University Press

the technological and environmental shocks ($\Delta ica_{ener,elec}$ and $\Delta\theta_{elec}$), ranging from 0 per cent (no shocks) to 30 per cent (additional production of electricity expected from CDM projects would replace 30 per cent of initial production achieved using fossil fuels). We present the results of these sensitivity tests in figure 2.

The sensitivity tests reveal first that, *ceteris paribus*, the growth effect induced by the technological shock increases with the intensity of this shock. In Scenario 1, without any technological change, expected economic growth due to CDM investments would be about 0.43 per cent (0.51 per cent in Scenario 2; 0.30 per cent in Scenario 3). With a maximum technological shock, these growth rates would increase to 0.90, 0.98 and 0.74 per cent, respectively, in the three scenarios. Secondly, a progressive technological shock generates a progressively positive impact on the environment. Thirdly, each sensitivity test reveals a breakpoint at which the friendly environmental effect of the technological shock starts to surpass the negative impact of the demand shock; that is, green GDP starts growing at a faster rate than the GDP. Scenario 3, with only renewable energy projects, achieves this breakpoint more quickly, by a technological shock of 11.5 per cent; this breakpoint occurs at 19 per cent for registered projects and 25 per cent for the registered and awaiting validation sample.

6. Conclusion

This study explores a model-based assessment of the impact of CDM investments on the Mexican economy since 2005, using a CGE model that also includes environmental topics. The numerical simulation of the impact of the projects already registered in Mexico shows that the CDM investments, as modelled in this study, partially meet their objectives. They would contribute positively to economic growth but also have negative environmental impacts. The simulations that include projects that are awaiting validation or focus solely on renewable energy projects confirm these trends; the numerical results reveal differences only in the magnitude of the impacts. These insights show that the overall environmental impact of CDM in Mexico depends on the nature of the sectors it affects and the intensity of the shocks it would generate. At a sectoral level, current CDM investments do not significantly reduce the costs of degradation and depletion of natural resources in Mexico, where negative environmental effects mainly stem from the mining, agriculture and services sectors, whereas these sectors generally attract few investments. Furthermore, as revealed by the business-as-usual scenario and sensitivity tests, a better balance between the environmentally harmful growth effects and the environmentally friendly technology effect could be achieved by projects that induce a stronger technological shock on electricity activity than have appeared previously, as the main target of projects in Mexico.

These results thus can guide the Mexican DNA in choosing which projects to support in order to improve the environmental quality of Mexican economic growth, although they would benefit from added nuance. For example, further research might pursue an even more integrated approach, combining simultaneously a genuine sectoral analysis of the production processes affected by CDM investments with global macroeconomic and environmental approaches.

References

Alexeew, J., L. Bergset, K. Meyer, J. Petersen, L. Schneider, and C. Unger (2010), 'An analysis of the relationship between the additionality of CDM projects and their contribution to sustainable development', *International Environmental Agreements: Politics, Law and Economics* **10**(3): 233–248.

Anagnostopoulos, K., A. Flamos, A.G. Kagiannas, and J. Psarras (2004), 'The impact of clean development mechanism in achieving sustainable development', *International Journal of Environmental Pollution* **21**(1): 1–23.

Anger, N., C. Böhringer, and U. Moslener (2007), 'Macroeconomic impacts of the CDM: the role of investment barriers and regulations', *Climate Policy* **7**: 500–517.

Armington, P. (1969), 'A theory of demand for product distinguished by place of production', *IMF Staff Paper* **16**(1): 159–178.

Banuri, T. and S. Gupta (2000), 'The Clean Development Mechanism and sustainable development: an economic analysis', in G.P. Manila (ed.), *Implementation of the Kyoto Protocol*, Manila: Asian Development Bank.

Barboza-Carrasco, I., J.M.P. Vázquez-Alvarado, and J.A. Matus-Gardea (2009), 'Mexico's social accounting matrix 2004', *Agrociencia* **43**(5): 551–558.

Begg, K., S. Parkinson, D.V.D. Horst, *et al.* (2003), 'Encouraging CDM energy projects to aid poverty alleviation', Final report of Project R8037 under the DFID KAR programme, Centre for Environmental Strategy, University of Surrey.

Böhringer, C. and A. Löschel (2006), 'Computable general equilibrium models for sustainability impact assessment: status quo and prospects', *Ecological Economics* **60**: 49–64.

Böhringer, C., T.F. Rutherford, and M. Springmann (2013), 'Clean development investments: an incentive-compatible CGE modelling framework', Oldenburg Discussion Papers in Economics No. V-354-13, University of Oldenburg.

Bourguignon, F., W. Branson, and J. De Melo (1989), 'Macroeconomic adjustment and income distribution: a macro-micro simulation model', Paris: Organisation for Economic Cooperation and Development.

Boyd, J. (2007), 'Nonmarket benefits of nature: what should be counted in green GDP?', *Ecological Economics* **61**: 716–723.

Boyd, E., N. Hultman, J. Roberts, *et al.* (2009), 'Reforming the CDM for sustainable development: lessons learned and policy futures', *Environmental Science & Policy* **12**(7): 820–831.

Bumpus, A.G. and J.C. Cole (2010), 'How can the current CDM deliver sustainable development?', *Climate Change* **1**(4): 541–547.

Cosbey, A. (2006), 'Defining and measuring the development dividend', Meeting of the Expert Task Force of the IISD, International Institute for Sustainable Development, Winnipeg: IISD, p. 12.

Cosbey, A., J.E. Parry, J. Browne, Y.D. Babu, P. Bhandari, J. Drexhage, and D. Murphy (2005), 'Realizing the development dividend: making the CDM work for developing countries', Phase 1 Report – prepublication version, Winnipeg: IISD, pp. 1–72.

Dechezleprêtre A., M. Glachant, and Y. Menière (2008), 'The Clean Development Mechanism and the international diffusion of technologies: an empirical study', *Energy Policy* **36**: 1273–1281.

Dervis, K., J. De Melo, and S. Robinson (1982), 'General equilibrium models for development policy', World Bank Research Publication CED BM, Washington, DC: World Bank, p. 36.

EIA (Energy Administration Information) (2004), *International Energy Statistics: Mexico*, [Available at] http://www.eia.gov.

European Commission, Food and Agriculture Organisation, International Monetary Fund, Organisation for Economic Co-operation and Development, United Nations, World Bank (2012), *System of Environmental-Economic Accounting: Central Framework*, White cover publication, pre-edited text subject to official editing, [Available at] http://unstats.un.org/unsd/envaccounting/White_cover.pdf

Fenhann, J. (2013), *UNEP Risø CDM Pipeline*, 1 April 2013, [Available at] http://www.CD4CDM.org.

Haites, E., M. Duan, and S. Seres (2006), 'Technology transfer by CDM projects', *Climate Policy* **6**(3): 327–344.

Huq, S. (2002), 'Applying sustainable development criteria to CDM projects: PCF experience', PCFPlus Report No. 10, Prototype Carbon Fund, World Bank, Washington, DC.

INEGI (Instituto Nacional de Estadística, Geografía e Informática) (2006), *Cuenta Satélite del Subsector Informal de los Hogares 1998–2003*, Instituto Nacional de Estadísticas y Geografía, Mexico.

INEGI (Instituto Nacional de Estadística, Geografía e Informática) (2010), *Sistema de Cuentas nacionales de México: Cuentas Económicas y Ecológicas de México 2003–2007*, Instituto Nacional de Estadísticas y Geografía, Mexico.

Jotzo, F. and A. Michaelowa (2002), 'Estimating the CDM market under the Marrakech Accords', *Climate Policy* **2**: 179–196.

Klepper, G. and S. Peterson (2005), 'Emissions trading, CDM, JI, and more: the climate strategy of the EU', FEEM Working Paper, Fondazione Eni Enrico Mattei, Milan, p. 55.

Kolshus, H.H., J. Vevatne, A. Torvanger, and K. Aunan (2001), 'Can the Clean Development Mechanism attain both cost-effectiveness and sustainable development objectives?', CICERO Working Paper, CICERO Senter for klimaforskning, Oslo, p. 8.

Mathy, S., J-C. Hourcade, and C. De Gouvello (2001), 'Clean Development Mechanism: leverage for development?', *Climate Policy* **1**: 251–268.

Michaelowa, A. and F. Jotzo (2005), 'Transaction costs, institutional rigidities and the size of the Clean Development Mechanism', *Energy Policy* **33**(4): 511–523.

Olhoff, A., A. Markandya, K. Halsnæs, and T. Taylor (2004), *CDM Sustainable Development Impacts*, Copenhagen: UNEP Risø Centre.

Olsen, K.H. (2007), 'The Clean Development Mechanism's contribution to sustainable development: a review of the literature', *Climatic Change* **84**(1): 59–73.

Olsen, K.H. and J. Fenhann (2008), 'Sustainable development benefits of Clean Development Mechanism projects. A new methodology for sustainability assessment based on text analysis of the project design documents submitted for validation', *Energy Policy* **36**(8): 2819–2830.

Robinson, S. (1989), 'Multisectoral models', in H. Chenery and T.N. Srinivasan (eds), *Handbook of Development Economics*, Vol. II, Amsterdam: North-Holland, Chapter 18.

Schlup, M. (2005), *The Gold Standard: Linking the CDM to Development and Poverty Reduction, Climate or Development?*, Hamburg: Hamburg Institute of International Economics.

Scrieciu, S.S. (2007), 'The inherent dangers of using computable general equilibrium models as a single integrated modelling framework for sustainability impact assessment. A critical note on Böhringer and Löschel (2006)', *Ecological Economics* **60**: 678–684.

SENER (Secretaría de Energía) (2010), 'El sector eléctrico mexicano', Mexico City: SENER, [Available at] http://www.renovables.gob.mx.

Seres, S. and E. Haites (2008), 'Analysis of technology transfer in CDM projects', Report prepared for UNFCCC Registration & Issuance Unit CDM/SDM, Montreal.
Subbarao, S. and B. Lloyd (2011), 'Can the Clean Development Mechanism (CDM) deliver?', *Energy Policy* **39**(3): 1600–1611.
Sutter, C. (2003), *Sustainability Check-Up for CDM Projects. How to Assess the Sustainability of International Projects Under the Kyoto Protocol*, Berlin: Wissenschaftlicher Verlag Berlin (WVB).
Sutter, C., and J.C. Parreño (2007), 'Does the current Clean Development Mechanism (CDM) deliver its sustainable development claim? An analysis of officially registered CDM projects', *Climatic Change* **84**(1): 75–90.
UNFCCC (2012), *Benefits of the Clean Development Mechanism 2012*, Bonn: United Nations Climate Change Secretariat, [Available at] http://cdm.unfccc.int.
United Nations (2000), *Integrated Environmental and Economic Accounting: An Operational Manual*, Handbook of National Accounting, Studies in Methods Series F, No. 78, ST/ESA/STAT/SER.F/78, New York: United Nations.

Appendix: CGE model

Formal activities or products: *i or j = Agriculture, Mining, Electricity, Fossil energy, Construction, Industry, Transport, Services*

Informal activities or products: *inf = Informal sector*

Domestic institutions: *H = Households; G = Government; F = Firms*

Rest of the World: *Row*

Production block

Formal production process

1. $QX_i = A_i^p \cdot \left[\alpha_i^p \cdot LD_i^{-\mu_i^p} + \left(1-\alpha_i^p\right) \cdot \overline{K_i}^{-\mu_i^p}\right]^{-\frac{1}{\mu_i^p}}$
2. $LD_i = QX_i \cdot \left[\frac{\alpha_i^p \cdot PVA_i}{(A_i^p)^{\mu_i^p} \cdot w_i}\right]^{\sigma_i}$
3. $PVA_i = PX_i - \sum_j PQ_j \cdot ica_{j,i} - tx_i$

Informal production process

4. $QD_{\inf}^r = \gamma_{\inf} \cdot LD_{\inf}$
5. $PVA_{\inf} = PD_{\inf} - \sum_j PQ_j \cdot ica_{j,\inf}$

Trade block

Exports and domestic sales (CET specification)

6. $QX_i = A_i^t \cdot \left[\alpha_i^t \cdot QE_i^{-\mu_i^t} + \left(1-\alpha_i^t\right) \cdot QD_i^{-\mu_i^t}\right]^{-\frac{1}{\mu_i^t}}$
7. $\frac{QD_i}{QE_i} = \left[\frac{\alpha_i^t}{(1-\alpha_i^t)}\right]^{\sigma_i^t} \cdot \left[\frac{PD_i}{PE_i}\right]^{\sigma_i^l}$

https://doi.org/10.1017/S1355770X15000169 Published online by Cambridge University Press

8. $PX_i = \frac{PD_i \cdot QD_i + PE_i \cdot QE_i}{QX_i}$
9. $PE_i = EXR\overline{PWE_i}$

Imports and domestic sales (Armington specification)

10. $QQ_i = A_i^m \cdot \left[\alpha_i^m \cdot QD_i^{-\mu_i^m} + \left(1 - \alpha_i^m\right) \cdot QM_i^{-\mu_i^m}\right]^{-\frac{1}{\mu_i^m}}$
11. $\frac{QM_i}{QD_i} = \left[\frac{\alpha_i^m}{(1-\alpha_i^m)}\right]^{\sigma_i^m} \cdot \left[\frac{PD_i}{PM_i}\right]^{\sigma_i^m}$
12. $PQ_i = \frac{PD_i \cdot QD_i + PM_i \cdot QM_i}{(1-tq_i) \cdot QQ_i}$
13. $PM_i = EXR\overline{PWM_i}$

Income and savings block

Factors

14. $RL = RL_{for} + RL_{\text{inf}} + \overline{RL_{Row}}$
15. $RL_{for} = \sum_i LD_i \cdot w_i$
16. $RL_{\text{inf}} = PVA_{\text{inf}} \cdot QX_{\text{inf}}$
17. $RK = \sum_i \left(PVA_i \cdot QX_i - LD_i \cdot w_i\right) + \overline{RK_{Row}}$

Households

18. $YH = \lambda_l^H \cdot RL + \lambda_k^H \cdot RK + \overline{DivF} + \overline{Trsf_H^G} + \overline{Trsf_H^{Row}}$
19. $YDH = (1 - t_y^H) \cdot YH$
20. $SH = mps \cdot YDH$
21. $CFMH = YDH - SH$

Firms

22. $YF = \lambda_k^F \cdot RK + \overline{Subv_F^G}$
23. $SF = (1 - t_y^F) \cdot YF - \overline{DivF}$

Administration

24. $YG = TAXY + TAXS + TAXX + \lambda_k^G \cdot RK + \overline{Trsf_G^{Row}}$
25. $TAXY = t_y^H \cdot YH + t_y^F \cdot YF$
26. $TAXS = \sum_i tva_i \cdot PQ_i \cdot QQ_i$
27. $TAXX = \sum_i tx_i \cdot PX_i \cdot QX_i$
28. $SG = YG - \overline{CFMG} - \overline{Trsf_H^G} - \overline{Subv_F^G}$

https://doi.org/10.1017/S1355770X15000169 Published online by Cambridge University Press

Demand block

Final consumption

29. $$PQ_i \cdot CFQH_i = C\min_i \cdot PQ_i + pmc_i \cdot \left[CFMH - \sum_{j \neq i} c\min_j \cdot PQ_j - PD_{\inf} \cdot CFQH_{\inf} \right]$$

30. $$PD_{\inf} \cdot CFQH_{\inf} = C\min_{\inf} \cdot PD_{\inf} + pmc_{\inf} \cdot \left[CFMH - \sum_i c\min_j \cdot PQ_j \right]$$

31. $$PQ_i \cdot CFQG_i = \varphi_i \cdot \overline{CFMG}$$

Intermediate consumption

32. $$DIQ_i = \sum_j ica_{j,i} \cdot QX_j + ica_{i,\inf} \cdot QD_{\inf}$$

Investment

33. $$IT = \sum_i \overline{INVQ_i} \cdot PQ_i + CDM$$

34. $$CDM = \sum_i \overline{CDMQ_i} \cdot PQ_i$$

Closure rules

Commodities

35. $$QQ_i = CFQH_i + CFQG_i + DIQ_i + \overline{INVQ_i} + \overline{CDMQ_i}$$

36. $$QD_{\inf} = CFQH_{\inf}$$

Foreign account

37. $$\sum_i EXR \cdot \overline{PWM_i} \cdot QM_i = \sum_i EXR \cdot \overline{PWE_i} \cdot QE_i + \overline{RL_{Row}} + \overline{RK_{Row}} + \overline{Trsf_G^{Row}} + \overline{Trsf_H^{Row}} + Srow$$

Capital

38. $$IT = SF + SH + SG + Srow$$

Labour market

39. $$\overline{LDS^S} = \sum_i LD_i + LD_{\inf}$$

40. $$w_i = \overline{w}$$

Price index and numeraire

41. $$Pindex = \sum_i \pi_i \cdot PQ_i$$

42. $$EXR = 1$$

https://doi.org/10.1017/S1355770X15000169 Published online by Cambridge University Press

Environmental equations

43. $GDP = \sum_i PVA_i \cdot QX_i$

44. $GreenGDP = PIB - \sum_i DEGC_i - \sum_i DEPC_i$

45. $DEGC_i = \theta g_i \cdot QX_i$

46. $DEPC_i = \theta p_i \cdot QX_i$

Simulation impacts on parameters

$$\theta_i = \overline{\theta_i^0} \quad \forall i \neq élec$$

$$\theta_{elec} = (1 - cdm_{effect}) \cdot \overline{\theta_{elec}^0}$$

$$ica_{j,i} = \overline{ica\,0_{j,i}} \quad \forall i \neq elec$$

$$ica_{Ener,Elec} = (1 - cdm_{effect}) \cdot \overline{ica\,0_{Ener,Elec}}$$

Endogenous variables

PVA_i	Value-added activity price
PVA_{inf}	Informal value-added activity price
PX_i	Aggregate producer commodities price
PD_i	Domestic commodities price
PD_{inf}	Informal commodities price
PE_i	Export commodities price
PM_i	Import commodities price
PQ_i	Composite commodities price
P_{index}	Consumer price index
EXR	Exchange rate
QX_i	Quantity of aggregate commodity i output
QD_i	Quantity of domestic supply of commodity i
QD_{inf}	Quantity of supply of informal commodity
QE_i	Quantity of commodity i exports
QM_i	Quantity of commodity i imports
QQ_i	Quantity of composite commodity i
$CFQH_i$	Quantity of consumption of composite commodity i by households
$CFQH_{\text{inf}}$	Quantity of consumption of informal commodity by households
$CFQG$	Quantity of consumption of composite commodity i by government
DIQ_i	Quantity of intermediate demand for composite commodity i
RL	Labour incomes
RL_{for}	Labour incomes from formal activities
RL_{inf}	Labour incomes from informal activities
RK	Capital incomes

YH	Households' income
YDH	Households' disposable income
SH	Households' savings
$CFMH$	Households' consumption expenditures
YF	Firms' income
SF	Firms' savings
YG	Government's income
$TAXY$	Income tax
$TAXS$	Sales tax
SG	Government's savings
$Srow$	Foreign savings
CDM	Nominal CDM investment
IT	Nominal investment
LD_i	Quantity of labour in activity i
LD_{inf}	Quantity of informal labour
w_i	Labour wage rate in activity i
GDP	Gross domestic product
$GreenGDP$	Green gross domestic product
$DEGC_i$	Degradation costs from activity i
$DEPC_i$	*Depletion* costs from activity i

Exogenous variables

$\overline{CFG}$	Government consumption expenditures
$\overline{Trsj_H^G}$	Transfers from government to households
$\overline{Subv_F^G}$	Transfers from government to firms
$\overline{DivF}$	Dividends from firms to households
$\overline{Trsf_H^R}$	Transfers from rest of the world to households
$\overline{PWE_i}$	Foreign export commodities price
$\overline{PWM_i}$	Foreign import price
$\overline{K_i}$	Quantity of capital factor in activity i
$\overline{w}$	labour wage rate
$\overline{INVQ_i}$	Quantity of investment demand for composite commodity i
$\overline{CDMQ_i}$	Quantity of CDM investment demand for composite commodity i
$\overline{RL_R}$	Labour income from rest of the world
$\overline{RK_R}$	Capital income from rest of the world
$\overline{LDS_S}$	Quantity supplied of labour factor
$\overline{CQNMG_c}$	Quantity of government consumption of non-marketed commodities
$\overline{Subv_{Healthg}^h}$	Price subvention of public health commodities

https://doi.org/10.1017/S1355770X15000169 Published online by Cambridge University Press

Parameters

A_i^p	Production function efficiency parameter for commodity i
α_i^p	Production function share parameter for commodity i
μ_i^p	Production function exponent for commodity i
σ_i^p	Production function substitution parameter for commodity i
$ica_{i,j}$	Quantity of intermediate input i per unit of product j
A_i^m	Armington function shift parameter for commodity i
α_i^m	Armington function share parameter for commodity i
μ_i^m	Armington function exponent for commodity i
σ_i^m	Armington function substitution parameter for commodity i
A_i^t	CET domestic–export function shift parameter for commodity i
α_i^t	CET domestic–export function share parameter for commodity i
μ_i^t	CET domestic–export function exponent for commodity i
σ_i^t	CET domestic–export function substitution parameter for commodity i
tva_i	Sales tax rate for commodity i
tx_i	Production tax rate for commodity i
t_y^H	Direct tax rate on households
t_y^F	Direct tax rate on firms
$c\min_i$	Subsistence consumption of commodity i for households
$c\min_{\text{inf}}$	Subsistence consumption of informal commodity for households
pmc_i	Marginal share of consumption of spending on commodity i for households
pmc_{inf}	Marginal share of consumption spending on informal commodity for households
φ_c	Share of commodity i in total government consumption
mps	Marginal propensity to save for households
π_i	Weight of commodity i in the consumer price index