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Abstract:

The Clean Development Mechanism (CDM) under the Kyoto Protocol constitutes a major tool in the fight against climate change; it also is an important foreign direct investment funding opportunity for southern countries. Yet few studies have focused on the economic impact of CDM on host countries. This study attempts such an assessment in Peru, using a computable general equilibrium model that accounts for both the productive and regional dualism of the national economy. The numerical simulation of macroeconomic shocks generated by current and future CDM investments reveals the significant potential impact of such projects in terms of employment, growth, and regional imbalance in this developing country.

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1 Introduction

The international community confronts significant challenges associated with encouraging southern countries to participate in the fight against climate change without hindering their development. The Clean Development Mechanism (CDM) under the Kyoto Protocol is one example of this dual development–environmental issue. This mechanism allows northern countries[1] to make foreign direct investment (FDI) at the lowest cost in southern countries,[2] through carbon credit granted in proportion to the greenhouse gas reductions achieved. Host countries benefit from environmentally friendly technology transfers and additional funding sources for their development.

Since the first CDM project was registered in November 2004, CDM investments have enjoyed great success, increasing to 3,395 projects in 2011: 81.1% in Asia, 14.1% in Latin America and the Caribbean, and 2.65% in Africa (Fenhann 2011). However, their influence in terms of development is an insufficiently explored research area. Most approaches are focused on the project's environmental objective, and the few assessments of their contribution to development tend to be partial, heterogeneous, and based on controversial qualitative approaches.

Our objective is to contribute a quantitative assessment of the macroeconomic impact of CDM investments on a developing economy, using the specific case of Peru. This country is particularly sensitive to environmental issues, considering its vulnerability to climate change, and it ratified the Kyoto Protocol in September 2002. Since 2005, CDM Peruvian projects have increased rapidly and broadly, representing a real investment opportunity for this developing country. In 2009, Peru was among the 10 most attractive countries for CDM investments (Point Carbon 2009).

This analysis is based on a computable general equilibrium (CGE) model that considers an essential characteristic of Peruvian underdevelopment, namely, its dualism. In the next section, we address the limits of the CDM assessment in terms of development. Then we explicate the CGE model and its database. Finally, we address the main results of the macroeconomic impact simulations of current and future CDM projects in Peru.

2 CDM contributions to development

In economic literature, CDM assessment analyses focus mainly on their capacity to reduce greenhouse gas emissions rather than on its development objective (Austin and Faeth 2000; Olsen 2007). The first explanation refers to the strong incentives to assess the environmental impact, especially because such assessments determine the level of revenues generated by each project with regard to the carbon market. On the other hand, the contribution to development is just one objective mentioned in the *project design document*[3] (PDD), designed to facilitate acceptance by the *designed national authority* (DNA) of the host country.

Since the signature of the Kyoto Protocol though, few analyses have managed to assess the potential impact of CDM on southern countries' development. Some studies adopt quantitative approaches (Banuri and Gupta 2000; Mathy et al. 2001), though the majority engage in qualitative

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[1] These "Annex I" countries are subject to mandatory quantified emission reduction objectives.
[2] These "non-Annex I" countries receive CDM projects. They must have adopted the Kyoto Protocol and appointed a *designed national authority* (DNA), which is responsible for validating each project.
[3] Each CDM project requires a PDD. It gives information on the project's legislative aspects, its implementation, its baseline scenarios adopted, its funding sources and the local operators concerned. It should also describe its potential impact in terms of infrastructure, jobs, social project funding or environmental quality improvement.

analyses. But multicriteria evaluations suggest heterogeneous assessments, distinguished by the choice and respective weight of development criteria, as well as the nature or location of the project (Anagnostopoulos et al. 2004; Begg et al. 2003; Huq 2002; Kolshus et al. 2001; Olhoff et al. 2004; Sutter 2003). In such a context, many authors emphasize the need to apply an international standard to rate CDM projects, in accordance with their contribution to the various dimensions of sustainable development (Cosbey 2006; Cosbey et al. 2005; Schlup 2005; Sutter and Parreño 2007).[4] Although these standardization efforts have contributed to clarifying the debate and homogenizing extant analyses, they do not address all the concerns linked to assessments of a CDM's development objective. In particular, their relevance is limited due to the arbitrary weight assigned to different indicators. The information pertaining to development listed in the PDDs also remains often incomplete and subject to discussion, at both quantitative and qualitative levels (Alexeew et al. 2010). Finally, the role played by national DNAs with regard to the selection of projects may bias assessments. Performed without ex post verification by independent studies (Subbarao and Lloyd 2011), this choice usually reflects national priorities and specific concepts of development (Boyd et al. 2009; Bumpus and Cole 2010) or even is guided by the competitive pressure of other DNAs that also try to attract CDM investments.[5]

In this context and despite these difficulties, we attempt an economic assessment of CDM impact in a developing country such as Peru. We work in turn to fit both quantitative and developmental approaches by modeling the ex post macroeconomic impact of CDM investment flows in this economy.

3 Multisectoral and multiregional CGE model of Peru

The model is based on a CGE framework. This kind of analysis has gradually imposed in development economics from the 80s (Dervis et al. 1982; Robinson 1989). Because it gives emphasis on global interactions among supply, income, and demand through market mechanisms, it allows simulating macroeconomic reactions of the economy in front of various external shocks. Here, CDM investments may be one of these shocks. On the other hand, it allows a wide range of choice of agents or productive structures in order to take into account the structural characteristics of the studied economy. In this spirit, we choose here to focus on a key characteristic of Peruvian underdevelopment: its dual-dual nature.[6] The model equations appear in Appendix.

3.1. Peru: a dual–dual economy

As Lewis (1954) established long ago, *dualism* is a primary symptom of underdevelopment. In Peru, this dual character is doubly prominent. First, we find an urban productive dichotomy between formal and informal sectors. This informal sector consists of small non-capitalistic microenterprises that operate outside the institutional framework or modern production standards. It relates to the formal sector through the labor market, in that it serves as a shelter segment for workers excluded from formal employment and unprotected by an efficient social insurance system. In 2011, the Peruvian informal sector constituted 10.1% of the GDP and almost 50% of employment (MTPE 2004). Second,

[4] Olsen and Fenhann (2008) show for example that the potential benefits of 744 CDM projects may be regrouped in five main principles: job creation, economic growth, air quality, access to energy and well-being of the people.
[5] Brown et al. (2004) emphasize the need for strong and independent local institutions to analyze the socio-environmental consequences of the CDMs.
[6] For an analysis of a dual-dual economy in a CGE framework see Thorbecke (1997)

dualism stems from the geographic imbalance across Peru's three regions: Costa, Sierra, and Selva. In 2011, Costa accounted for 54% of national employment (33% for Selva, 13% for Sierra) and 70% of the national GDP (25% for Selva, 5% for Sierra) (see INEI 2011a, b). This regional disparity historically has been explained by the demographic, administrative, and commercial importance of Lima and its strong contributions to the development of Costa.[7] In recent years, the disparity has been particularly reinforced, because dynamic sectors (transport, construction, industries) have been mostly developed in Costa, whereas declining sectors (agriculture and mining) are located inland.

3.2 Model structure

The CGE model divides the national Peruvian economy into two regions: Costa and inland.[8] Each works as a whole economy, with its own agents and production sectors, linked through interregional commercial trade and, at the macroeconomic level, through a common balance of payments, a central public administration, a common job market, and a national capital market that ensures a savings–investment balance.[9] Each region hosts two groups of activities (formal and informal), two types of households (rural and urban), and two levels of labor qualifications (skilled and unskilled).

On the supply side, formal activities maximize profit by combining fixed capital with skilled and unskilled labor (see Eq. 1–4). Their products may be sold locally, to the rest of the world, or to other regions (Eq. 6–9); they are imperfectly substitutable with imported products (Eq. 10–13). Informal products can be obtained only from unskilled labor with a low fixed physical productivity (Eq. 5). They are only sold in regional markets for final household consumption.

On the demand side, urban and rural households perceive income from their initial endowments as input factors and their respective access to central Peruvian State transfer incomes (Eq. 14–20). Their consumption of formal products should to be a Linear Expenditure System function (Eq. 22-23). Their consumption of informal products is residual and allocated, according to budget coefficients assumed to be fixed in the short term (Eq. 24).

Regional price variations ensure the market balance of goods and services in each region (Eq. 37–38). The labor market closure is based upon a labor interregional mobility hypothesis. Skilled labor supply should be fixed in volume at the national level, and the real wage variations ensure the market balance (Eq. 41). A skilled wage differential between regions instead may be introduced to consider the differences in standards of living between the Costa region and the rest of the country (Eq. 42). For the non-skilled labor segment, supply is fixed at the national level (Eq. 43), and real wages should be rigid to increases. The market balance exists due to informal employment volumes. In each region, a worker who is not employed in formal urban activities creates an individual informal microenterprise. Inland, these workers have the additional option of migrating toward Costa, which occurs according to a Harris-Todaro specification, that is, by comparing the average earnings obtained through an inland informal sector and the probable gains expected in Costa (Eq. 44). At the end of the migration process, labor surplus distribution among informal activities reflects an exogenous key, calibrated from the base year database (Eq. 45).[10] In each region, informal trade activity receives particular treatment, because the volume of demand is determined by the volume of economic activity. Its labor productivity parameter thus plays a role as an adjustment variable (Eq. 40) (also see Kelley 1994).

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[7] Lima hosts 30.8% of the Peruvian population and centralizes its main administrations. Its proximity to Callao Harbor also makes it an essential location in foreign trade.
[8] Combining the Selva and Sierra regions into a single, inland also reflects data availability, and particularly the existence of two regional social accounting matrices (Nin-Pratt et al. 2011).
[9] For a similar approach to Peru, see Nin-Pratt et al. (2009).
[10] These keys may be interpreted as indicators of barriers to entry for each informal branch.

Foreign account closures and saving–investment balances refer to the national level (Eq. 48–49). CDM investments are taken into account at this level and considered as FDI that may be regionally and sectorally allocated across formal activities. Their impact on the Peruvian economy thus can be understood only in terms of demand shocks.[11]

3.3 Model database

The parametrical calibration of the model stems from two regional social accounting matrices (SAM), for Costa and inland (Nin-Pratt et al. 2011). For the purposes of our analysis, we reduced the number of formal activities to 17, while we also introduced 6 informal activities. This addition is possible because we use data from Peruvian employment surveys (MTPE 2004) and secondary sources (Loayza 2007; Robles 2003; Rodriguez and Higa 2010), which support an estimation of informal activities' contributions to employment and the GDP of each region. A restricted definition of informal employment, corresponding to individual entrepreneurs—with the main hypothesis that, in the absence of taxes or social charges, microentrepreneurs receive the full value added they generate—suggests that, at initial equilibrium, the informal sector represents 10.1% of the Peruvian GDP and 52.8% of total employment, with 30% of informal production found inland and 70% in Costa.[12]

4 Simulations and results

4.1 Baseline scenarios of CDM impact on the Peruvian economy

The data pertaining to the type, location, amount, and stage of completion of CDM investments in Peru come from the CDM pipeline (Fenhann 2012), supplemented by data from the UNFCCC[13] to detail each PDD and from FONAM (2010, 2011).[14] We thus can identify three successive waves of CDM projects: 26 "registered" projects already validated by the CDM executive board, 31 projects still "at validation," and 90 pending projects, described only in the Peruvian DNA's portfolio. Each project analysis enables the identification of their impact in terms of demand on other economic activities and on the pertinent region. We summarize these data in Table 1. They constitute the reference framework for our numerical simulations.

The first simulation, which is the most restricted one, considers the impact of the 26 "registered" projects (i.e., US$1079.3 million). The second one denotes the effect of the 31 CDM projects currently "at validation" (US$2411.4 million). Finally, a last simulation offers a prospective scenario of the potential impact of the 90 pending projects (US$8709.4 million).

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[11] An analysis in terms of supply would imply a structural modification of the model's parameters and particularly of the Peruvian energy matrix. However, considering the diversity of CDM projects, their different temporary horizons, and the absence of reliable data about their impact on intermediate energy consumers, we chose not to consider this supply effect.

[12] To avoid upsetting the initial coherence of each regional SAM, we deducted the added value estimated of informal activities from the value of corresponding formal activities, as estimated in official national accounts.

[13] United Nations Framework Convention on Climate Change. [Available online from http://cdm.unfccc.int].

[14] In Peru, the MINAM (*Ministerio del Ambiente*) evaluates the quality of projects, whereas the FONAM's (*Fondo Nacional del Ambiente*) mission is to promote CDM.

Table 1 Regional and sectoral distribution of CDM investments to Peru by achievement stage (US$ millions)

	Registered	***At Validation***	***Portfolio***
Region			
Costa	856,5	1784,9	6128,0
Inland	222,8	1705,8	6072,1
Total national	1079,3	3490,7	12200,1
Activities			
Machinery and equipment (act.9)			
Costa	231,3	481,9	1654,6
Inland	60,1	460,6	1639,5
Total national	291,4	942,5	3294,0
Construction (act.10)			
Costa	453,9	946,0	3247,8
Inland	118,1	904,1	3218,2
Total national	572,0	1850,1	6466,1
Transport and communication (act.14)			
Costa	68,5	142,8	490,2
Inland	17,8	136,5	485,8
Total national	86,3	279,3	976,0
Business services (act.15)			
Costa	68,5	142,8	490,2
Inland	17,8	136,5	485,8
Total national	86,3	279,3	976,0
Other private services (act.16)			
Costa	34,3	71,4	245,1
Inland	8,9	68,2	242,9
Total national	43,2	139,6	488,0

4.2 Results

Simulations are conducted according to a cumulative dynamic logic. The general equilibrium obtained after simulation 1 serves as initial reference equilibrium for simulation 2, which then does so for simulation 3. The results appear in Tables 2 and 3.

In the first simulation, the demand shock generated by the CDM investments accounts for 1.8% of the formal GDP, largely concentrated in the Costa region, which captures 79.4% of new investments. The results also reveal the globally positive impact of this shock at the national level, in the form of GDP growth of 0.37%. It increases inflation in both formal (+1.94%) and informal (+0.70%) sectors. The global increase of incomes for skilled and unskilled labor primarily benefits rural households. Urban households instead are more affected by reductions in informal employment, so they see their incomes decrease. The portion of public deficit in the GDP decreases (-4.36%) due to the effects of revenue and activity growth. The national volume of imports and exports also increases, improving the trade balance. This first simulation reveals an emphasis of Peruvian regional dualism in favor of the Costa region, whose dominance in terms of production, revenues, and employment increases. Its GDP grows 0.97%, whereas that of the inland region decreases by -1.22%. Inflation also is stronger in Costa (+2.12%) than inland (+1.53%), and the proportion of exports from this region, which grow relatively less competitive, also decreases. Therefore, productive dualism declines, and the informal sector effectively plays its role as a labor reservoir at the national level. The volume of informal employment decreases in both regions. Taking into account the compensation differentials between regions and labor migration movements, we recognize that this reallocation of resources basically moves in favor of unskilled formal employment in Costa (+2.09%), while unskilled formal employment inland slightly decreases (-0.62%).

The second simulation reveals an even more intense demand shock caused by the CDMs (about 5.9% of the formal GDP) and initiates a process of regional rebalancing because the inland region receives close to 49% of investments. These results reinforce the previous scenario: The impact of CDM investments is globally positive for the national economy. Supply, employment, and incomes increase, though the price effects grow stronger in both the formal and the informal sectors at this point. Regional imbalance tends to diminish in terms of non-skilled employment and production, as well as sectoral dualism, though the price effects ultimately mean an increase of the informal GDP as a proportion of the national economy.

Considering the importance of the demand shock envisaged in the third simulation, we note much more important price effects than in the previous two simulations (+12.49% in the informal sector, +13.79% in the formal sector, national level). These effects contribute to a general increase of income and GDP in both economic spheres. Productive dualism continues to decrease in volume, with a strong decrease of informal employment in favor of unskilled formal employment. Finally, the informal sector accounts for only 33.72% of total employment compared with 40.08% at the beginning. This evolution is particularly sensitive in the Costa region, whose part decreases by close to 10% (cf. 3% in the inland region). The contribution of the informal sector to total GDP increases, considering the pressure on prices. Finally, we note a catch-up effect inland in terms of employment, though it appears insufficient to threaten the hegemony of the Costa region.

Table 2 CDM investment effects on Peruvian economic variables (variation)

	COAST			**INLAND**			**NATIONAL**		
	SC1/SC0	**SC2/SC1**	**SC3/SC2**	**SC1/SC0**	**SC2/SC1**	**SC3/SC2**	**SC1/SC0**	**SC2/SC1**	**SC3/SC2**
CDM investment	10.65	20.06	57.36	4.51	32.79	88.55	8.32	24.73	69.56
INFORMAL SECTOR									
Employment	-0.10	-5.26	-21.52	-1.25	-3.12	-0.70	-0.65	-4.25	-11.57
GDP (value)	0.48	5.38	41.71	-0.63	1.55	24.72	0.15	4.24	36.78
Commission rate	5.53	11.23	80.58	8.35	4.82	25.60	0.80	8.86	54.67
Informal price index	0.98	8.33	12.49	0.04	7.20	12.98	0.70	7.99	12.59
FORMAL SECTOR									
Skilled employment	0.88	1.34	-4.41	-2.36	-3.71	12.85	0.00	0.00	0.00
Unskilled employment	2.09	2.93	12.65	-0.62	3.72	5.50	0.52	3.38	8.53
GDP (value)	1.02	4.09	8.44	-1.28	0.32	2.87	0.37	3.03	6.92
Skilled labor income	0.78	21.06	-2.31	-2.46	15.04	15.32	0.17	19.95	0.80
Unskilled labor income	2.09	2.93	12.65	-0.62	3.72	5.50	1.31	3.16	10.61
Capital income	0.60	0.81	9.37	-1.43	-2.90	-0.09	-0.01	-0.29	6.64
Income urban households	1.22	1.92	10.84	-1.15	-0.81	2.48	-0.59	-0.15	4.55
Income rural households	1.24	5.56	8.39	-1.15	2.49	6.78	0.69	4.87	8.04
Formal price index	2.12	7.14	13.79	1.53	12.96	41.53	1.94	8.88	21.81
MACRO									
GDP	0.97	4.21	11.73	-1.22	0.45	5.2	0.34	3.15	9.94
Part of public deficit/GDP (%)							1.02%	0.97%	1.89%
Public savings	-3.71	40.63	-29.81	-3.08	-15.67	0.10	-4.36	99.76	-43.07
Foreign savings							161.2	172.9	173.5

Sources: Numerical model simulations, using GAMS software.

Table 3 CDM investment effects on the dualism of Peruvian economy

Productive dualism: Evolution of the informal sector (%) in the national economy												
	NATIONAL				COAST				INLAND			
	Initial	**SC1**	**SC2**	**SC3**	**Initial**	**SC1**	**SC2**	**SC3**	**Initial**	**SC1**	**SC2**	**SC3**
Employment	40.08	39.83	38.13	33.72	42.66	42.21	40.29	32.85	37.58	37.47	36.02	34.52
Unskilled employment	44.62	44.33	42.45	37.54	50.20	49.66	47.58	38.74	39.74	39.59	37.97	36.56
GDP	10.00	9.98	10.09	12.55	9.81	9.76	9.87	12.52	10.49	10.55	10.67	12.64
Income urban households	11.50	11.47	11.50	14.19	11.91	11.83	11.84	14.91	10.65	10.70	10.75	12.51

Regional dualism: Evolution of each region (%) in the national economy								
	COAST/NATIONAL				INLAND/NATIONAL			
	Initial	**SC1**	**SC2**	**SC3**	**Initial**	**SC1**	**SC2**	**SC3**
Imports	80.66	80.57	69.24	57.27	19.34	19.43	30.76	42.73
Exports	58.13	53.59	51.12	52.26	41.87	46.41	48.88	47.74
Skilled employment	72.83	73.47	74.46	71.17	27.17	26.53	25.54	28.83
Unskilled employment	46.63	47.10	46.56	44.88	53.37	52.90	53.44	55.12
GDP	71.36	71.80	72.54	73.72	28.64	28.20	27.46	26.28
Skilled labor income	81.09	81.59	82.34	79.80	18.91	18.41	17.66	20.20
Unskilled labor income	70.74	71.20	71.32	73.03	29.26	28.80	28.68	26.97
Capital income	69.87	70.29	71.07	72.89	30.13	29.71	28.93	27.11
Income rural households	23.80	24.23	24.74	26.22	76.20	75.77	75.26	73.78
Income urban households	76.10	76.50	77.05	77.48	23.90	23.50	22.95	22.52

Sources: Numerical model simulations, using GAMS software.

5 Conclusion

Faced with a lack of analysis in extant economic literature, this study proposes a macroeconomic assessment of the impacts of CDM investments on the Peruvian economy, which is characterized by both productive and regional dualism. The numerical simulations obtained with a CGE model capture the endemic features of Peruvian underdevelopment and effectively reveal the globally positive impact of the CDM investments and their demand shock on national growth, as well as on the reduction of productive dualism. Even if the regional unbalance may be reinforced at the first step of CDM process, it tends to diminish as the projects gradually reach completion.

Despite these interesting initial results, there is room to improve our approach. For example, an effective research extension would include the environmental dimension of the CDM impact, together with the macroeconomic dimension. Unfortunately, the current condition of Peruvian environmental accounting does not support such a joint analysis yet. Similarly, the integration of the effects of the technological transfer linked to the CDM in the production function of agents also could enrich our analysis, by allowing for the consideration of the supply effects that result from these investments.

APPENDIX: Peruvian CGE Model

1. Index and Sets

Regions – r ∈ R = {Costa, Inland}

Households – h ∈ H= {Urb:Urban households, Rur: Rural households}

Activities or commodities – a∈ A ={Act1:Agriculture and Forestry; Act2: Fisheries; Act3: Mining and oil; Act4: Food processing; Act5: Textiles and Clothing; Act6: Wood products; Act7: Paper products and Publishing industries; Act8: Chemicals, Pharmaceutical industries and Refined petroleum; Act9: Non-metallic minerals, Metals, Machinery and equipment; Act10: Construction; Act11: Water and electricity; Act12: Retail and wholesale trade; Act13: Hotels and catering; Act14: Transport and communication; Act15: Business services; Act16: Other private services; Act17: Government services; Act18: Informal manufacturing; Act19: Informal Construction; Act20: Informal Trade; Act21: Informal Restaurants; Act22: Informal Transport; Act23: Other informal services }

Formal activities - for (or i) ∈ FOR ⊂ A / FOR= {Act1,.., Act17 }
Formal trade services - Comf ∈ FOR / Comf ={ act12}

Informal activities - nf (or j) ∈ NF⊂ A / NF = { Act18,.., Act23 }
Informal trade services- Comnf ∈ NF ={ act20}

2. Equations

Regional Production Block

Formal production process

1. $$QX^r_{for} = Ax^r_{for}.\left[\delta x^r_{for}.LD^{r\ -\mu x^r_{for}}_{for} + \left(1-\delta x^r_{for}\right)\overline{K}^{\ -\mu x^r_{for}}_{for}\right]^{-\frac{1}{\mu x^r_{for}}}$$

2. $$LD^r_{for} = QX^r_{for}.\left[\frac{\delta x^r_{for}.PVA^r_{for}}{\left(Ax^r_{for}\right)^{\mu x^r_{for}}.w^r_{for}}.\right]^{\sigma x^r_{for}}$$

3. $$LD^r_{for} = Al^r_{for}.\left[\delta l^r_{for}.LDS^{r\ -\mu l^r_{for}}_{for} + \left(1-\delta l^r_{for}\right)LDNS^{r\ -\mu l^r_{for}}_{for}\right]^{-\frac{1}{\mu l^r_{for}}}$$

4. $$\frac{LDS^r_{for}}{LDNS^r_{for}} = \left[\frac{\overline{w_{ns}}}{w_s}.\frac{\delta l^r_{for}}{1-\delta l^r_{for}}\right]^{\sigma l^r_{for}}$$

Informal production process

5. $$QD^r_{nf} = \gamma_{nf}.LDNS^r_{nf}$$

Output transformation for locally sold and non-locally sold formal products

6. $$QX^r_{for} = At^r_{for}.\left[\delta t^r_{for}.QE^{r\ -\mu t^r_{for}}_{for} + \left(1-\delta t^r_{for}\right)QD^{r\ -\mu t^r_{for}}_{for}\right]^{-\frac{1}{\mu t^r_{for}}}$$

7. $$\frac{QE^r_{for}}{QD^r_{for}} = \left[\frac{\delta t^r_{for}}{1-\delta t^r_{for}}.\frac{PE^r_{for}}{PD^r_{for}}\right]^{\sigma t^r_{for}}$$

Export transformation for interregional and international formal markets

8. $$QE^r_{for} = Ae^r_{for}.\left[\delta e^r_{for}.QER^{r\ -\mu e^r_{for}}_{for} + \left(1-\delta e^r_{for}\right)QEW^{r\ -\mu e^r_{for}}_{for}\right]^{-\frac{1}{\mu e^r_{for}}}$$

9. $$\frac{QER^r_{for}}{QEW^r_{for}} = \left[\frac{\delta e^r_{for}}{1-\delta e^r_{for}}.\frac{PER^r_{for}}{ER.\overline{PEW}_{for}}\right]^{\sigma e^r_{for}}$$

Substitution between local and non-local formal products

10. $$QQ^r_{for} = Aq^r_{for}.\left[\delta q^r_{for}.QM^{r\ -\mu q^r_{for}}_{for} + \left(1-\delta q^r_{for}\right)QD^{r\ -\mu q^r_{for}}_{for}\right]^{-\frac{1}{\mu q_{for}}}$$

11. $$\frac{QM^r_{for}}{QD^r_{for}} = \left[\frac{\left(PD^r_{for} + icd^r_{for}.PQ^r_{comf}\right)}{PM^r_{for}}.\frac{\delta q^r_{for}}{1-\delta q^r_{for}}\right]^{\sigma q^r_{for}}$$

Substitution between interregional and international formal products

12. $$QM^r_{for} = Am^r_{for}.\left[\delta m^r_{for}.QMR^{r\ -\mu m^r_{for}}_{for} + \left(1-\delta m^r_{for}\right)QMW^{r\ -\mu m^r_{for}}_{for}\right]^{-\frac{1}{\mu m_i}}$$

13. $$\frac{QMR^r_{for}}{QMW^r_{for}} = \left[\frac{PMW^r_{for}}{PMR^r_{for}}.\frac{\delta m^r_{for}}{1-\delta m^r_{for}}\right]^{\sigma m^r_{for}}$$

Regional Income, Demand and Savings Block

Formal incomes

14. $$YK^r = \sum_{for}\left(PVA^r_{for}.QA^r_{for} - w^r_{for}.LD^r_{for}\right)$$

15. $$YSL^r = \sum_{for} w_s.LDS^r_{for}$$

16. $$YNSL^r = \sum_{for}\overline{w_{ns}}.LDNS^r_{for}$$

Informal incomes

17. $$YINF^r = \sum_{nf} PVA^r_{nf}.QD^r_{nf}$$

18. $$inc^r_{nf} = \frac{YINF^r}{\sum_{nf} LDNS^r_{nf}}$$

Regional institutions incomes

19. $$Y^r_{rur} = \phi s^r_{rur}YSL^r + \phi ns^r_{rur}.YNSL^r + \phi k^r_{rur}YK^r + Pindex.\overline{Transf^r_{rur}}$$

20. $$Y^r_{urb} = \phi s^r_{urb}YSL^r + \phi ns^r_{urb}.YNSL^r + \phi k^r_{urb}YK^r + Pindex.\overline{Transf^r_{urb}} + YINF^r$$

21. $Y_G = \sum_r \sum_h ty_h^r . Y_h^r + \sum_r tk^r .YK^r + \sum_r \sum_{for} tm_{for}^r .ER.\overline{PWM}_{for}^r .QMW_{for}^r + \sum_r \sum_{for} tq_{for}^r .PQ_{for}^r .QQ_{for}^r$

Regional household's consumption demand

22. $PQ_{for}^r .CQH_{h,for}^r = \overline{c\min}_{h,for}^r .PQ_{for}^r + pmc_{h,for}^r . \left[EH_h^r - \sum_{for} \overline{c\min}_{h,for}^r .PQ_{for}^r \right]$

23. $EH_h^r = (1 - ty_h^r - pmc_{h,nf}^r).Y_h^r - S_h^r$

24. $PD_{nf}^r .CQH_{h,nf}^r = pmc_{h,nf}^r .Y_h^r$

Savings

25. $S_h^r = mps_h^r .(1 - ty_h^r).Y_h^r$

26. $S_G = Y_G - \sum_r \sum_{for} PQ_{for}^r .\overline{CQG}_{for}^r - Pindex. \sum_r \sum_h \overline{Transf}_h^r$

27. $S_K^r = (1 - tk^r - \sum_h \phi k_h^r).YK^r$

Regional Price System Block

28. $PX_{for}^r = PVA_{for}^r + \sum_i ica_{i,for}^r PQ_i^r$

29. $PD_{nf}^r = PVA_{nf}^r + \sum_{for} ica_{for,nf}^r PQ_{for}^r$

30. $w_{for}^r .LD_{for}^r = \overline{w_{ns}} .LDNS_{for}^r + w_s .LDS_{for}^r$

31. $PX_{for}^r .QX_{for}^r = PD_{for}^r .QD_{for}^r + PE_{for}^r .QE_{for}^r$

32. $PE_{for}^r .QE_{for}^r = PER_{for}^r .QER_{for}^r + ER.\overline{PEW_{for}} .QEW_{for}^r$

33. $PQ_{for}^r .(1 - tq_{for}^r).QQ_{for}^r = \left(PD_{for}^r + icd_{for}^r .PQ_{Comf} \right) QD_{for}^r + PM_{for}^r .QM_{for}^r$

34. $PM_{for}^r .QM_{for}^r = PMW_{for}^r .QMW_{for}^r + PMR_{for}^r .QMr_{for}^r$

35. $PMW_{for}^r = ER.\overline{PWM_{for}} + icm_{for}^r .PQ_{comf}^r + tm_{for}^r$

36. $PMR_{for}^r = \overline{PER_{for}^{r'}} + icr_{for}^{r'} .PQ_{comf}^{r'}$

Closure Rules Block

Regional commodity markets

37. $QQ_{for}^r = \sum_h CQH_{h,for}^r + \overline{CQG}_{for}^r + \sum_{for'} ica_{for,for'}^r .QX_{for'}^r + \sum_{\inf} ica_{for,\inf}^r .QD_{\inf}^r + \overline{QINVP}_{for}^r$

38. $QD_{nf}^r = \sum_h CQH_{h,nf}^r$

39. $QQ_{comf}^r = \sum_i \left(icd_i^r .QD_i^r + icm_i^r .QMw_i^r + ice_i^r .QEw_i^r + icr_i^r .QEr_i^r \right)$

40. $QQ_{comnf}^r = \Theta_{comnf}^r \sum_i QD_i^r$

National labor markets

41. $\overline{LS} = \sum_r \sum_{for} LDS_{for}^r$

42. $w_s^{Inland} = (1 + \rho).w_s^{Costa}$

43. $\overline{LNS} = \sum_r \sum_{for} LDNS_{for}^r + \sum_r \sum_{\inf} LNS_{\inf}^r$

44. $inc_{nf}^{Inland} = T. \left[\overline{w}_{ns}^{Costa} . \frac{\sum_{for} LDNS_{for}^{Costa}}{\sum_{for} LDNS_{for}^{Costa} + \sum_{nf} LDNS_{nf}^{Costa}} + inc_{nf}^{Costa} . \frac{\sum_{\inf} LDNS_{nf}^{Costa}}{\sum_{for} LDNS_{for}^{Costa} + \sum_{nf} LDNS_{nf}^{Costa}} \right]$

45. $LNS_{nf}^r = \Psi_{nf}^r \sum_{nf} LNS_{nf}^r$

Interregional trade linkage

46. $QM_{for}^{Costa} = QEr_{for}^{Inland}$

47. $QM_{for}^{Inland} = QEr_{for}^{Costa}$

National current account balance

48. $\sum_r \sum_{for} ER.\overline{PWM}_{for}^r .QMW_{for}^r = \sum_r \sum_{for} ER.\overline{PEW}_{for}^r .QEW_{for}^r + S_{row}$

National savings–investment balance

49. $\sum_r \sum_{for} PQ_{for}^r .\overline{QINVP}_{for}^r + \sum_r \sum_{for} \overline{CDM}_{for}^r = \sum_r \left(\sum_h S_H^r + S_G^r + S_K^r \right) + S_{row}$

National Price index

50. $Pindex^r = \sum_i \pi_i^r .PQ_i^r$

51. $ER = 1$

3. Variables and parameters

VARIABLES

ER	Exchange rate
PD_a^r	Demand price for local commodities
$Pindex^r$	Regional consumer price index
PE_{for}^r	Composite export formal commodities price
PER_{for}^r	Regional export formal commodities price
$\overline{PEW_{for}}$	Foreign export formal commodities price
PM_{for}^r	Composite import formal commodities price
PMR_{for}^r	Regional import formal commodities price
$LDNS_a^r$	Quantity of unskilled labor in activity a
LDS_{for}^r	Quantity demanded of skilled labor in formal sector activities
$\overline{LS}$	Quantity supplied of skilled labor factor
$\overline{LNS}$	Quantity supplied of unskilled labor factor
inc_{nf}^r	Average informal activities incomes
w_{for}^r	Average price of composite labor factor in formal activities
$\overline{w_{ns}}$	Unskilled labor wage rate
w_s	Skilled labor wage rate

PMW^r_{for}	Foreign import formal commodities price
PVA^r_a	Value-added activity price
PQ^r_{for}	Composite formal commodities price
PX^r_{for}	Aggregate producer formal commodities price
$\overline{PWM^r_{for}}$	Foreign import price in foreign currency units
QD^r_a	Quantity of domestic supply of commodity a
QE^r_{for}	Quantity of composite regional and foreign formal commodities exports
QER^r_{for}	Quantity of regional formal commodities exports
QEW^r_{for}	Quantity of foreign formal commodities exports
QM^r_{for}	Quantity of composite regional and foreign formal commodities imports
QMR^r_{for}	Quantity of regional imports formal commodities
QMW^r_{for}	Quantity of foreign imports formal commodities
QQ^r_{for}	Quantity of formal composite domestic and import formal commodities
QX^r_{for}	Quantity of aggregate formal commodities output
$\overline{K}_{for}$	Quantity capital factor in formal activities
LD^r_{for}	Quantity demanded of composite skilled and unskilled labor from formal sector activities

YK^r	Firms' revenue
Y_G	Government revenue
Y^r_h	Household h income
$YINF^r$	Informal incomes
$YNSL^r$	Unskilled labor incomes
YSL^r	Skilled labor incomes
S^r_h	Household h savings
S_G	Government savings
S^r_K	Firm savings
S_{row}	Foreign savings in local currency units
EH^r_h	Household h consumption expenditures
$CQH^r_{h,a}$	Quantity of consumption of commodities for household h
$\overline{CQG^r_{for}}$	Quantity of consumption of formal commodities for government
$\overline{QINVP^r_{for}}$	Quantity of fixed investment demand for formal commodities
$\overline{Transf^r_h}$	Transfers from government to households h

PARAMETERS

Ax^r_{for}	Formal production function efficiency parameter
δx^r_{for}	Formal production function share parameter
μx^r_{for}	Formal production function exponent
σx^r_{for}	Formal production substitution parameter
γ_{nf}	Informal production productivity parameter
Al^r_{for}	Composite formal labor function shift parameter
δl^r_{for}	Composite formal labor function share parameter
μl^r_{for}	Composite formal labor function exponent
σl^r_{for}	Composite formal labor function substitution parameter
At^r_{for}	CET domestic-export function shift parameter
δt^r_{for}	CET domestic-export function share parameter
μt^r_{for}	CET domestic-export function exponent
σt^r_{for}	CET domestic-export function substitution parameter
Ae^r_{for}	CET regional-foreign function shift parameter
δe^r_{for}	CET regional-foreign function share parameter
μe^r_{for}	CET regional-foreign function exponent
σe^r_{for}	CET regional-foreign function substitution parameter
Aq^r_{for}	Armington domestic-import function shift parameter
δq^r_{for}	Armington domestic-import function share parameter
μq^r_{for}	Armington domestic-import function exponent
σq^r_{for}	Armington domestic-import function substitution parameter
Am^r_{for}	Armington regional-foreign function shift parameter

δm^r_{for}	Armington regional-foreign function share parameter
μm^r_{for}	Armington regional-foreign function exponent
σm^r_{for}	Armington regional-foreign function substitution parameter
ty^r_h	Direct tax rate on household h
tk^r	Direct tax rate on factor capital
tm^r_{for}	Import tariff rate
tq^r_{for}	Sales tax rate
$ica^r_{a,a'}$	Quantity of intermediate input a' per unit of product a
icd^r_{for}	Quantity of trade input per unit of formal domestic product.
icm^r_{for}	Quantity of trade input per unit of formal foreign imported product
$icr^{r'}_{for}$	Quantity of trade input per unit of formal regional imported product
ϕs^r_h	Share of household h in income of skilled labor factor
ϕns^r_h	Share of household h in income of unskilled labor factor
ϕk^r_h	Share of household h in income of capital factor
$\overline{c\min^r_{h,for}}$	Subsistence consumption of formal commodity for household *h*
$pmc^r_{h,a}$	Marginal share of consumption spending on commodity a for household h
mps^r_h	Marginal propensity to save for household h
Θ^r_{comnf}	Informal trade activity parameter
T	Migration function parameter
ρ	Skilled wage premium between Costa and Inland
Ψ^r_{nf}	Informal labor surplus distribution key
π^r_a	Weight of commodity a in the consumer price index

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