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MACROCLOSURES IN COMPUTABLE GENERAL EQUILIBRIUM MODELS : A PROBABILISTIC TREATMENT WITH AN APPLICATION TO MOROCCO

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RÉSUMÉ

Nous testons ci-après, à l'aide d'un modèle illustratif d'équilibre général calculable de l'économie marocaine, le caractère significatif des résultats de simulation lorsque la nature de la fermeture macroéconomique n'est pas connue avec certitude. La procédure consiste à calculer des bornes inférieure et supérieure pour les résultats de la simulation, étant donné des probabilités *a priori* attachées à trois fermetures possibles (classique, à la Johansen, keynésienne). Notre conclusion est que, lorsqu'il y a incertitude sur les fermetures, plusieurs variations endogènes perdent leur caractère significatif, ce qui limite l'usage du modèle pour l'élaboration de politiques économiques.

Mots clés : fermetures macroéconomiques, modèles d'équilibre général calculable, Maroc

ABSTRACT

With the help of an illustrative computable general equilibrium (CGE) model of the Moroccan economy, we test for the significance of simulation results in the case where the exact macroclosure is not known with certainty. This is done by computing lower and upper bounds for the simulation results, given *a priori* probabilities attached to three possible closures (Classical, Johansen, Keynesian). Our conclusion is that, when there is uncertainty on closures, several endogenous changes lack significance, which, in turn, limits the use of the model for policy prescriptions.

Key words : macroclosures, computable general equilibrium models, Morocco

1. INTRODUCTION

More than 30 years ago, Sen (1963) showed that in a closed economy with neoclassical production, it is impossible to achieve predetermined levels of real investment and public consumption, to pay production factors the value of their marginal product and to maintain factor full-employment at the same time. The system is simply overdetermined. Sen, himself, suggested various ways of getting rid of that overdeterminancy or, more fashionably, different possible macroclosures of the model.

With the proliferation of increasingly complex computable general equilibrium (CGE) models applied to developed and developing countries, there has been a renewed interest in Sen's original dilemma.[1] Indeed, CGE modellers often find themselves in a quandary similar to Sen's. If neoclassical income distribution and factor full-employment are the rule, and if real investment and public consumption levels are predetermined, the CGE model may face undeterminacy. As such, the modeller has to find some way of closing the system, i.e., rendering it mathematically determined.

Borrowing much from Sen's 1963 contribution and terminology, CGE modellers have become accustomed to distinguishing between four possible macroclosures, at least in the case of a closed economy : the Keynesian, the Johansen, the Classical and the Kaldorian.[2] In the case of the Keynesian macroclosure, labour full-employment is no longer mandatory; employment thus becomes endogenous. In the Johansen closure, it is the turn of the public consumption volume to become endogenous; as such, given the level of government revenue, it is up to public savings to fill the gap between the exogenous investment volume and private savings. With the Classical closure, the real investment target is abandoned; the volume of investment, which is now endogenous, adjusts itself to the total available savings. Finally, with the Kaldorian closure, production

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1 For surveys of these applications, see Shoven and Whalley (1984), Manne (1985), Devarajan, Lewis and Robinson (1986), Decaluwé and Martens (1988), Gunning and Keyzer (1995).

2 See, e.g., Lysy (1982).

factors are not necessarily paid according to their marginal-value productivity; a mechanism generally determined outside the model, forces, through a change in income distribution, real savings to adjust to the total investment target, considering that different income groups have different propensities to save. When the economy is open to trade, the necessity of choosing one of the above four macroclosures remains if we are in a floating foreign exchange regime or if the exchange rate is kept at a fixed level in real terms. In both cases, the supply of foreign savings is not perfectly elastic and, as such, does not necessarily fill the gap between the real investment target and available national savings. It is only when the exchange rate is fixed in nominal terms that the necessity to look for a macroclosure disappears. In such a case, the model is initially fully determined. If there is fixed exchange parity, supply of foreign savings is indeed perfectly elastic and automatically fills the savings gap. As pointed out by Dewatripont and Michel (1983), who were the first to systematically analyze the closure problem under alternative exchange-rate regimes, there is, however, a possible cost attached to a policy of fixed parity : long-term and permanent external indebtedness.[3]

Until now, the choice of a specific macroclosure has largely depended on how the CGE modeller views the functioning of the economy at hand. If he leans toward a structuralist interpretation, he favors the Keynesian, Johansen or Kaldorian closures. If he does not believe in the notion of a planned investment, he adopts a Classical closure, etc. In some cases, the model is simulated under different closures. However, the problem remains that, as shown, for example, by Decaluwé, Martens and Monette (1988), simulation results are very often highly sensitive to the closure retained, not only from a quantitative point of view, but also from a qualitative one.

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3 It is clear from the above that the use of the labels "Keynesian", "Johansen", "Classical" and "Kaldorian" by CGE modellers is no claim that the corresponding closing procedures can exactly be traced to the original work of the authors involved (Keynes, Johansen, etc). Moreover, each closure can have its own variants [see, e.g., Rattso (1982), in the case of the Johansen closure]. Finally, "Kaldorian" has become a generic name for any closure where the neoclassical income distribution rule is ignored in view of generating enough savings, given the total investment target, whether the modeller calls his closure neo-Keynesian, neo-Ricardian, Marxian, neo-Marxian, Cambridge or Kaldorian itself. [For further reading on the possible distinction between various "Kaldorian" closures, see, e.g., Taylor (1979, 1983), Taylor and Lysy (1979), Gibson, Lustig and Taylor (1982) and Marglin (1984)].

In the present paper, we suggest a new approach for the treatment of macroclosures in CGE models. Instead of choosing a given closure or exploring the impact on the model's results of alternative closures taken one at the time, we assume that the modeller makes use of an *a priori* probability distribution of the various possible closures or, at least, of those which are meaningful for the economy to which the CGE model applies. This will permit him to construct confidence sets for the model's endogenous variables, these sets being themselves a function of the probability distribution chosen for the alternative closures. Let us briefly consider, e.g., a modeller who is interested, for the sake of simplicity, in only two closures : the Classical one, where investment adjusts to available savings and a non-Classical one - whether it is Keynesian, Johansen or Kaldorian - where real investment is fixed. Let us also assume that the modeller makes use of a discrete density probability function where the two closures are weighted according to their *a priori* probability of occurrence. If he attaches a high weight to the Classical closure and, consequently, a low weight to the non-Classical one, he considers, in all likelihood, that the economy is mainly driven by market forces though not entirely. If, on the contrary, he weighs heavily the non-Classical closure and thus attaches little weight to the Classical one, his view is that the economy still has a long way to go before being lead by the Invisible Hand.

In Section 2, we give the basic formulation needed for such a probabilistic treatment of macroclosures. Section 3 gives the formulation of the probabilistic treatment itself, the latter being general enough as to encompass all mathematically possible closures and not only the four mentioned above. In Section 4, we present a simple CGE of the Moroccan economy, which is our illustrative model. In Section 5, we apply to the Moroccan model an algorithm which permits the numerical implementation of the probabilistic treatment we developed in Section 3, given an exogenous increase in the private transfers from the rest of the world or workers' remittances.

2. BASIC FORMULATION

The general structure of a CGE model can be written in its computable formulation as :

$$Y = M\ (X, \beta, \gamma) \tag{2.1}$$

where Y is a vector of m endogenous variables, M a function which is usually nonlinear but computable, X a vector of ℓ exogenous variables, some of them being economic policy variables, β a vector of p free parameters belonging to a subset Ω of $\mathbb{R}^p$, and γ a vector of k calibration parameters. If one considers that the model can be "closed" in n different manners, n being finite, (2.1) is written under closure f (f = 1, ..., n) as :

$$Y^f = M^f(X^f, \beta, \gamma) \tag{2.2}$$

where Y^f and X^f are the vectors of, respectively, the m endogenous variables and ℓ exogenous variables under closure f (f = 1, ..., n).

The number of n possible closures is, itself, equal to the number of nonrepetitive combinations of ℓ variables among (m + ℓ), i.e. :

$$n = \binom{m + \ell}{\ell} = \frac{(m + l)\ !}{l\ !\ m\ !}\ . \tag{2.3}$$

The probabilistic treatment that we develop in Section 3 applies to any number of closures, i.e., for any finite value of n. In reality, however, the number of economically meaningful closures is generally restricted. In what follows, we shall posit that, under the economically meaningful closures retained by the modeller, there is a subset of m* (with m* < m) endogenous variables which are, in all cases, of interest to him. In other words, these m* variables can never be made exogenous in an effort to close the model.

We shall call such variables, for lack of a better term, *strictly endogenous* variables. Examples of these variables could be real GDP or the volume of imports. In order to further simplify our presentation, we shall assume, on the other hand, that the parameters remain the same for all closures. Differently stated, the structure of the model is not modified with the choice of closures. What changes are the exogenous variables.[4] The calibration procedure then consists in finding the γ vector by solving :

$$Y_0 = M\ (X_0, \beta, \gamma) \qquad (2.4)$$

where Y_0 and X_0 are the values of the vectors of, respectively, the endogenous and exogenous variables taken in the base year, these values being independent of the chosen closure. If (2.4) has a solution which is unique, one can then write :

$$\gamma = H\ (Y_0, X_0, \beta) = h\ (\beta)\ . \qquad (2.5)$$

When an estimate $\hat{\beta}$ of the vector β of free parameters is available, γ can also be estimated after β is replaced by $\hat{\beta}$ in (2.4) and (2.5). Given our assumption that the values of the various parameters (β and γ) remain constant under all closures, (2.2) can even be rewritten in the more compact form :

$$Y^f = g^f\ (X^f) \qquad \forall\ f = 1, ..., n\ . \qquad (2.6)$$

Similarly, every strictly endogenous variable i (i = 1, ..., m*) under closure f (f = 1, ..., n) can be written as :

$$Y^f_i = M_i^f\ (X^f, \beta, \gamma) = g^f_i\ (X^f)$$
$$\forall\ i = 1, ..., m^* \ \text{ and } \ \forall\ f = 1, ..., n\ . \qquad (2.7)$$

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4 It can be shown that the probabilistic treatment given in Section 3 is also valid if the structure of the model changes for different closures.

This basic formulation will prove essential for what follows.

3. A PROBABILISTIC TREATMENT : GENERAL FORMULATION

When constructing a CGE, the modeller traditionally had to make a decision on what closure to apply. This choice was analogous to a choice made under uncertainty, nothing guaranteeing that the closure retained was the appropriate one for the economy under study. Moreover, had he decided to solve the model under not only one but several closures, he was hardly in a more favorable position having no objective criterion to select the "best" closure, in the absence of a well-defined loss function.

In our treatment, by analogy with the theory of decision which associates different probabilities to the different states of nature, we associate different probabilities to the occurrence of the different closures, the set of probabilities being itself subjective. In order to do so, we define a vector $\pi = (\pi_1, ..., \pi_n)$ of elementary probabilities where π_f is the probability associated to closure f (f = 1, ..., n) such as :

$$P(d = f) = \pi_f \quad \forall\ f = 1, ..., n\ ,$$
$$0 \leq \pi_f \leq 1 \qquad \sum_{f=1}^{n} \pi_f = 1\ , \tag{3.1}$$

the values of the various π_f being exogenously chosen *a priori* probabilities.

The model, when solved for a given change in policy measures or another exogenous shock, gives the value taken by each of the strictly endogenous variables under a given closure or Y_i^f (i = 1, ..., m*, f = 1, ..., n). Having associated probabilities to the different closures, we can then derive the moments of each of these variables, particularly, their mathematical expectation, variance and standard deviation :

$$E(Y_i) = \sum_{f=1}^{n} Y_i^{\,f}\,\pi_f \tag{3.2}$$

$$V(Y_i) = \sum_{f=1}^{n} (Y_i^{\,f} - E(Y_i))^2\,\pi_f = \sum_{f=1}^{n} (Y_i^{\,f})^2\,\pi_f - (E(Y_i))^2 \tag{3.3}$$

$$\sigma(Y_i) = \sqrt{V(Y_i)}$$ (3.4)[5]

In turn, (3.2) and (3.4) will enable us to construct empirical confidence sets for those same strictly endogenous variables. We could even compute a covariance matrix, that one could use for the construction of empirical joint confidence regions, though the covariance between two strictly endogenous variables does not necessarily have a clear economic meaning in this context.

There are, of course, many ways to specify the probability vector π. The simplest specification is to assume a discrete uniform distribution. In that case, (3.1), (3.2) and (3.3) become :

$$P(d = f) = \pi_f = \frac{1}{n} \qquad \forall\, f = 1, \ldots, n \tag{3.5}$$

$$E(Y_i) = \sum_{f=1}^{n} Y_i^{\,f}\,\pi_f = \frac{1}{n}\sum_{f=1}^{n} Y_i^{\,f} \tag{3.6}$$

$$V(Y_i) = \sum_{f=1}^{n} (Y_i^{\,f} - E(Y_i))^2\,\pi_f = \frac{1}{n}\sum_{f=1}^{n} (Y_i^{\,f})^2 - (E(Y_i))^2 \tag{3.7}$$

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5 In (3.2) - (3.4), Y_i is clearly random, given the uncertainty about the choice of closures, whereas $Y_i^{\,f}$ is not random since it is computed under a given closure.

Moreover, the traditional treatment of closures becomes a particular case of (3.5) to (3.7) where a probability of one is associated to one of the possible closures, let us say the h closure. Equations (3.5) to (3.7) can indeed be rewritten in such a case :

$$P(d = h) = \pi_h = 1 \qquad (3.8)$$
$$P(d = f) = \pi_f = 0 \quad \forall f \neq h$$

and

$$E(Y_i) = Y_i^h \qquad (3.9)$$

$$V(Y_i) = 0 \qquad (3.10)$$

4. AN ILLUSTRATIVE CGE OF THE MOROCCAN ECONOMY

The model, which is static in nature and kept deliberately simple, has three production activities (agriculture, industry, administrative services)[6], four economic agents (households, firms, government, rest of the world) and two types of production factors (labor and capital). Agricultural and industrial commodities are tradables whereas administrative services are nontradables. Labor is perfectly mobile between agriculture and industry, and specific to administrative services. As such, there are two kinds of wages ("private" wage for agriculture and industry, "public" wage for administrative services). Capital is specific respectively to agriculture and industry. There are thus two kinds of capital returns (agricultural and industrial). Administrative services do not use capital. Households consume mainly agricultural and industrial commodities. Administrative services which are "consumed" by the government constitute public consumption.[7] Households' income is made of wages, capital income (dividends, etc.)

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6 Industry includes also nonadministrative services.

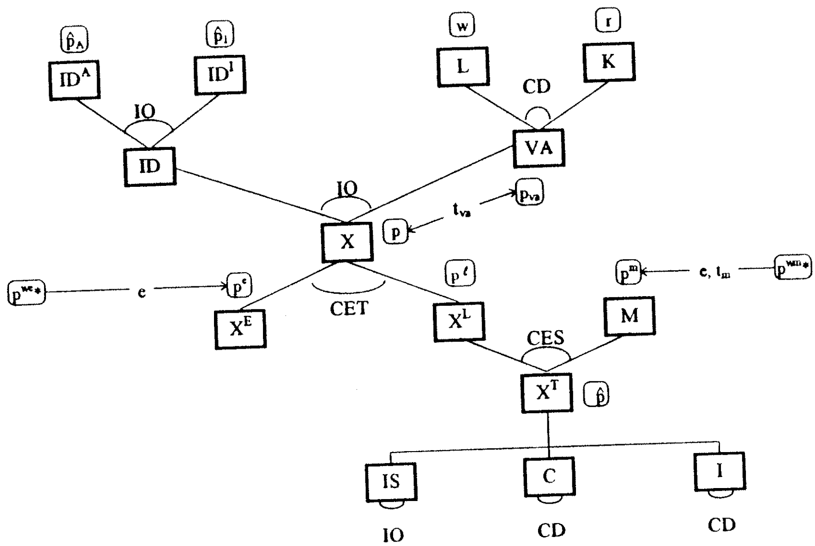
7 Though the largest bulk of administrative services is public consumption, there is a small amount of these services which is consumed by households, the Moroccan Government selling some products of the public domain at a price roughly equal to their factor cost, wood being a good example.

and transfers from the government and the rest of the world (workers' remittances). The government has three sources of fiscal revenue (taxes on income of households and firms, tax on agricultural and industrial value added, duties and taxes on imports, net of subsidies) as well as nonfiscal revenue (foreign budgetary aid and capital income from state-owned enterprises). Firms' income is made of capital income (undistributed profits) and transfers from the government and the rest of the world. The rest of the world's receipts are imports (at CIF prices), capital income from foreign-owned firms located in Morocco, and tranfers from households, firms and the government. The rest of the world's expenditures are exports (at FOB prices) and the above-mentioned transfers to households, firms and the government. Since the model applies only to the real sector of the economy, there are no financial markets. The social accounting matrix consistent with the flow structure, which has just been described, is given in Appendix 1 for 1990, our year of reference [for details on the construction of the matrix, see Zaoujal (1995)].

The technological and behavioral relationships (or "specifications") of the model are quite standard. They are summarized in Table 4.1 for agricultural and industrial activities, and in Table 4.2 for administrative services, the full model being given in Appendix 2.

Agricultural and industrial outputs are produced according to "nested" Cobb-Douglas production functions (i.e., with unitary substitution elasticity between labor and capital, and zero substitutability between intermediate inputs, and between the latter and total value added). A constant-elasticity product transformation function allocates this output to local and foreign markets, given the domestic and export price ratio. The elasticity of transformation values were assumed to be 0.7 for agriculture and 0.5 for industry. Export demand is itself perfectly price-elastic. Total supply of agricultural and industrial commodities consists of domestically produced and imported goods and services. The choice between sources of supply, local or foreign, is made according to a constant trade elasticity of substitution (or "Armington" relationship), given the domestic price ratio of local production and imports. This trade elasticity was assumed to be 0.8 for agricultural commodities and 0.6 for industrial ones. Production of administrative

Table 4.1
Specifications for Agriculture and Industry



Aggregates

C	:	sales to private consumption
ID^A, ID^I	:	intermediate purchases of agricultural and industrial inputs
ID	:	intermediate purchases
IS	:	intermediate sales
I	:	sales to investment
L	:	labor
K	:	capital
M	:	imports
VA	:	value added
X	:	domestic output
X^E	:	exports
X^L	:	domestic output locally supplied
X^T	:	total supply

Prices

$\hat{p}$	:	composite price
$\hat{p}_A$	:	composite price of agricultural commodities
$\hat{p}_I$	:	composite price of industrial commodities
p	:	output price at farm or factory gate
p^l	:	market price on the local market
p^{we*}	:	world price of exports (in foreign currency)
p^e	:	domestic price of exports
p^{wm*}	:	world price of imports (in foreign currency)
p^m	:	domestic price of imports
p_{va}	:	price of value added
r	:	capital rental value
w	:	wage rate ("private")
e	:	nominal exchange rate (dirhams per unit of foreign currency)

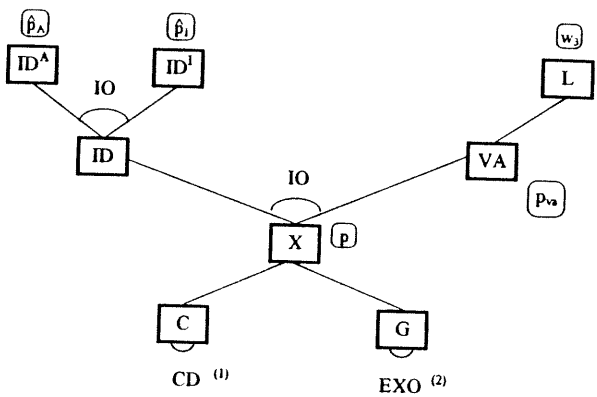
Taxation rates

t_{va}	:	on value added
t_m	:	on imports

Specifications

CD	:	Cobb-Douglas
CES	:	constant elasticity of substitution
CET	:	constant elasticity of transformation
IO	:	Leontief

Table 4.2
Specifications for Administrative Services



[1] See Table 4.1.

[2] In value.

Aggregates

C	:	sales to private consumption
G	:	public consumption
ID^A,ID^I	:	intermediate purchases of agricultural and industrial inputs
ID	:	intermediate purchases
L	:	labor (i.e., civil servants)
VA	:	value added (i.e., government wage bill)
X	:	output

Prices

w_3	:	wage rate ("public")
p_{va}	:	price of value added (=w_3)
$\hat{p}_a$	:	composite price of agricultural commodities
$\hat{p}_I$	:	composite price of industrial commodities
p	:	output price

Specifications

CD	:	Cobb-Douglas
IO	:	Leontief
EXO	:	exogenous

services assumes perfect complementary between intermediate inputs and labor. The household-expenditure system is derived from a Cobb-Douglas utility function, which means that budgetary shares are constant in value. The share composition of investment in agricultural and industrial commodities is also constant in value. Domestic and foreign transfers are exogenous, respectively in local and foreign currencies. Administrative labor and the two types of capital are in fixed supply. "Private" labor (i.e., labor used in agriculture and industry), the value of public consumption and total investment volume are either exogenous or endogenous according to the closure retained. Finally, a floating foreign exchange regime is assumed to prevail.[8]

5. SIMULATIONS, RESULTS AND CONCLUSIONS

In our simulations, we proceeded as follows :

- the external shock retained was a 20 % increase in the foreign currency tranfers from the rest of the world to households [TRH*];[9]

- given that shock, the model was solved under three closures (Classical, Johansen and Keynesian) using the GAMS-MINOS computer program. In the Classical closure, real investment (IQ) was made endogenous. In the non-Classical one, it was exogenously fixed at its initial level. The exogeneity of real investment was made possible, in the Johansen closure, by rendering the value of public consumption (G) endogeneous, and in the Keynesian closure, by making endogenous total private employment;

8 In reality, in 1990, Morocco had a fixed foreign exchange regime, the local currency (the dirham) being pegged to a basket of foreign currencies. In such a regime, as stated above, the closure problem disappears; hence our assumption, for purely illustrative purposes, of a floating system.

9 These transfers consist mainly of remittances by Moroccans working abroad. They are important for Morocco since they constitute the largest source of foreign exchange, before tourism and the export of phosphates.

- three probability vectors were then chosen : $\pi^{(1)} = (0.5, 0.2, 0.3)$, $\pi^{(2)} = (0.3, 0.2, 0.5)$ and $\pi^{(3)} = (1/3, 1/3, 1/3)$, the first element of each vector referring to the Classical closure, the second to the Johansen closure and the third to the Keynesian closure;

- having computed the percentage changes from the initial values for 16 selected strictly endogenous variables under the three closures, we were finally able to calculate for each of these variables and for each probability vector the mathematical expectation of the percentage changes [E(.)], their standard deviation $\sigma(.)$ and their lower and upper bounds defined as $E(.)\pm 2\sigma(.)$.

The results are given in Tables 5.1, 5.2 and 5.3, respectively, for probability vectors $\pi^{(1)}$, $\pi^{(2)}$ and $\pi^{(3)}$.

The results of Tables 5.1, 5.2 and 5.3 are suprisingly similar. If indeed we consider as *non*significant any change whose lower and upper bounds have opposite signs, we can see that changes in variables M_1, M_2, X_1^E, X_2^E, C_1, C_2, SH, YM, r_1 and e are significant, whereas changes in variables VA_1, VA_2, SG, w, w_3, and r_2 are nonsignificant. The source of the significant changes can, in general, be easily traced. The appreciation of the dirham on the foreign exchange market, induced by an increase in the transfers from abroad to households, explains the increase in imports and the decrease in exports. These transfers seem also to dominate what happens to households : though the changes in the two types of salaries and in one type of capital return are nonsignificant - which in all likelihood explains the lack of significance of the changes in value added and government savings - the increases in the income, savings and consumption of the transfer beneficiaries are all significant.

In conclusion, our experiments have shown that :

1) not only does the choice of macroclosures matter, as it was already illustrated in Decaluwé, Martens and Monette (1988), but uncertainty about the exact nature of the

Table 5.1
Results with Probability Vector $\pi^{(1)} = (0.5, 0.2, 0.3)$
(Changes in Percentage from Initial Values for Selected Strictly Endogenous Variables)

	Mathematical Expectation E(.)	Standard Deviation σ(.)	Lower Bound E(.)-2σ(.)	Upper Bound E(.)+2σ(.)
Volumes				
Agricultural value added [VA_1]	0.34476	0.22808	-0.11140	0.80092
Industrial value added [VA_2]	-0.36215	0.29750	-0.95715	0.23284
Agricultural imports [M_1]	3.84023	0.28812	3.26399	4.41646
Industrial imports (M_2]	2.01114	0.25491	1.50132	2.52095
Agricultural exports [X_1^E]	-2.22878	0.20019	-2.62917	-1.82839
Industrial exports [X_2^E]	-1.82963	0.32384	-2.47731	-1.18196
Private consumption of agricultural commodities [C_1]	0.99366	0.22353	0.54661	1.44071
Private consumption of industrial commodities [C_2]	2.04820	0.34209	1.36402	2.73238
Values				
Government savings [SG]	-2.88870	1.92651	-6.74172	0.96431
Households' savings [SH]	1.64649	0.27023	1.10603	2.18694
Households' personal income (YH)	1.56803	0.27173	1.02458	2.11149
Prices				
"Private" wage [w]	0.36890	0.29121	-0.21352	0.95132
"Public" wage [w_3]	0.70640	1.02485	-1.34330	2.75610
Agricultural capital rental value [r_1]	1.28600	0.31970	0.64660	1.92540
Industrial capital rental value [r_2]	-0.27910	0.27498	-0.82906	0.27086
Nominal exchange rate [e]	-3.09940	0.073745	-3.24689	-2.95191

Table 5.2
Results with Probability Vector $\pi^{(2)}$ = (0.3, 0.2, 0.5)
(Changes in Percentage from Initial Values for Selected Strictly Endogenous Variables)

	Mathematical Expectation E(.)	Standard Deviation $\sigma(.)$	Lower Bound $E(.)-2\sigma(.)$	Upper Bound $E(.)+2\sigma(.)$
Volumes				
Agricultural value added [VA_1]	0.26362	0.25587	-0.24812	0.77536
Industrial value added [VA_2]	-0.49564	0.31997	-1.13558	0.14431
Agricultural imports [M_1]	3.76418	0.32006	3.12406	4.40430
Industrial imports (M_2]	1.89533	0.27140	1.35253	2.43814
Agricultural exports [X_1^E]	-2.31351	0.22060	-2.75471	-1.87231
Industrial exports [X_2^E]	-1.97389	0.34988	-2.67365	-1.27414
Private consumption of agricultural commodities [C_1]	0.91711	0.25082	0.41547	1.41875
Private consumption of industrial commodities [C_2]	1.95496	0.38072	1.19352	2.71640
Values				
Government savings [SG]	-3.35990	1.73115	-6.82221	0.10241
Households' savings [SH]	1.55534	0.30319	0.94895	2.16172
Households' personal income (YH)	1.47652	0.30487	0.86678	2.08627
Prices				
"Private" wage [w]	0.48190	0.32534	-0.16877	1.13258
"Public" wage [w_3]	0.70160	1.02725	-1.35290	2.75610
Agricultural capital rental value [r_1]	1.18320	0.35839	0.46642	1.89998
Industrial capital rental value [r_2]	-0.40530	0.27512	-0.95553	0.14493
Nominal exchange rate [e]	-3.12140	0.065732	-3.25287	-2.98994

Table 5.3
Results with Probability Vector $\pi^{(3)} = (1/3, 1/3, 1/3)$
(Changes in Percentage from Initial Values for Selected Strictly Endogenous Variables)

	Mathematical Expectation E(.)	Standard Deviation σ(.)	Lower Bound E(.)-2σ(.)	Upper Bound E(.)+2σ(.)
Volumes				
Agricultural value added [VA_1]	0.35945	0.25611	-0.15277	0.87166
Industrial value added [VA_2]	-0.39424	0.29875	-0.99174	0.20327
Agricultural imports [M_1]	3.88735	0.33872	3.20992	4.56479
Industrial imports (M_2]	1.97822	0.25235	1.47352	2.48293
Agricultural exports [X_1^E]	-2.23736	0.21019	-2.65774	-1.81699
Industrial exports [X_2^E]	-1.86122	0.32750	-2.51622	-1.20623
Private consumption of agricultural commodities [C_1]	1.01176	0.25326	0.50523	1.51829
Private consumption of industrial commodities [C_2]	2.10141	0.40099	1.29942	2.90340
Values				
Government savings [SG]	-3.62977	2.02951	-7.68879	0.42924
Households' savings [SH]	1.67004	0.30717	1.05570	2.28438
Households' personal income (YH)	1.59189	0.30898	0.97393	2.20985
Prices				
"Private" wage [w]	0.36333	0.31837	-0.27340	1.00007
"Public" wage [w_3]	1.04600	1.20919	-1.37238	3.46438
Agricultural capital rental value [r_1]	1.31967	0.36672	0.58622	2.05312
Industrial capital rental value [r_2]	-0.34200	0.25761	-0.85721	0.17321
Nominal exchange rate [e]	-3.12733	0.074838	-3.27701	-2.97766

dominant closure casts a serious doubt on the significancy of several of the simulation results and hence on the policy implications one can derive from the use of CGE models;[10]

2) moreover, it suffices to introduce uncertainty on macroclosures to obtain the same outcome, the latter being seemingly rather insensitive to the numerical values attached to the probabilities, at least as long as the extreme case of unitary or near unitary probability of closure is not retained.

However, on the basis of our procedure, it would be dangerous to generalize any further. The procedure has no asymptotic properties and the definition of the lower and upper bounds $E(.)\pm 2\sigma(.)$ remains somewhat arbitrary. The choice of probabilities contains a certain degree of arbitrariness as well, though it is not greater than in the case where only one closure is explored at a time. One could argue that it is even smaller.

10 Since our probabilistic procedure can be applied to any undetermined model, this conclusion might also be valid for policy models different from CGEs, such as purely macro models.

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APPENDIX 1
THE 1990 MOROCCAN SOCIAL ACCOUNTING MATRIX (MILLIONS OF DIRHAMS)

	FACTORS		AGENTS				ACTIVITIES			LOCAL MARKET			EXPORT MARKET			TOTAL
	LABOR	CAPITAL	HOUSEH.	FIRMS	GOVERNM.	R.W.	AGRICULT.	INDUSTRY	ADM.SERV.	AGRI.PROD.	INDUS. PROD.	ADM. SERV.	AGRI. PROD.	INDUS. PROD.	ACCUMULAT	
FACTORS																
1 - LABOR							13 487,53	57 948,52	25 588,00							97 024,05
2 - CAPITAL							22 201,53	45 331,61								67 533,14
AGENTS																
3 - HOUSEHOLDS	96 956,45	42 853,29			2 695,00	13 194,65										155 699,39
4 - FIRMS		16 482,04			2 725,44	914,65										20 122,13
5 - GOVERNMENT		6 592,81	8 322,00	10 241,34		6 265,00	1 561,49	18 065,62		(391,79)	10 048,10					60 704,57
6 - REST OF THE WORLD	67,60	1 605,00	154,67	(113,97)	7 816,00					4 248,00	59 327,90					73 105,20
ACTIVITIES																
7 - AGRICULTURE										65 341,32			5 522,00			70 863,32
8 - INDUSTRY											257 868,02			46 501,30		304 369,32
9 - ADMINISTRATIVE SERVICES												34 456,00				34 456,00
LOCAL MARKET																
10 - AGRICULTURAL PRODUCTS			46 558,12				17 659,05	6 903,83	47,19						(1 970,66)	69 197,53
11 - INDUSTRIAL PRODUCTS			70 799,07				15 953,72	176 119,74	8 820,81						55 550,68	327 244,02
12 - ADMINISTRATIVE SERVICES			1 233,00		33 223,00											34 456,00
EXPORT MARKET																
13 - AGRICULTURAL PRODUCTS						5 522,00										5 522,00
14 - INDUSTRIAL PRODUCTS						46 501,30										46 501,30
15 - ACCUMULATION			28 632,53	9 994,76	14 245,13	707,60										53 580,02
TOTAL	97 024,05	67 533,14	155 699,39	20 122,13	60 704,57	73 105,20	70 863,32	304 369,32	34 456,00	69 197,53	327 244,02	34 456,00	5 522,00	46 501,30	53 580,02	

( ) : Negative values.

APPENDIX 2

THE EQUATIONS AND VARIABLES OF THE CGE MODEL	NO.
Production and employment	
$VA_j = A_j L_j^{\alpha_j} K_j^{1-\alpha_j} (j = 1, 2)$	(1)
$VA_3 = L_3$	(2)
$ID_{ij} = a_{ij} ID_j \quad (i = 1, 2; j = 1, 2, 3)$	(3)
$ID_j = u_j X_j$	(4)
$X_j = \frac{VA_j}{v_j} \quad (j = 1, 2, 3)$	(5)
$L_i \cdot w = \alpha_i p_{va,i} VA_i \quad (i = 1, 2)$	(6)
$L_3 \cdot w_3 = p_3 X_3 - \sum_{i=1}^{2} \hat{p}_i ID_{i3}$	(7)
$GDP = \sum_{i=1}^{3} p_{va,i} VA_i$	(8)
Income and savings	
$RK = \sum_{i=1}^{2} r_i K_i$	(9)
$RKH = \lambda_h RK$	(10)
$RKE = \lambda_e RK$	(11)
$RKG = \lambda_g RK$	(12)
$RKR = (1 - \lambda_h - \lambda_e - \lambda_g) RK$	(13)
$YHP = (1 - \mu)\left[w \sum_{i=1}^{2} L_i + w_3 L_3\right] + RKH$	(14)
$YH = YHP + TGH + e \cdot TRH^*$	(15)
$YHD = (1 - t_h) YHP + TGH + e \cdot TRH^* - THR$	(16)
$YE = RKE + TGE + e \cdot TRE^*$	(17)

THE EQUATIONS AND VARIABLES OF THE CGE MODEL	NO.
$YG = RKG + t_h YHP + t_e RKE + eTRG^* + \sum_{i=1}^{2} TVA_i + \sum_{i=1}^{2} TM_i$	(18)
$TVA_i = t_{va,i}\, p_{va,i}\, VA_i \quad (i = 1, 2)$	(19)
$TM_i = t_{mi}\, p_i^{wm*}\, e \cdot M_i \quad (i = 1, 2)$	(20)
$SH = s\, YHD$	(21)
$SE = YE - t_e\, RKE - TER$	(22)
$SG = YG - TGH - TGE - TGR - G$	(23)
Demand for commodities	
$C = YHD - SH$	(24)
$\hat{p}_i\, C_i = c_i\, C \quad (i = 1, 2, 3)$	(25)
$G = p_3\, X_3 - c_3\, C$	(26)
$ID_i = \sum_{j=1}^{3} ID_{ij} \quad (i = 1, 2)$	(27)
$\hat{p}_i\, I_i = i_i\, I \quad (i = 1, 2)$	(28)
$I = p_{inv}\, IQ$	(29)
Balance of payments	
$X_i = B_i \left[\gamma_i (X_i^E)^{\theta_i} + (1 - \gamma_i)(X_i^L)^{\theta_i}\right]^{\frac{1}{\theta_i}} \quad (i = 1, 2)$	(30)
with $\theta_i = \dfrac{1 + \tau_i}{\tau_i} \quad [0 < \tau_i < +\infty] \quad (i = 1, 2)$	
$X_i^E = \left(\dfrac{p_i^e}{p_i^l}\right)^{\tau_i} \left(\dfrac{1 - \gamma_i}{\gamma_i}\right)^{\tau_i} X_i^L \quad (i = 1, 2)$	(31)

THE EQUATIONS AND VARIABLES OF THE CGE MODEL	NO.
$X_i^T = D_i\left[\delta_i(M_i)^{-\rho_i} + (1 - \delta_i)(X_i^L)^{-\rho_i}\right]^{-\frac{1}{\rho_i}}$ (i = 1, 2)	(32)
with $\rho_i = \frac{1 - \sigma_i}{\sigma_i}$ $[0 < \sigma_i < +\infty]$ (i = 1, 2)	
$M_i = \left(\frac{p_i^l}{p_i^m}\right)^{\sigma_i} \left(\frac{\delta_i}{1 - \delta_i}\right)^{\sigma_i} X_i^L$ (i = 1, 2)	(33)
$e\ YR^* = \mu\left[w\sum_{i=1}^{2} L_i + w_3 L_3\right] + RKR + THR + TER + TGR + e\sum_{i=1}^{2} p_i^{wm*} M_i$	(34)
$F^* = YR^* - TRH^* - TRE^* - TRG^* - \sum_{i=1}^{2} p_i^{we*} X_i^E$	(35)
Equilibrium conditions	
$L^s = \sum_{i=1}^{2} L_i$	(36)
$L_3^s = L_3$	(37)
$X_i^T = ID_i + C_i + I_i$ (i = 1, 2)	(38)
$X_3 = C_3 + G/p_3$	(39)
$I = SH + SE + SG + eF^*$	(40)

THE EQUATIONS AND VARIABLES OF THE CGE MODEL	NO.

Prices

$$r_i = \frac{p_{va,i}\, VA_i - wL_i}{K_i} \quad (i = 1, 2)$$ (41)

$$p_{va,j} = \frac{p_j X_j - \sum_{i=1}^{2} \hat{p}_i\, ID_{ij}}{VA_j(1 + t_{va,j})} \quad (j = 1, 2)$$ (42)

$$p_{va,3} = w_3$$ (43)

$$p_i^m = p_i^{wm*} e(1 + t_{mi}) \quad (i = 1, 2)$$ (44)

$$p_i^e = p_i^{we*} e \quad (i = 1, 2)$$ (45)

$$\hat{p}_i = \frac{p_i^l X_i^L + p_i^m M_i}{X_i^T} \quad (i = 1, 2)$$ (46)

$$\hat{p}_3 = p_3$$ (47)

$$p_i = \frac{p_i^l X_i^L + p_i^e X_i^E}{X_i} \quad (i = 1, 2)$$ (48)

$$p_{num} = \sum_{i=1}^{3} \beta_i p_i$$ (49)

$$\text{with } \beta_i = \frac{X_i^0}{\sum_{i=1}^{3} X_i^0} \quad (i = 1, 2, 3)$$

$$p_{inv} = \prod_{i=1}^{2} \hat{p}_i^{\,i_i}$$ (50)

Symbols

i, j = 1 (agriculture), 2 (industry), 3 (administrative services)

Aggregates

(expressed in dirhams unless they are followed by an asterisk, in which case they are in foreign currency)

C : private consumption (value)

C_i : private consumption of commodity i (volume)

F^* : current external deficit or foreign savings (value)

G : public consumption (value)

GDP : gross domestic product at factor cost (volume)

I : investment (value)

I_i : investment in commodity i (volume)

ID_i : intermediate sales of commodity i (volume)

ID_{ij} : purchases of commodity i by activity j (volume)

ID_j : intermediate purchases by activity j (volume)

IQ : investment (volume)

K_j : demand for capital by activity j (volume)[1]

L_j : demand for labor by activity j (volume)[2]

L^s : supply of labor to agriculture and industry (volume)

L_3^s : supply of labor to administrative services (volume)

M_i : imports of commodity i at CIF prices (volume)

RK : total capital income (value)

---

1 Capital is defined in the base year as total capital income.

2 Labor is defined in the base year as the wage bill.

RKE : firms' capital income (value)

RKG : government capital income (value)

RKH : households' capital income (value)

RKR : rest of the world capital income (value)

SE : firms' savings (value)

SG : government savings (value)

SH : households' savings (value)

TER : transfers from firms to rest of the world (value)

TGE : net transfers from government to firms (value)

TGH : net transfers from government to households (value)

TGR : transfers from government to rest of the world (value)

THR : transfers from households to rest of the world (value)

TM_i : duties and taxes on imports of commodity i (value)

TRE* : transfers from rest of the world to firms (value)

TRG* : transfers from rest of the world to government (value)

TRH* : tranfers from rest of the world to households (value)

TVA_i : tax on activity i value added (value)

VA_j : activity j value added (volume)

X_i^E : exports of commodity i at FOB prices (volume)

X_i^L : sales of domestically produced commodity i on the local market (volume)

X_i^T : total supply of commodity i on the local market (volume)

X_j : output of activity j at farm or factory gate prices (volume)

YE : income of firms (value)

YG : government income (value)

YH : households' total income (value)

YHD : households' disposable income (value)

YHP : households' primary income (value)

YR* : current receipts of the rest of the world (value)

Prices

e : nominal exchange rate (dirhams per unit of foreign currency)

p_i : farm or factory gate price of commodity i

$\hat{p}_i$: composite price of commodity i

p_i^e : domestic price of commodity i exports

p_i^l : market price of commodity i supply on the local market

p_i^m : domestic price of commodity i imports

p_i^{we*} : world price of commodity i exports in foreign currency

p_i^{wm*} : world price of commodity i imports in foreign currency

p_{inv} : price of investment

p_{num} : price of numeraire

$p_{va,i}$: price of activity i value added

r_i : rental value of capital in activity i

w : private wage rate

w_3 : public wage rate

Parameters

a_{ij} : volume of input i as a share in activity j total volume of intermediate demand

A_j : level parameter in activity j production function

B_i : level parameter in transformation function of commodity i

c_i : value share of commodity i in total private consumption

D_i : level parameter in Armington substitution function of commodity i

i_i : value share of commodity i in total investment

s : households' marginal propensity to save

t_e : tax rate on firms' capital income

t_h : tax rate on households' primary income

t_{mi} : tax rate on commodity i imports

$t_{va,i}$: tax rate on activity i value added

u_j : share of intermediate purchases in activity j total output

v_j : value added share in activity j total output

α_j : labor elasticity of value-added supply in activity j

β_i : share of commodity i base year value (volume) in total domestic output base year value (volume)

γ_i : share parameter of exports in transformation function of commodity i

δ_i : share parameter of imports of composite commodity i in the Armington function

θ_i : parameter of transformation function of commodity i

λ_e : share of firms in total capital income

λ_g : share of government in total capital income

λ_h : share of households in total capital income

μ : share of total wages paid to rest of the world

ρ_i : parameter of Armington function of commodity i

σ_i : trade substitution elasticity of commodity i

τ_i : elasticity of transformation of commodity i

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