

Trade Liberalization and the Dynamic of Poverty in Tunisia? A Layered CGE Microsimulation Analysis[^]

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Abstract

The effects of trade liberalization on poverty in Tunisia are examined, using a layered dynamic CGE-microsimulation approach. A dynamic CGE model endogenously generates the evolution of prices and, for each household group, income paths under protection and freer trade assumptions. These results are then used to assess the equivalent income of each household, using a sample from 1995 household survey, and so the effects of the simulated changes on poverty. Dominance tests are also used to avoid the arbitrariness of choosing a poverty line and a poverty measure. Simulation results show that although trade openness slows down the downward trend of poverty in the short and medium-run, it enhances poverty reduction in the long-run.

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1. Introduction

The links between trade reform and poverty are diverse and complex. In the developing countries, the poor, i.e., households with income falling below the poverty line, share common broad features: (i) they are generally concentrated in rural (subsistence) agriculture and in urban informal sector; (ii) they have limited assets, the most abundant of which is low-skilled labor; (iii) and food is by far the most important item of their expenditure. Both the direct and indirect effects of trade liberalization on the poor are then to be connected with its impact on this poverty profile¹.

Trade reform works directly through the transmission of price signals. Then, if it increases the price of something the poor households sell (unskilled labor, goods, services), and/or forces downward the price of something the poor households consume (goods, services), it will increase the real income (purchasing power) of the poor households and push more poor people from below to above the poverty line, and vice versa.

Economic growth is the indirect channel through which freer trade could contribute to poverty alleviation. There is now substantial empirical evidence supporting a positive association between open trade regimes and growth and development². Indeed, trade openness reduces the anti-export bias of protection, allows efficient allocation of scarce resources and brings incentive to investment and innovation. In addition, trade reform is usually associated with higher flows of FDI with attendant spillovers of technologies, new business practices and other effects on domestic firms that increase the overall level of productivity and growth. In turn, economic growth is a powerful force for permanent and sustained poverty reduction. The extent to which growth affects poverty, however, depends on how the additional income generated by growth is distributed across the population. The more the income of the bottom segment of the population rises, the more the growth pattern is deemed to be as pro-poor. Dollar and Kraay (2002) find that the incomes of the poorest fifth of the population grew one-for-one with GDP per head in a sample of 80 countries over four decades.

Trade liberalization is therefore expected to help the poor, given the positive association between openness and growth and growth and poverty reduction. However, alone trade reform is not a panacea and relying on the solely growth effect of a liberal trade policy is not sufficient to address the poverty problem. Trade liberalization should be supported by a stable macroeconomic environment and a competitive real exchange rate. Furthermore, it should be supplemented by a cocktail of other pro-poor growth policies, targeted directly towards the vulnerable segments of society. In this regard, government has an important role to play in fostering (rural) development, including through encouraging absorption of new technologies, expanding access to education, providing basic social services to poor people and investing in infrastructure.

¹ A detailed synthesis of the different mechanisms through which changes in trade policy can affect the poor could be found among others in Bannister and Thugge (2001), Hoekman et al. (2001) and Winters et al. (2002).

² Support comes from several studies including Coe et al. (1997) and Feenstra et al. (1999).

The aim of this paper is to trace through the dynamic impact of trade liberalization on the Tunisian poor, while accounting for many of the above structural features that the Tunisian poverty profile shares with the other developing countries. Indeed, trade liberalization was an integral part of the structural adjustment program that has been adopted by Tunisia since 1986. The trade policy reform has been pursued and consolidated by joining the WTO in 1990 and by concluding a FTA with the EU in 1995. The agreement called for a gradual removal of all tariff and non tariff barriers on industrial goods and the creation of a nonagricultural free-trade zone, over a twelve years transition period. It has been progressively implemented since 1996 and came into force on 1998. A complete dismantlement of these barriers on EU imports will be then achieved by 2008.

In Tunisia, the large share of the work force is unskilled, having not attained the university. In 1999 for example, the distribution of employment reveals that 92.2% of the labor force is unskilled. Among them, 20.5% are working in the rural agriculture, whereas 30.7% are in the urban informal sector. As to poverty, it is mainly a rural phenomenon and to less extent urban informal in 1990, since about 65% of the poor live in the rural area and about 10% of the poor are working in the urban informal sector.³

The extreme complexity of the linkages between trade reform and poverty motivates the use of a dynamic computable general equilibrium (DCGE) model, accounting for many of the above mentioned channels of transmission, in order to check whether the great openness of the Tunisian economy to the world market hurts the less well-off of the society. To address issues related to poverty within the framework of economy-wide models, one can identify in the literature three broad varieties of CGE methodologies. The most common method, pioneered by Adelman and Robinson (1978), consists in stratifying as much as possible the representative household into a small number of homogenous groups according to occupation, location or income criteria. Using a household income and expenditures survey, the authors assume that incomes within each group follow a lognormal distribution and then proceed to the estimation of the mean and variance of each distribution. In this approach, the CGE model provides the counterfactual change in the average income level of each of the groups, while the variance of this income and thereby the within-group inequality is assumed fixed and unaltered by the CGE experiments. Hence, changes in overall inequality can only result from a redistribution between groups, whereas analyses of household surveys indicate that changes in intra-group inequality contribute at least as much as changes in inter-group inequality to the overall disparity.

Recent studies attempt to come to grips with the issue of fixed intra-group inequality by complementing CGE models with microsimulation. They can be classified into two broad categories: layered and integrated CGE-microsimulations⁴.

The layered CGE-microsimulation or top-down technique is conducted in two separate and sequential steps. In the first step, the CGE model is simulated to generate a full vector of commodity and factor prices, owing to a policy experiment. These are fed, in the second step, into a microsimulation framework which utilizes the CGE model

³ See the World Bank (1995). Note that this poverty profile would not have been changed since 1990.

⁴ Davies (2004) and Hertel and Reimer (2004) offer a survey of recent studies relying on these new approaches.

results on prices to conduct a detailed analysis of income distribution and poverty at the household level.

This approach has two limitations. First, there is no consistency imposed between the data in the micro-simulation and the CGE models. Second, the reactions of households to commodity and factor prices changes are not (fully) transmitted back to the CGE model, so that only a fraction of the endogenous intra-group inequality is captured; in opposition to the integrated CGE-microsimulation technique. Indeed, the latter is able to incorporate directly into a single CGE model the behavior of as many households as it is found in an income and expenditure household survey⁵. Although appealing, this technique needs to reconcile household data with the national data, to secure full consistency between the micro-analysis and the CGE model prediction, and this is done at the cost of restructuring households' income or expenditures.

In the present paper, we rely on the second aforementioned layered CGE-microsimulation approach to study the effect of trade liberalization on the dynamic of poverty and we suggest our own approach. In a first layer, we build a recursively DCGE model, accounting for many of the structural features of the Tunisian economy, which description is provided in section 2. The DCGE provides the resulting price and income changes from any reform over the period 1998 – 2015, which in turn will be used to communicate with the second layer microsimulation model, in a way that will be developed in section 3. Finally, section 4 exposes the consequential impact on poverty of the projected reforms and section 5 concludes.

2. DCGE model general features

The DCGE we use is deeply inspired from the (MINI)-IMMPA framework, developed by Agénor (2003) and Agénor et al. (2003). The model is calibrated to data for 1998, the latest year for which definitive information was available at sectoral level. The Tunisian economy in the reference year is desegregated into 14 production sectors, one rural agriculture and 13 urban industries and services. Except for the urban government public services, the composite output of each of the remaining 12 urban sectors results at least from one of three types of firms: private, informal, and public. They are assumed to produce imperfect substitutes in local demand.⁶ The Tunisian national accounts data reveal indeed that the three types of firms do not co-exist in all sectors. Some sectors are only informal like construction, while others are only public like water and electricity. There are also sectors with both private and public or private and informal firms.

Since our focus in this study is about poverty and income distribution, the household sector is disaggregated in the reference year into six household groups, identified by their source of income: two rural and four urban.

Production structure

⁵ This approach has found application in Cogneau (1999), Cogneau and Robillard (2000), Cockburn (2001), Boccanfuso et al. (2003) and Rutherford et al. (2004).

⁶ The informal sector can be defined in various ways. In Tunisia, the official institute of statistics (see INS (1998)) consider as informal small sized non-agricultural firms with less than 6 employees.

Production functions in the model are of the nested form and exhibit constant returns to scale over private inputs. Gross output of all categories of firms is produced by combining in fixed proportions intermediates goods and primary factors composite. The primary factors composite is either Cobb-Douglas or CES aggregate of the various factors used in production. Indeed, we distinguish in the model four broad categories of factors: skilled and unskilled labor, land, and specific physical capital.

Land is specific to the production of agriculture. In addition, physical capital is specific to the firms to which it belongs, whereas skilled and unskilled labor are treated as predetermined policy variables in the government public services sector.

In addition to private inputs, it is assumed along the lines of Rioja (1999) and Kato (2002) that private and public firms as well as farmers use the economywide composite public stock of infrastructure and health, which is provided by the government, as a given external input. In this, we rely on Morrison and Schwartz (1996) and Kamps (2004) who give evidence that public capital is productive and payoffs in terms of increases in sectoral value-added and private investment. This assumption signifies that the total output of the latter firms is distributed entirely to the private inputs and the consideration of the return to the government from the public capital stock is ignored⁷.

All informal firms produce non tradable goods, as well as almost all public firms. Two exceptions for the latter categories of firms are represented by the transport and telecommunications services and mining and petroleum, since public firms are the only ones involved in export activity. The private formal firms are the main exporters in all the tradable sectors. Finally, exporting firms allocate their output to the local and international markets according to the constant elasticity of transformation aggregation.

Labor market segmentation

The model accounts for various sources of labor market segmentation. Unskilled workers are employed both in the rural agriculture and the urban economy. Skilled workers however are employed only in the urban formal economy.

There is no unemployment in the rural region, nominal wage indeed is flexible and adjusts to clear the rural unskilled labor market. The supply of labor in the rural area is predetermined at any point in time, but grows over time at the exogenous rural population growth rate net of workers migration to urban area. Following Harris and Todaro (1970), the incentive to migrate is taken to depend negatively on the ratio of the expected real wage in rural area to that prevailing in urban area.

Unskilled workers in the urban economy may be employed either in the informal, private, or public enterprises. In the formal activities, it is assumed along the lines of Kheo et al. (1995), that unions fix the uniform unskilled (skilled) labor real wage. The latter depends negatively on the unskilled (skilled) labor unemployment. It is also assumed that the wage rate of unskilled (skilled) labor is equal in the private and public enterprises, and it is greater than that paid in the informal sector. This gives an incentive to unskilled workers to seek a job in the private and public enterprises first.

The total supply of unskilled workers in the formal sector is allowed to adjust over time according to the expected wage differential between the informal and formal

⁷ In this we depart from the (MINI)-IMMPA framework, which considers the public capital as an internal input of production.

sectors. The total supply of unskilled workers in the informal labor market is instead determined residually and it always equals the induced demand for unskilled labor by all informal enterprises. The wage in the informal market is therefore uniform and flexible.

The supply of unskilled labor in the urban sector evolves as a result of (exogenous) natural urban population growth and migration of unskilled labor from the rural economy. Moreover, given the skilled and unskilled wage differential and the public capital stock of education per capita, some urban unskilled workers become skilled and leave the unskilled workforce to increase the supply of skilled labor.

Skilled workers who are unable to find a job in the formal economy opt to remain openly unemployed, instead of entering the informal economy, and the progress of the skilled labor force supply depends on the rate at which unskilled workers acquire skills.

The distribution of unskilled employment in the reference year reveals that the rural agriculture and the urban informal sector provide together 51.2 percent of unskilled labor employment, whereas each of the public and private sectors offers around 16 percent of unskilled jobs. As a consequence of this unskilled job distribution, 16.8 percent of the unskilled workforce is unemployed in the reference year.

Job provision for skilled workers in 1999 is such that the public sector is the main sector creating jobs for the more-educated workers, as it employs 82 percent of the skilled workforce in the base year.⁸ Government administration accounts for 91 percent of total public sector skilled labor employment, whilst public enterprises account for the remaining 9 percent. Compared to public sector, private sector absorbs only 8.7 percent of the skilled workforce.

Since the agriculture and informal sectors do not rely on skilled work in their production process, the remaining 8.6 percent of the skilled find themselves without a job.⁹ This figure shows that the public sector plays an important role in skilled labor policy for the economy as a whole. More details about the distribution of labor between the different sectors and firms could be found in Table 1.

Demand structure

Producers demand composite goods, imported and local, for intermediate use, according to a Leontief input-output technology; that is, the coefficients of intermediate goods in production are fixed. The model furthermore explicitly features the expenditures flows arising from government behavior and the activities of private investors.

It is assumed that both government expenditures, saving and transfers to households are in fixed proportion of its revenue. Government expenditures consist of current unproductive expenditures as well as productive public investment. It is also made in the model a distinction between the investments in infrastructure, education and health. In 1998, the public investment in infrastructure accounts for 1.7 percent of current

⁸ Although we use a 1998 SAM, we rely on information from the 1999 population census to allocate all the labor force between sectors and firms.

⁹ In reality, the agriculture and the informal sector employ very small shares of the skilled workforce, 0.1 percent in agriculture (see INS (2002b)) and 0.4 percent in the informal sector (see INS (1998)). Since the distribution of wages between skilled and unskilled was not available, we have considered that these two sectors are not relying on skilled work.

GDP, whereas public investments in health and education represent respectively 0.3 percent and 1 percent of GDP.

Table 1: Sectoral features of the Tunisian sectors in 1998 (in percentage)

Sector	Status	VA/GDP	uld/tot_uld	sld/tot_sld	USAL/tot_USAL	SSAL/tot_SSAL
Agriculture	Rural	14.6	24.7	0.0	3.5	0.0
	Public	0.5	0.9	0.3	1.0	0.3
Food processing	Private	1.4	1.2	0.3	1.3	0.3
	Informal	1.7	1.6	0.0	0.9	0.0
Quarrying products	Public	0.7	0.7	0.3	0.8	0.3
	Private	0.8	0.6	0.3	0.7	0.3
	Informal	0.4	0.5	0.0	0.3	0.0
Mechanical	Public	0.5	0.8	0.4	0.9	0.4
	Private	1.9	1.9	0.8	2.1	0.8
	Informal	0.4	0.2	0.0	0.1	0.0
Chemicals	Public	1.4	0.7	0.4	0.8	0.4
	Private	1.0	0.7	0.3	0.8	0.3
	Informal	0.1	0.1	0.0	0.0	0.0
Textile, apparel and leather	Public	0.0	0.0	0.0	0.0	0.0
	Private	6.6	6.5	1.5	6.9	1.5
	Informal	1.0	1.8	0.0	1.1	0.0
Miscellaneous manufacture	Public	0.2	0.2	0.1	0.3	0.1
	Private	1.2	1.0	0.5	1.2	0.5
	Informal	1.3	0.7	0.0	0.4	0.0
Mining and petroleum	Public	2.5	1.2	1.2	1.7	1.2
	Private	1.3	0.1	0.1	0.1	0.1
	Informal	0.0	0.0	0.0	0.0	0.0
Electricity	Public	1.8	0.6	1.2	1.1	1.2
	Private	0.0	0.0	0.0	0.0	0.0
	Informal	0.0	0.0	0.0	0.0	0.0
Water	Public	0.5	0.5	0.4	0.7	0.4
	Private	0.0	0.0	0.0	0.0	0.0
	Informal	0.0	0.0	0.0	0.0	0.0
Construction	Public	0.0	0.0	0.0	0.0	0.0
	Private	0.0	0.0	0.0	0.0	0.0
	Informal	5.3	16.9	0.0	9.9	0.0
Transport and telecom.	Public	6.7	5.8	3.9	7.1	3.9
	Private	1.2	0.9	0.6	1.1	0.6
	Informal	1.0	1.7	0.0	1.0	0.0
Other services	Public	0.0	0.0	0.0	0.0	0.0
	Private	8.9	6.4	5.0	8.2	5.0
	Informal	18.9	13.4	0.0	7.9	0.0
Public services	Public	15.9	7.6	82.3	38.2	82.3
Total		100.0	100.0	100.0	100.0	100.0

Notes: VA/GDP represents the contribution of each type of firm in each sector to GDP; uld/tot_uld is the share of each type of firm in each sector in total unskilled labor demand; sld/tot_sld is the share of each type of firm in each sector in total skilled labor demand; usal/tot_usal is the contribution of each type of firm in each sector to total unskilled labor wage bill; ssal/tot_ssar is the contribution of each type of firm in each sector to total skilled labor wage bill.

Each distinguished type of public investment allows the endogenous accumulation of the corresponding public capital stock. The accumulation process is modeled in a conventional way, where the next period stock of each public capital stock is equal to the amount invested in the current period plus the surviving stock. We further assume geometric depreciation that is, the capital stock depreciates at a constant rate.

The public stock in education affects positively the skills formation, whereas the public stock of infrastructure has, in one hand, a positive effect on private investment and, in the other hand, combines with the public stock of health to increase the total factor productivity in agriculture, public and private firms, as above explained.

Following, the World Bank (1996) estimations for Tunisia, an increase in public investment or government spending on education as a share of GDP by 1 percentage point would enhance the per capita GDP growth by 0.2 percent. Furthermore, a rise in the ratio of government consumption net of education spending to GDP by 1 percentage point would reduce the per capita GDP growth by 0.12 percent. Finally, an expansion of the share of exports in GDP by 1 percentage point would contribute to the augmentation of the per capita GDP by 0.06 percent. Adding the population growth rate to these estimates, we obtain an approximate of the impact of these changes on the total factor productivity. Thus, we have taken the latter estimates of the determinants of productivity explicitly into consideration in addition to the productive contribution of the public stock in infrastructure and health. It is assumed that they affect simultaneously the shift parameter in the production function of agriculture, public and private firms. It is also assumed that the contribution of the change in the ratios of infrastructure and health expenditures to GDP is equal to that of education spending.

The government revenue derives from the transferred returns on capital of public firms and from the collection of taxes on revenues, tariffs and consumption.

In the base year, 30 percent of the government fiscal revenue is driven from tariffs on imports and 34.2 percent from consumption taxes, whereas the contribution of households' income and corporate taxation to total fiscal revenue are respectively equal to 21.8 and 14.1 percent. This fiscal structure allows the government to reap 25 percent of the 1998 GDP.

The investment demand for the different composite goods by sector of origin are also assumed to be in fixed shares of total investment demand, which is equal to total saving. Capital accumulation is assumed to occur only in the urban private firms, according to the same conventional process as the public capital stock accumulation. The decision to invest hinges positively on the after tax rate of return to capital relative to cost of funds and on the public capital stock in infrastructure as well as the real GDP change.

As already mentioned, the model identifies six household types grouped by socio-economic status and labeled by h , $h=1,6$. The landholders in agriculture and the agricultural workers represent two distinct households living in the rural area. The remaining four urban households are the unskilled households working in the informal enterprises, the unskilled employees working both in the formal private and public sectors, the skilled households working in the formal private and public sectors and the capitalists. Classifying households groups in this way allows the model to identify the impact of economic reforms on income distribution and poverty. Household revenue is based on salaries and/or distributed profits, in addition to government and ROW

transfers. Table 2 sets out the characteristics of each group, including shares of population, per capita income, and poverty index.

Households' preferences are represented by Cobb-Douglas utility indices defined over saving and the 14 composite goods. Saving and demands are so a constant fraction of households' after tax revenue.

Each composite consumption good is then a sum of households groups, government and investors final consumption demands and all producers' intermediate composite goods demands. It is also assumed to be a CES aggregation of imported and composite domestic goods. The latter are deemed to be imperfect substitutes by the local demanders. Furthermore, it is assumed that the composite domestic good is a CES aggregation of informal, private and public domestic goods.

The above DCGE model, which formal description is given in annex, is designed in a way to capture the relevant structural features of the Tunisian economy, in order the price and income changes it generates embody both the effective direct and indirect effects of the policy reform and the attribution of these changes to the reform are unambiguous. In this way, any change of poverty obtained from the microsimulation model, which we describe in the subsequent section, will be as close as possible to what would be expected.

3. An Overview of the Microsimulation Approach

Incorporating directly into a DCGE model as many households as there are in a household survey would be certainly the ideal approach to address the question of the dynamics of poverty following any economic change. This is indeed the best way to keep all the information about the households' heterogeneity with regards to their pattern of endowment and consumption. Unfortunately, the Tunisian household expenditures survey is notable for its under-reporting of the source and level of each household member's income and its composition. The relevant information it records for our purpose is the households' expenditures for various items, the household's head level of education and occupation. The latter information is used to roughly decompose, not without making some assumptions, the available sample of 2500 households from the 1995 household survey into the closest six groups in the DCGE model.¹⁰ The aim is to proceed to a layered CGE-microsimulation analysis.

As pointed out by Ganuza et al. (2004), in the top-down methodology, microsimulations range from pure accounting approaches to models with behavioral equations based on econometric estimates. The seminal work by Bourguignon et al. (2003) falls in the latter category. The authors indeed estimate the microsimulation model which is based on a set of equations representing a detailed description of the real income generation mechanism at the household level. The estimated model captures the heterogeneity of households in terms of income sources, area of residence, endowment in human capital and consumption preferences.

¹⁰ The 1995 household survey is multipurpose and provides reliable information on consumption expenditures on many commodities and extensive socio-demographic information on about 10000 households. The survey does not include, however, information on incomes leading to the use of total household expenditure *per capita* for characterizing the dynamics of poverty.

Table 2: Characteristics of household groups

Household type	Population Share (%)	Poverty Index ^a (%)	Per capita income (TND)
HH_Land: Landholders	13.7	10.6	670
HH_AGR: Agriculture laborer	9.9	19.7	498
HH_INF: Unskilled households in the informal sector	29.3	4.1	747
HH_ULF: Unskilled households in the formal (private and public) sector	33.8	4.8	764
HH_SLF: Skilled households in the formal (private and public) sector	9.9	0	1937
HH_CAP: Capitalists in the private and informal sectors	3.4	0	2957

^a Percentage of households in the group below the poverty line, based on 1995 household survey and lower poverty line (The world-bank (1999)).

The accounting approach however, consists in simply calculating a welfare indicator (change) at the household level using the transmitted commodity and factor prices (change) from the CGE model. For example, knowing the source of income of each household, Ganuza et al. (2004) calculate the nominal income level resulting from the new set of factor prices and then infer the poverty level. In doing this, they place strong emphasis on the earning-side effects, as a channel for transmission to poverty, over consumption side effects of any reform. Chen and Ravallion (2004) as well as Hertel et al. (2004) however, focus both on the contribution of the labor and commodity markets to the poverty change and calculate a linear first-order approximation to the welfare change in a neighborhood of the household's optimum. In these two studies, there is no need to specify a utility function, yet the methodology is only robust for small (or marginal) changes in prices.

Whilst enabling non marginal changes of prices, the alternative approach we suggest in this paper requires, nevertheless, to explicitly specifying a utility function.¹¹ Our approach works as follows. In a first step, the DCGE model provides an estimation of the consumption goods prices, $\mathbf{p}_t$, resulting from the economic environment change. For each household group, it yields too the growth rate in its average nominal income, g_t^h .¹² We then apply, in a second step, these results to assess the real income of each household in the sample. Since households within the same group h do not have the same budgetary share for each good, the real income resulting from a policy change varies from one household to another even within the same group.

¹¹ This is not a major limit whenever the goods consumed by households are, to a large extent, additively separable; so that utility functions like the Cobb Douglas or Stone Geary characterizes well the households' preferences.

¹² The assumption of a common nominal income shift for all households within the same representative group represents a limitation of this approach. It can be easily relaxed if we have more information about the different sources of income for each household.

More precisely, we assume that each household m within a group h has an original income per capita $Y_0^{h,m}$ and faces the price system $\mathbf{p}_0$ in the baseline year. From one year to the other, each household in the sample faces a new vector of prices and income $(\mathbf{p}_t, Y_t^{h,m})$. Since we aim to compare the levels of an individual's welfare over time, we consider the baseline price vector $(\mathbf{p}_0)$ as the reference price system.¹³ Then, we define as King (1983) the concept of *equivalent income*: for a given budget constraint $(\mathbf{p}_t, Y_t)$, the equivalent income is defined as that income level which allows, at $\mathbf{p}_0$, the same utility level as can be reached under the given budget constraint. Formally, we have:

$$v(\mathbf{p}_0, Y_e(\mathbf{p}_0, \mathbf{p}_t, Y_t)) = v(\mathbf{p}_t, Y_t) \quad (1)$$

where $v(\cdot)$ is the indirect utility function, $\mathbf{p}_t$ is a vector of price system at t , and Y_t is the per capita household's nominal income. Notice that since $\mathbf{p}_0$ is fixed across all households, $Y_e(\cdot)$ is an exact monetary metric of actual utility $v(\mathbf{p}_t, Y_t)$ because $Y_e(\cdot)$ is an increasing monotonic transformation of $v(\cdot)$. Thus, inverting the indirect utility function, we obtain the *equivalent income*, $Y_e(\mathbf{p}_0, \mathbf{p}_t, Y_t)$.

We take the predicted price and income changes from the DCGE model as given for the analysis of welfare impacts at the household level. Since we assume that the growth rate within each household group is the same for all households belonging to the same group and equal to g_t^h , we have:

$$Y_t^{h,m} = (1 + g_t^h) Y_0^{h,m} \quad (2)$$

By (2), and assuming a Cobb-Douglas utility function, we can compute the indirect utility function, $v(\cdot)$ for each household in the sample using this formula:

$$v(\mathbf{p}_t, Y_t^{h,m}) = \frac{1}{(1 + g_t^h) Y_0^{h,m}} \prod_{i=1}^I (p_{i,t})^{w_i^{h,m}} \quad (3)$$

where $p_{i,t}$ is the price of good i at the period t and $w_i^{h,m}$ is the budget share devoted to the good i by the household m within the group h . Using (1) and (3), the equivalent income of each household in the sample at each period t is then given by:

$$Y_e(\mathbf{p}_0, \mathbf{p}_t, Y_t^{h,m}) = \prod_{i=1}^I \left(\frac{p_{i,0}}{p_{i,t}} \right)^{w_i^{h,m}} (1 + g_t^h) Y_0^{h,m} \quad (4)$$

Further to information about the distribution of equivalent income among households, it is worthy to assess the social impact of the change. A natural measure could be given by the variation of a pre-specified poverty yardstick. An important class of poverty measures is the FGT class of additively decomposable indices suggested by Foster et al. (1984), which can be written in terms of equivalent income as:¹⁴

$$\begin{aligned} P_a^t(z_0, y_e^t) &= \frac{1}{N} \sum_{m=1}^M n^{h,m} \left(1 - \frac{Y_e(\mathbf{p}_0, \mathbf{p}_t, (1 + g_t^h) Y_0^{h,m})}{z_0} \right)_+^a \\ &= \frac{1}{N} \sum_{m=1}^M n^{h,m} \left(1 - y_e(\mathbf{p}_0, \mathbf{p}_t, (1 + g_t^h) Y_0^{h,m}) \right)_+^a \end{aligned} \quad (5)$$

¹³ Following King (1983), the choice of the reference price system is to some extent arbitrary, although for the analysis based on computable general equilibrium models, the baseline price vector, $\mathbf{p}_0$, is a natural choice. The reason for this is that any comparison must use a common reference price system.

¹⁴ Writing poverty measures in terms of equivalent income make them sensitive to both income and prices variations.

where N is the population size, M is the number of households, $n^{h,m}$ is the household size, z^0 is the poverty line at the baseline year and which is fixed in real terms over time,¹⁵ and a may be considered as a measure of poverty aversion: a larger a gives greater emphasis to the poorest of the poor. The incidence of poverty or the headcount ratio (the proportion of the population living with less than the poverty line) is obtained for $a = 0$. When $a = 1$, the resulting index yields the average poverty gap (or the deficit of poverty); and when $a > 1$ poverty measures additionally take account of distribution among the poor. When a becomes very large, $P_a(\cdot)$ approaches a Rawlsian measure, which considers only the poorest individuals' welfare.

4. Simulation results

We consider four alternative scenarios. The first one, labeled *ref*, illustrates the Tunisian economy path of growth between 1998 and 2015, in the absence of any technical progress or trade reform. The dynamics of the economy is the fact of rural and urban labor force growth and both private and public capital accumulation.¹⁶

This first simulation provides a benchmark against which to judge the contribution of trade reform and public spending structuring to poverty alleviation in the remaining alternative scenarios. In this regard, we simulate in the second and third scenarios, labeled respectively *opn* and *tpf*, an annual 10 percent decrease of all tariffs on non agricultural imports during the first decade, compensated by an annual 9 percent increase of all consumption taxes until 2008, the year of the complete achievement of the agreement with the EU.¹⁷ From the latter date, consumption taxes become fixed to the level they have reached. This trade reform is not sustained by total factor productivity change in *opn*, in order to isolate the contribution of openness to poverty alleviation, while there is an additional technical progress in *tpf*.

In all previous scenarios, subsidies on agricultural goods and food processing have been maintained unchanged. In the fourth scenario, we thus eliminate progressively and uniformly the subsidies on these goods over the transition period 1998 – 2015. Each year, the saved amount of subsidies is allocated to increase both investments in education, health and infrastructure according to the share of each one in total public investment. This simulation is labeled *edu* and it aims to check whether investment in infrastructure and human capital is a better tool to combat better and more poverty than food subsidies.

The Figure 1 displays the incidence of poverty trend in the reference scenario (referred to as *P0_ref*), the trade reform scenario (referred to as *P0_opn*), the trade reform with total productivity progress scenario (referred to as *P0_tpf*), and in the final scenario

¹⁵ Note that $Y_e(\mathbf{p}_0, \mathbf{p}, z_t) = Y_e(\mathbf{p}_0, \mathbf{p}_0, z_0) = z_0$. z_0 appears as the equivalent poverty line, i.e. the minimum expenditure level required at $\mathbf{p}_0$ to reach the indifference curve corresponding to the minimum standard of living one. Fixing the poverty line in real terms over time underlines an absolute approach to poverty analysis. The relative poverty, which is beyond the scope of this paper, is based on the setting of a real poverty line which rises with the average income.

¹⁶ For the active labor natural population growth, we have used the trend projected in the INS (1996b) for the period of interest, assuming in addition it is the same for rural and urban unskilled labor. As to the skilled labor growth, it is endogenously determined by the model, starting with an average of 2.5 percent between 1997 and 1998, as it is suggested in the World-Bank (2004a).

¹⁷ The growth rate in all consumption taxes until 2008 is calibrated so as to maintain approximately constant the government fiscal revenue as a share of GDP.

when the saving from food subsidies removal are used to enhance investment in education, health and infrastructure (referred to as P0_edu). The left-hand side of this figure displays the headcount ratio trend under these different scenarios. Interestingly enough, trade liberalisation and food subsidy removal appear to be not pro-poor in the short run but really pro-poor in the long run. Indeed, the left-hand side of Figure 1 shows that until 2005 (and even until 2008, the year of the complete achievement of tariffs dismantlement), the simulated reforms and mainly the one where subsidies are removed would push up the downward trend of poverty. Yet, from 2008 onwards, the substitution of public investment to food subsidies would contribute most to the achievement of the Millennium Development Goal of halving poverty, as measured by the headcount ratio, by 2015. Indeed, while more than 5 percent of the population are in extreme poverty in 1998, by 2015 less than 2 percent of the population would remain in extreme poverty under the last scenario.

The headcount ratio could fail to accurately capture the impact of any change on poverty, indeed it only records those who escape or reach the segment of the poor. Thus, it could under-estimate the effectiveness of the other reforms, since most poor people could find their welfare improved but not enough to lift poverty. To curb this likely drawback, the right-hand side of Figure 1 displays the estimates of the poverty deficit, $P_1(\cdot)$, during the period under consideration resulting from the different changes. These curves show similar decreasing trend as the poverty incidence, meaning that the average income of those staying below the poverty line has increased. Further, from 2008 to 2015, the poverty deficit curve resulting from the elimination of subsidies will lie always below the others.

The above analysis could depend critically on the choice of the poverty line and poverty measures. Since both of these choices are somewhat arbitrary, so could be the dynamics of poverty characterised using the m. Drawing on the recent study of Ravallion and Chen (2003), it is fortunately possible to curb such degrees of arbitrariness by computing first the growth rate in the mean of each income quantile:

$$g(q) = \frac{y_e^t(q)}{y_e^{t-1}(q)} - 1 \quad (6)$$

where $g(q)$ is the growth rate in the King's (1983) equivalent income of the q th quantile between t and $t-1$ and $y_e^t(q)$ is the mean of $y_e(\mathbf{p}_0, \mathbf{p}_t, y_t)$ within the quantile q at the pertinent period.¹⁸ Considering the full range of possible q , $g(q)$ traces out the *growth incidence curve* (henceforth *GIC curve*), showing how the growth rate is distributed across different quantiles, ranked by equivalent income.

Figure 2 splits the period of transition in two: one going from 1998 to 2000 and the other from 2000 to 2015. For each period, we give the average income rate of growth of the 25 percent least endowed individuals and the remaining segments of the society, under the different reforms. The top left and right sides of Figure 2 show that the *GIC curves* lie nowhere below 0, meaning that poverty will certainly fall within the period under consideration, regardless of the chosen poverty line and the poverty measure. In the stochastic dominance literature, this finding is known as “first-order dominance” (FOD).¹⁹

¹⁸ Alternatively, $y_e(q)$ could be expressed as $y_e(\mathbf{p}_0, \mathbf{p}_t, y_t(q))$.

¹⁹ See, among many others, Atkinson (1987) for a detailed description on the stochastic dominance tests.

The same graphs show that in the first period, the income growth pattern of the poorest is the lowest under food subsidies removal reform (referred to as g_{2000_edu}), while it becomes the highest within the same scenario in the second period, once the indirect effect of investment in infrastructure and human capital begins to bear fruit to the poor.

The right-hand side of Figure 2 also shows that from 2000 to 2015, the trade reform improves the equivalent income of all the individuals. However, the total productivity progress (referred to as g_{2015_tpf}) considered in addition to openness reform (referred to as g_{2015_opn}) adds roughly nothing to the gains achieved through better allocation of scarce resources, since the two *GIC curves* are very close. As to the reform of subsidies program (referred to as g_{2015_edu}), it even boosts the gains obtained from trade liberalization.

Finally, all the *GIC curves* displayed in Figure 2 do not switch sign. Then there is no need to test higher order dominance to study less robustly the dynamics of poverty.²⁰ Testing solely FOD conditions is not yet really informative about the distributional pattern of economic growth. For instance, the *GIC curves* displayed in the left-hand side of Figure 2 are approximately horizontal. This means that the Lorenz curve does not really shift at the beginning period under consideration, and the economic growth is to some extent, distribution-neutral. Nevertheless, the right-hand side of Figure 2 shows that $g(q)$ exhibits an upward sloping across different income quantiles. Thus, while curbing absolute poverty, this growth pattern will worsen all inequality measures, and then relative poverty, since the richest quantiles profit more from economic growth than the poorest ones.

²⁰ On the higher dominance tests about the link between economic growth and poverty, see for instance Son (2004) and Bibi (2005).

Figure 1: Poverty trend over 1998 – 2015

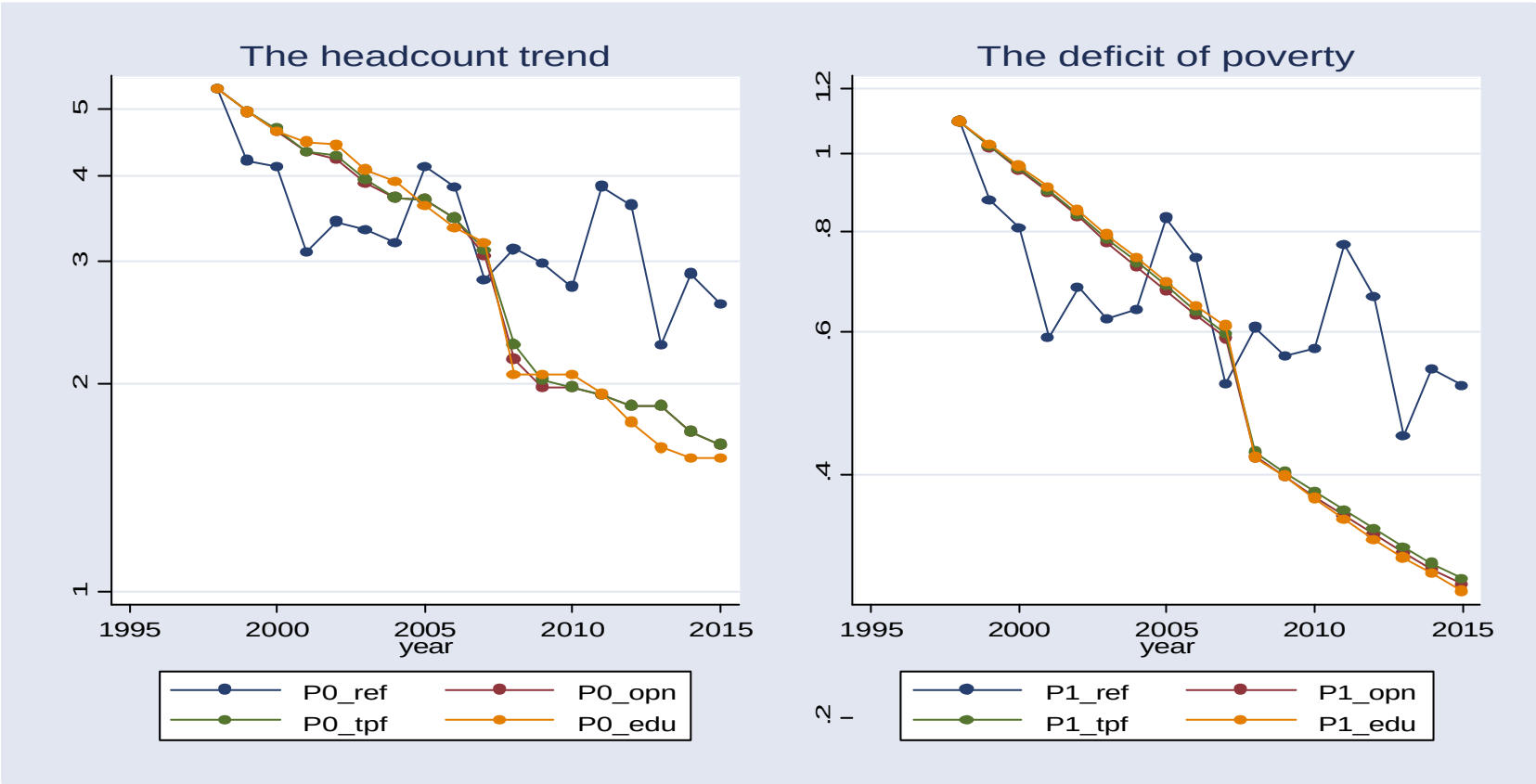
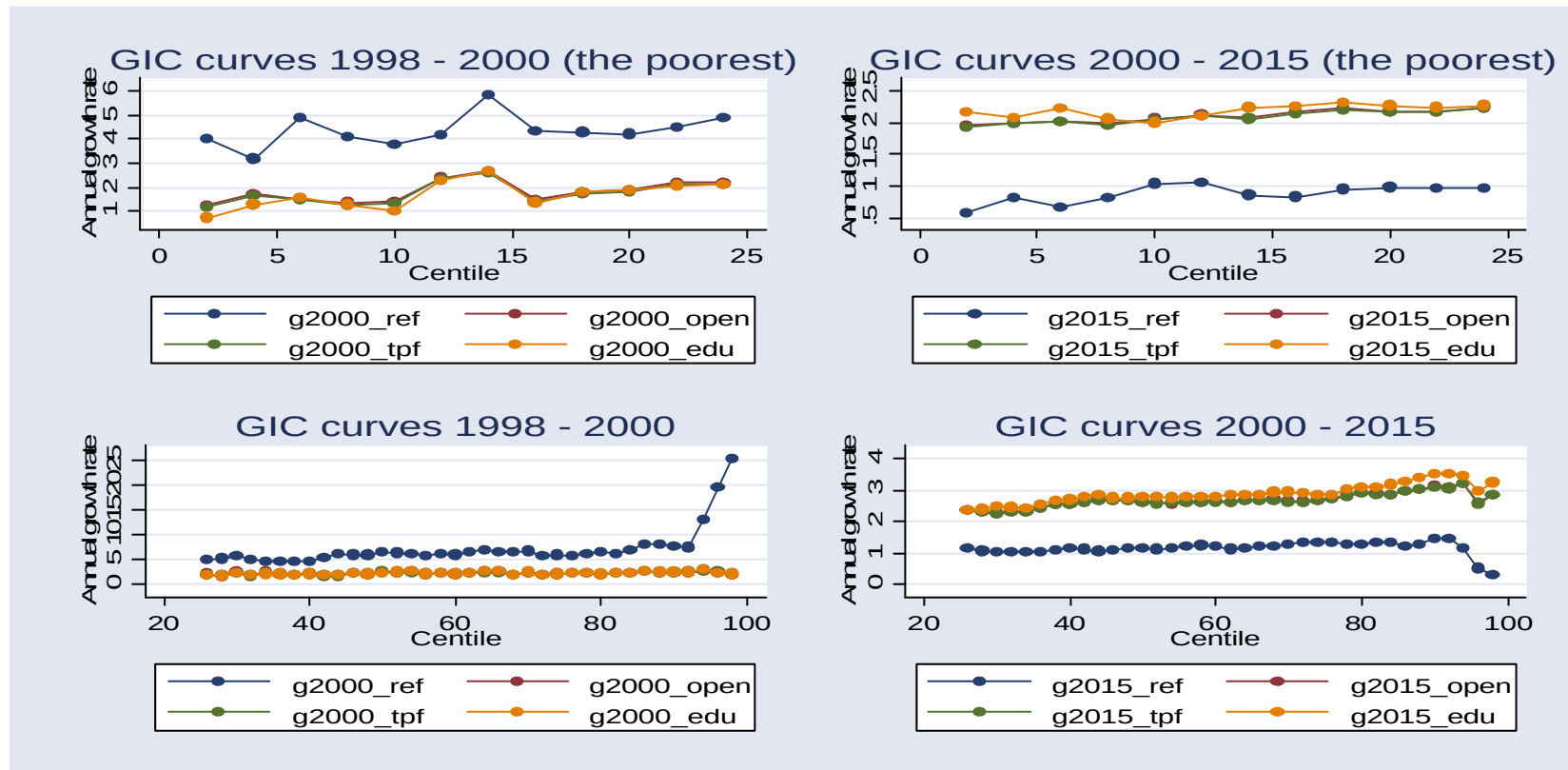


Figure 2: GIC Curves under different scenarios



5. Conclusion

In this paper, a DCGE model is used to assess the impact of trade liberalization on poverty in Tunisia. To achieve this goal, it was common in the literature to classify foremost households according to some socio-economic grouping. Then, a distribution function (usually a log-normal distribution) for each household group is constructed in order to describe the variation of income distribution and poverty following a policy change. The main drawback of such approach is that the intra-group variances are specified exogenously. Therefore, this type of models will not capture the within-group variation of inequality (following a policy change) which represents generally a large share of the overall change of inequality. This would provide a biased estimation of poverty change, essentially when the poverty indices used are sensitive to the distribution of the well-being within the poor. The alternative route is to include all households from a survey directly into the CGE model. However, the lack of the relevant information on the (source of) revenue in the Tunisian household survey impedes us to proceed to an integrated microsimulation. We instead limit ourselves to layered microsimulation, which captures a (good) fraction of the within-group variation of inequality, in addition to the between-group variation of inequality.

In this regard, we infer the prices change and the variation rate of each household income group provided by the DCGE simulation change into the households of the survey, previously classified by groups, to assess the equivalent income of each one. Since households do not have the same budgetary share for each good, the equivalent gain (or loss) varies from a household to another even within the same group. This enables a better characterization of poverty change within each group and has several policy implications in terms of the choice of groups that should benefit from an anti-poverty program and the cost of such program.

The empirical illustration of this methodology computes the likely effects of trade liberalization and more public investment on infrastructure and human capital financed by food subsidy removal. The main results are outstanding, showing that such changes could slowdown the poverty reduction in the short run, but enhance it in the long run.

The present study is mainly illustrative. The analysis of the effects of trade liberalization on income distribution and poverty requires more detailed information. For instance, earnings and occupational choice of households' head should be modeled as a function of their specific characteristics. Thus, whenever there is a change in the aggregate demand for wage labor, which workers move from the formal to the informal sector (and reciprocally) depends on their specific characteristics. Such a shift can be at the root of a significant change in income distribution and poverty. Capturing these effects requires, nevertheless, that our methodology should be supplemented by an econometric model which characterizes the households' labor market responses to external shocks. Although such characterization is needed to improve the predictive power of any layered microsimulation framework, it is precluded by data availability for the present study. However, the outcome of this analysis highlights the potential return from a more refined research that could provide guidelines for policymakers on the optimal level of any change as well as its expected effects.

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Appendix: Model Equations

$i,j=A(\text{agriculture}), 2-14$; $k = R(\text{rural}), I(\text{informal}), P(\text{private}), G(\text{public})$; $f = I, P, G$; $gk = INF(\text{infrastructure}), EDU(\text{education}), HEL(\text{health})$; $H = H1-H6$

$$\text{Intermediate goods demand} \quad iQ_{jk}X_{jk} = CI_{ijk} \quad (A1)$$

$$\text{Total intermediate goods cost} \quad TIC_{ik} = \sum_j iQ_{jik} PQ_j X_{ik} \quad (A2)$$

$$\text{Total costs} \quad TC_{ik} = PFC_{ik} + TIC_{ik} \quad (A3)$$

$$\text{Price cost margin} \quad PX_{ik} X_{ik} = TC_{ik} \quad (A4)$$

$$\text{Unskilled labor demand in agriculture} \quad ULD_{AR} = \frac{X_{AR}}{AT_{AR}} \left(\frac{a_{X_{AR}} PL}{(1 - a_{X_{AR}}) WR} \right)^{1-a_{X_{AR}}} \quad (A5)$$

$$\text{Land demand in agriculture} \quad LAND_{AR} = \frac{X_{AR}}{AT_{AR}} \left(\frac{(1 - a_{X_{AR}}) WR}{a_{X_{AR}} PL} \right)^{a_{X_{AR}}} \quad (A6)$$

$$\text{Primary factors cost in agriculture} \quad PFC_{AR} = WR ULD_{AR} + PL LAND_{AR} \quad (A7)$$

$$\text{Land market equilibrium condition} \quad \overline{LAND}^S = \sum_A \sum_R LAND_{AR} \quad (A8)$$

$$\text{Rural labor market equilibrium condition} \quad RUR_ULS = \sum_A \sum_R ULD_{AR} \quad (A9)$$

$$\text{Unskilled labor demand by informal urban firms} \quad ULD_{il} = \frac{X_{il}}{AT_{il}} \left(\frac{a_{X_{il}} R_{il}}{(1 - a_{X_{il}}) WI} \right)^{1-a_{X_{il}}} \quad (A10)$$

$$\text{Specific capital demand by informal urban firms} \quad \overline{KD}_{il} = \frac{X_{il}}{AT_{il}} \left(\frac{(1 - a_{X_{il}}) WI}{a_{X_{il}} R_{il}} \right)^{a_{X_{il}}} \quad (A11)$$

$$\text{Primary factors cost of informal urban firms} \quad PFC_{il} = WI ULD_{il} + R_{il} \overline{KD}_{il} \quad (A12)$$

$$\text{Unskilled labor demand by SOEs} \quad ULD_{iG} = \frac{X_{iG}}{AT_{iG}} \frac{\left(\frac{a_{X_{iG}} R_{iG}}{(1 - a_{X_{iG}} - b_{X_{iG}}) WM} \right)^{1-a_{X_{iG}}}}{\left(\frac{b_{X_{iG}} R_{iG}}{(1 - a_{X_{iG}} - b_{X_{iG}}) WS} \right)^{b_{X_{iG}}}} \quad (A13)$$

$$\text{Skilled labor demand by SOEs} \quad SLD_{iG} = \frac{X_{iG}}{AT_{iG}} \frac{\left(\frac{b_{X_{iG}} R_{iG}}{(1 - a_{X_{iG}} - b_{X_{iG}}) WS} \right)^{1-b_{X_{iG}}}}{\left(\frac{a_{X_{iG}} R_{iG}}{(1 - a_{X_{iG}} - b_{X_{iG}}) WM} \right)^{a_{X_{iG}}}} \quad (A14)$$

$$\text{Specific capital demand by SOEs} \quad \overline{KD}_{iG} = \frac{X_{iG}}{AT_{iG}} \frac{\left(\frac{a_{X_{iG}} R_{iG}}{(1 - a_{X_{iG}} - b_{X_{iG}}) WM} \right)^{-a_{X_{iG}}}}{\left(\frac{b_{X_{iG}} R_{iG}}{(1 - a_{X_{iG}} - b_{X_{iG}}) WS} \right)^{b_{X_{iG}}}} \quad (A15)$$

Primary factors cost of SOEs	$PFC_{iG} = WM ULD_{iG} + WS SLD_{iG} + R_{iG} \overline{KD}_{iG}$	(A16)
Primary factors cost of Central Government	$PFC_{GOV} = WM \overline{ULD}_{GOV} + WS \overline{SLD}_{GOV}$	(A17)
Unskilled labor demand by formal private firms	$ULD_{iP} = \left(\frac{X_{iP}}{AT_{iP}} \right)^{1-\Omega_{X_{iP}}} \left(\frac{a_{iP} PFC_{iP}}{WM} \right)^{\Omega_{X_{iP}}}$	(A18)
Capital and skilled labor composite demand by formal private firms	$SK_{iP} = \left(\frac{X_{iP}}{AT_{iP}} \right)^{1-\Omega_{X_{iP}}} \left(\frac{(1-a_{iP}) PFC_{iP}}{PSK_{iP}} \right)^{\Omega_{X_{iP}}}$	(A19)
Primary factors cost of formal private firms	$PFC_{iP} = WM ULD_{iP} + PSK_{iP} SK_{iP}$	(A20)
Skilled labor demand by formal private firms	$SLD_{iP} = SK_{iP} \left(\frac{AK_{iP}(1-g_{iP})PSK_{iP}}{WS} \right)^{\Psi_{X_{iP}}}$	(A21)
Specific capital demand by formal private firms	$KD_{iP} = SK_{iP} \left(\frac{AK_{iP}g_{iP}PSK_{iP}}{R_{iP}} \right)^{\Psi_{X_{iP}}}$	(A22)
Capital and skilled labor composite price	$PSK_{iP}SK_{iP} = WS SLD_{iP} + R_{iP} KD_{iP}$	(A23)
Informal labor market equilibrium condition	$ILS = \sum_i ULD_{iI}$	(A24)
Urban unskilled labor unemployment	$U_Unemp = \frac{FSUF - \sum_i (ULD_{iP} + ULD_{iG})}{FSUF}$	(A25)
Urban total labor population	$URB_ULS = ILS + FSUF$	(A26)
Union unskilled labor wage determination	$\frac{WM}{CPI_{H4}} = A_{UNEMP} \left(\frac{1 - U_Unemp}{1 - U_Unemp_0} \right)^{\frac{1}{s_{U_Unemp}}}$	(A27)
Skilled labor unemployment	$S_Unemp = \frac{URB_SLS - \sum_i (SLD_{iG} + SLD_{iP})}{URB_SLS}$	(A28)
Union skilled labor wage determination	$\frac{WS}{CPI_{H5}} = A_{S_UNEMP} \left(\frac{1 - S_Unemp}{1 - S_Unemp_0} \right)^{\frac{1}{s_{S_Unemp}}}$	(A29)
Imports demand	$XM_i = Q_i \left(\frac{AM_i a_{M_i} PQ_i}{PM_i} \right)^{\Phi_{M_i}}$	(A30)
Composite local good demand	$XD_i = Q_i \left(\frac{AM_i (1-a_{M_i}) PQ_i}{PD_i} \right)^{\Phi_{M_i}}$	(A31)
Armington composite good price	$PQ_i Q_i = PD_i XD_i + PM_i XM_i$	(A32)
Import price	$PM_i = ER(1+tm_i)(1+tc_i - sc_i) \overline{WPM}_i$	(A33)
Local demand of informal, private and SOEs goods	$XDF_{if} = \frac{XD_i}{AD_i} \left(\frac{a_{D_{if}} AD_i PD_i}{PDFD_{if}} \right)^{\Phi_{D_i}}$	(A34)
Local composite good unit price	$PD_i XD_i = \sum_f XDF_{if} PDFD_{if}$	(A35)
Export supply	$XE_{ik} = \frac{X_{ik}}{AE_{ik}} \left(\frac{PE_{ik}}{AE_{ik} a_{E_{ik}} PX_{ik}} \right)^{\Phi_{E_{ik}}}$	(A36)
Local supply by local firm type	$XDF_{ik} = \frac{X_{ik}}{AE_{ik}} \left(\frac{PDF_{ik}}{AE_{ik} (1-a_{E_{ik}}) PX_{ik}} \right)^{\Phi_{E_{ik}}}$	(A37)
Gross production unit price	$PX_{ik} X_{ik} = PDF_{ik} XDF_{ik} + PE_{ik} XE_{ik}$	(A38)

Export price	$PE_{ik} = \overline{WPE}_{ik} ER$	(A39)
	$PDFD_{ik} = (1 + tc_i - sc_i) PDF_{ik}$	(A40)
Operating surplus in rural activities	$PROF_R = \sum_A PL_{LAND_{AR}}$	(A41)
Operating surplus of urban firms	$PROF_f = \sum_i R_{if} KD_{if}$	(A42)
Non-distributed profit	$NPROF_k = PROF_k (1 - ct\alpha_k) - ER u_k BOP$	(A43)
Firms saving	$SAVF_k = sf_k NPROF_k$	(A44)
Households' non labor revenue	$NLYH_h = \sum_k r_{hk} (1 - sf_k) NPROF_k + e_h GTH + c_h ER \overline{ROWTH}$	(A45)
Landholders group revenue	$YH_{h1} = NLYH_{h1}$	(A46)
Agricultural workers group revenue	$YH_{h2} = NLYH_{h2} + WR ULD_{AR}$	(A47)
Urban informal household group revenue	$YH_{h3} = NLYH_{h3} + WM \sum_i ULD_{il}$	(A48)
Formal unskilled workers group revenue	$YH_{h4} = NLYH_{h4} + WM \sum_i (ULD_{ip} + ULD_{ig})$	(A49)
Formal skilled workers group revenue	$YH_{h5} = NLYH_{h5} + WS \sum_i (SLD_{ip} + SLD_{ig})$	(A50)
Urban capitalists group	$YH_{h6} = NLYH_{h6}$	(A51)
Household group disposable revenue	$YD_h = (1 - rt\alpha_h) YH_h$	(A52)
Household group saving	$SAVH_h = sh_h YD_h$	(A53)
Total consumption expenditures	$HTC_h = (1 - sh_h) YD_h$	(A54)
Final consumption demand	$XAC_{ih} = con_{ih} \frac{HTC_h}{PQ_i}$	(A55)
Fiscal revenue	$TXREV = \sum_i tm_i ER \overline{WPM}_i XM_i + \sum_i \sum_k tx_{ik} PX_{ik} X_{ik} + \sum_h rt\alpha_h YH_h + \sum_k ct\alpha_k PROF_k - \sum_i (sc_i + sc_i tm_i) \overline{WPM}_i XM_i - \sum_i \sum_{sr} sc_i PDF_{i,sr} XDF_{i,sr}$	(A56)
Government revenue	$YG = TXREV + \sum_i R_{ig} \overline{KD}_{ig}$	(A57)
Government transfers to households	$GTH = j YG$	(A58)
Government total expenditures	$CTG = h YG$	(A59)
Public investment	$IPub_{gk} = IPubshr_{gk} CTG$	(A60)
Government current expenditures	$GC = \left(1 - \sum_{gk} IPubshr_{gk} \right) CTG$	(A61)
Government saving	$SAVG = (1 - j - h) YG - n ER BOP$	(A62)
Government consumption	$XAG_i = agov_i \frac{CTG}{PQ_i}$	(A63)
Investment demand by sector of origin	$XAI_i = ainvi_i \frac{PK ZI}{PQ_i}$	(A64)
Domestic absorption	$Q_i = \sum_h XAC_{ih} + \sum_k \sum_j CI_{ijk} + XAG_i + XAI_i$	(A65)
Equality of total saving and investment	$PK ZI = \sum_H SAVH_H + \sum_k SAVF_k + SAVG + ER BOP$	(A66)

Investment profitability	$RK_{iP} = \frac{R_{iP}}{PK}$	(A67)
Investment demand	$\frac{IND_{iPT}}{KD_{iP(T-1)}} = AI_{UPT} \left[\frac{KPub_{INF(T-1)}}{KPub_{INF(T-1)}} \right]^{s_{KI}} \left[\frac{GDP_T}{GDP_{(T-1)}} \right]^{s_{GDP}} [(1 + RK_{iPT})(1 - rt_{x_{Ht}})$	(A68)
Total investment	$ZI = \sum_i IND_{iP}$	(A69)
Capital accumulation	$KD_{iPT} = (1 - d_{iP})KD_{iP(T-1)} + IND_{iP(T-1)}$	(A70)
Value-added	$VA_{i,k} = \alpha x_{i,k} X_{i,k}$	(A71)
Value-added price	$PVA_{i,k} VA_{i,k} = PX_{i,k} X_{i,k} - \sum_j PQ_j CI_{j,i,k}$	(A72)
Real GDP	$GDP = \sum_i \sum_k PVA_{i,k} VA_{i,k}$	(A73)
Real GDP growth	$GDP_T = (1 + g_{GDP})GDP_{(T-1)}$	(A74)
Rural population growth	$RUR_ULS_T = (1 + \bar{g}_{RUR})RUR_ULS_{(T-1)} - MIG_T$	(A75)
Migration	$MIG_T = A_{MIG}RUR_ULS_{(T-1)} \left(\frac{WUE}{WRE} \right)^{s_{MIG}}$	(A76)
Expected urban wage	$WUE = \frac{q \cdot WM_{(T-1)} + (1-q)WI_{(T-1)}}{CPI_{H4(T-1)}}$	(A77)
Expected rural wage	$WRE = \frac{WR_{(T-1)}}{CPI_{H2(T-1)}}$	(A78)
Weight in the expected urban wage	$q = \frac{\sum_i ULD_{iP(T-1)}}{URB_ULS_{(T-1)} - \sum_i ULD_{iG(T-1)}}$	(A79)
Consumer price index	$CPI_H = \sum_i acon_{iH} PQ_i$	(A80)
Urban unskilled labor growth	$URB_ULS_T = (1 + \bar{g}_U)URB_ULS_{(T-1)} + MIG_T - SKL_T$	(A81)
Formal labor population growth	$\frac{FSUF_T}{FSUF_{(T-1)}} = B_{FSUF} \frac{\sum_i ULD_{iP(T-1)}}{FSUF_{(T-1)} - \sum_i ULD_{iG(T-1)}} \left(\frac{WM_{(T-1)}}{WI_{(T-1)}} \right)^{s_{FSUSF}}$	(A82)
Skilled labor population growth	$URB_SLS_T = URB_SLS_{(T-1)} + SKL_T$	(A83)
Skill Formation	$SKL_T = l_{SKL}URB_SLS_{(T-1)} \left(\frac{WSE}{WUE} \right)^{s_W} \left(\frac{KPub_{EDU(T-1)}}{URB_SLS_{(T-1)}} \right)^{s_{KE}} + (1 - l_{SKL})SKL_{(T-1)}$	(A84)
Expected skilled labor wage	$WSE = \frac{WS_{(T-1)}}{CPI_{H5(T-1)}}$	(A85)
Public capital accumulation	$KPub_{GKT} = (1 - d_{GK})KPub_{GK(T-1)} + IPub_{GK(T-1)}$	(A86)
Composite of Public capital stocks	$KGT = \left[v KPub_{INF}^r + (1 - v) KPub_{HEL}^r \right]^{\frac{1}{r}}$	(A87)
Public capital externality	$AT_{ik} = AT_{ik0} KGT^z$	(A88)
Balance of payment deficit	$walras = \sum_i \overline{WPM}_i XM_i - (1 - u - u_k)BOP - \overline{ROWTH} - \sum_i \sum_k \overline{WPE}_{ik} XE_{ik}$	(A89)
Numéraire	$\overline{PINDEX} = PQ_A$	(A90)

List of endogenous variables

CI_{ijk}	Intermediate consumption of good i by firm k in sector j
X_{ik}, PX_{ik}	Quantity and price of composite output
$TIC_{ik}, PFC_{ik}, TC_{ik}$	Total intermediate goods, primary factors and total costs
ULD_{ik}, SLD_{ik}	Unskilled and skilled labor demands
VA_{ik}, PVA_{ik}	Value added quantity and price
WR, WI, WM, WS	Rural, informal, formal unskilled and skilled wages
WRE, WUE, WSE	Expected rural, urban unskilled and skilled wages
$RUR_ULS, URB_ULS, URB_SLS$	Rural, urban unskilled and urban skilled labor supply
$FSUF, ILS$	Formal and informal unskilled labor supply
U_Unemp, S_Unemp	Unskilled and skilled labor unemployment
MIG, SKL	Migration and skill formation
$?$	Weight in the migration function
$KPub_{gk}, IPub_{gk}$	Public capital stock and investment in infrastructure, education or health
SK_p, PSK_{ip}	Composite of skilled and capital level and price
KD_{ik}, R_{ik}	Capital demand and price; demand is fixed for informal and public firms
$Land_{AR}, PL$	Land demand and price
XM_i, PM_i	Import level and price
XD_i, PD_i	Composite local good demand and price
$XDF_{ik}, PDF_{ik}, PDFD_{ik}$	Local supply by firm type and supply and demand price of firm's local good
XE_{ik}, PE_{ik}	Export level and price by sector and firm
Q_i, PQ_i	Armington composite good level and price
GDP, g_{GDP}	Real GDP level and growth
KGT	Composite public capital stock
AT_{ik}	Total factor productivity growth
$PROF_k, NPROF_k$	Firms' operating surplus and non-distributed operating surplus
YH_H, YD_H	Household groups' revenue and disposable revenue
$SAVF_k, SAVH_H, SAVG$	Firms', households' and government saving
XAI_i, XAC_{iH}, XAG_i	Composite demand of good I for investment and households and government consumption
RK_{ip}, IND_{ip}	Investment profitability and investment demand
ZI, PK	Total investment and total investment deflator
$YG, TXREV$	Government revenue and fiscal receipts net of subsidies
CTG, GC, GTH	Government total and current expenditures and transfers to household groups
$NLYH_H, HTC_H$	household groups' non labor revenue and total consumption expenditures
CPI_H	Household groups' consumption price index
Walras	Walras law

List of exogenous variables

$LAND^s$	Land supply
WPM_i, WPE_i	World price of import and export
tm_i, tc_i, sc_i	Tariff rates and consumption taxes and subsidies
BOP	Balance of payment deficit
$PINDEX$	Price index chosen as numéraire
io_{ijk}	Input-output coefficient

