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Macroeconomic and Distributional Impacts of Jatropha-based Biodiesel in Mali

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Abstract

Mali, a landlocked West African nation at the southern edge of the Sahara Desert, has introduced a program to produce biodiesel using *jatropha curcas*, a non-edible shrub widely available throughout the country by farmers for generations as a living fence for their gardens. The aim of the program is to partially substitute diesel, which is entirely supplied through imports, with domestic biodiesel produced from a feedstock that does not have any commercial value otherwise and thus has zero opportunity cost. This paper uses a computable general equilibrium model to investigate economy-wide and distributional impacts of large-scale jatropha production on different types of lands, and conversion of jatropha oil to biodiesel for domestic consumption. It assesses impacts on agricultural and other commodity markets, resource and factor markets, and international trade. The results are fed into a detailed household survey-based micro-simulation model to assess impacts on poverty and income distribution. The study finds that the expansion of jatropha farming would be beneficial in terms of both macroeconomic and distributional impacts as long as idle lands, which have been neither used for agriculture nor protected as forests, are utilized. However, if jatropha plantation is carried out on existing agriculture lands, the economy-wide impacts would be negative although it would still help reduce rural poverty.

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Introduction

Some Sub-Saharan African countries, such as Mali, have expressed interest in biofuels because these countries do not have significant land supply constraints for producing biofuels and they are dependent on imported fossil fuels for meeting their fuel demand for transportation and electricity generation. The energy consumption of Mali, in 2007, was 3.6 million tons per year oil equivalent (Mtoe) of which biomass (wood, charcoal, agricultural wastes) was the predominant (80%). The country is strongly dependent on petroleum products imported primarily via the ports of Abidjan and Dakar. These petroleum products account for 18% of energy consumption (DNE-Mali 2009). The average rates of annual increase in the hydrocarbon imports during the decade 1994-2003 were approximately +33% for super gasoline, +4% for regular gas and +13% for gas oil. According to estimates, the national demand for hydrocarbons will reach nearly 2 million tons in 2015 and more than 3 million tons in 2020. As for electricity, its share is 3% in the national energy balance. In 2004 only 13% of the Malian population had access to electricity, with strong disparities between urban and rural areas. Moreover, this weak access is compounded by a weak share of renewable energies. However, Mali has strong potential in this field with solar energy, wind energy and bioenergy (pourghère,[2] cotton stems, etc.). It is only in 2006 that Mali ironed out its national strategy to develop biofuels over the 2008-2023 period. The creation of the National Agency for the Development of Biofuels (ANADEB)[3] in 2009 was an essential part of this strategy. Another reason behind the government promotion of this agricultural product in the last few years is that this feedstock does not directly compete with food supply.

Although large-scale jatropha plantations look attractive from a project perspective, their indirect impacts on the economy and the environment are not clear. The overall economic and environmental costs and benefits associated with jatropha, such as food security, waste water pollution, reduction of local air pollution, energy dependency and the fight against soil erosion, could be significant. In terms of food security, the main concern is to maintain cereal production, which is the principal staple for rural Malian households (République du Mali, 2008). Concerns have been raised with respect to the potential needs of land and labor to contribute to the expansion of the biofuel sectors. These factors could be taken directly from the other agricultural sectors such as cereal subsector. This competition for production

[2] Pourghere is the French word for *Jatropha curcas L*. In English, this plant is called physic nut or purging nut. In Bambara (Mali), the usual term is *bagani*. In this paper, we use jatropha, bagani and pourghère, which are the common names in Mali.

[3] ANADEB was created in March 2009 with the mandate to: i) define technical and quality norms for biofuels, and monitor and evaluate these norms, ii) initiate research and development of biofuels, iii) train and support private operators in the field and iv) improve institutional frameworks for biofuels and ensure national and international partnerships.

factors could have an impact on the level of other food products and on their prices. These concerns were raised in a June 2008 consultation, leading to a reflection on the risks and opportunities of the jatropha industry in the country and represented by the MaliFolke Center,[4] Mali Biocarburant SA,[5] Jatropha Mali Initiative (JMI)[6] and the Groupe Energies Renouvelables, Environnement et Solidarités **(**GERES)[7] (Pallière et al., 2009).

More recently, Mitchell (2011) has raised additional concerns about how the economics of jatropha production are linked to soil fertility. Jatropha can be grown on poor quality land (low fertility, rainfall) that is unusable for food crops and hence not competing for land. However,, jatropha yields more on better soils with better economic returns. Moreover jatropha production is quite labor intensive, especially for harvesting, and this will have an impact on labor markets. Although the labor intensive harvesting increases production costs, it could provide new jobs to unskilled labor in rural areas.

Thus, it is important to gain better understanding of the impacts of the growth of jatropha production and the biofuels sector, such as how they affect food prices in the long run. How would such a scaling up of biofuels affect the production of other tradable as well as non-tradable commodities? How would it alter the terms of trade? Could large-scale diversion of land for biofuel production help reduce poverty and inequality in Mali?

The overall objective of this study is to assess the economic and distributional impact of large-scale expansion of jatropha production and biofuels linked to this output in Mali. While the economy-wide impacts are assessed using a CGE model, the distributional impacts are assessed using a micro-simulation model. The CGE impacts are measured in terms of changes in key economic variables, such as GDP, economic welfare, international trade, whereas the distributional impacts are measured with a range of poverty and inequality indices. Analyses are also presented to verify whether the simulated scenarios benefit or penalize the poorest Malian households.

The rest of this paper is structured as follows. We first introduce the biofuel context and challenges in Mali, followed by a presentation of the model used for the analysis including a brief review of CGE micro-simulation models. In the next section, we describe the scenarios simulated and move on to the analysis of our macro and distributional impact. We provide concluding remarks in the final section.

[4] A Malian NGO following the initiative of a communal industry producing jatropha oil for rural electrical distribution (Garalo Commune).

[5] A private business producing biodiesel for the Malian transportation sector in partnership with the Union Locale des Sociétés Coopératives des Producteurs de Poughère (Koulikoro Cercle).

[6] JMI is a private business producing pure vegetable oil for the Malian industrial market, in partnership with the farmers of the Kita Cercle.

[7] A French NGO supporting a village industry producing oil in view of rural electrical distribution (commune of Yorosso).

1 Biofuels in Mali: An overview

In the last few decades, Mali and its development partners have implemented numerous projects and programs that aimed to develop alternative energy sources (alcohol biofuel and pourghère, etc.). Recently, Mali undertook a reform of its energy sector by setting up a national strategy for the development of biofuels. This strategy resulted in the establishment of a program for valuing pourghère cultivated areas (2004-2008),[8] the elaboration of the national energy policy[9] (2005) and the creation of the national agency for the development of biofuels (ANADEB) (2009). The jatropha industry is still in its infancy. Although the market for the formal commercial sales and trade of jatropha and its oil are weak, many countries including Mali are realizing the large potential of this plant to produce green energy and substituting fossil fuels (hydrocarbons).

1.1 Jatropha around the world and in Mali

The cultivation of pourghère was introduced in Mali by the French at the end of the 1930s in the Office du Niger and popularized in 1990s by the German development cooperation organization (GTZ). The plant came to be used as a barrier protecting agricultural areas from livestock damage (sheep, goats, etc.), and soil erosion due to water run-off and wind, particularly in rural areas. It was also used by women as traditional medicine against malaria or general pain. On a global scale in 2008, approximately 900,000 ha were planted, of which 85% were in Asia (Indonesia, Myanmar, India, China). The shrub was thought to cover 120,000 ha in Africa, primarily in Madagascar, Zambia, Tanzania and Mozambique. World production is expected to reach 13 million hectares by 2015. For Africa, Ghana and Madagascar alone will account for 1.1 million of the two million hectares expected for the continent (GEXSI, 2008).[10]

It is also interesting to note that farm sizes are on the rise. In 2008, only 11% of jatropha production in Africa was accounted for by large plantations. GEXSI (2008) predicts that in 2013, 38% of production on the continent will be done in large farms, including 23% in plantations of more than 1000 hectares. In 2002, Mali had at its disposal roughly 10,000 kilometers of jatropha shrubs, with a growth rate estimated at approximately 2,000 kilometers per year (Latapie, 2007)[11]. In 2011, field experts estimated that 5,000 of pourghère

[8] The Programme National de Valorisation Énergétique de la Plante Pourghère (PNVEP) comes within the scope of Malian policies and strategies presented in the Programme National d'Action Environnementale (PNAE), the Cadre Stratégique de Lutte contre la Pauvreté (CSLP) and the promotion of the Stratégie Nationale des Énergies Renouvelables. It is implemented by the Centre national de l'énergie solaire et des énergies renouvelables (CNESOLER) under the supervision of the Direction Nationale de l'Énergie of the ministère de l'Énergie, des Mines, et de l'Eau.

[9] The National energy policy aims to increase local production of energy by developing biofuels to satisfy the socioeconomic needs of the country at a lower cost.

[10] These figures were estimated by the Global Exchange for Social Investment (GEXSI) sponsored by the World Wildlife Fund (WWF) to carry out a global market study on jatropha. The goal was to present the situation of jatropha cultivation in 2008 and to foresee the development of projects from now to 2015 for Latin America, Africa and Asia. (Cf. http://www.jatropha-platform.org/index.htm).

[11] The plant has historically been planted as linear edges to protect crop and therefore plantation figures are often presented in kilometer of edges.

shrubs were planted, with an objective for producers to reach 23,000 hectares by 2015 (GEXSI, 2008). However, as stated in the OECD and FAO joint paper (OCDE-FAO, 2009), African projects tied to the expansion of the industry are still modest in Africa. In 2009, Pallière et al. estimated that the total cultivated surface reached 3,730 ha. The model plantation in Mali is 1000 plants per hectare, which allows for production of 1 ton of Jatropha seeds with a production of 1.5 average ton per hectare of an associated food crop (mostly maize or sorgho) In Mali, the quest for transforming grain into biofuel is not a new issue, since it started in the early part of the 20th century in the region of Segou (Haïdara, 1996). The properties of this biofuel are very close to those of some diesel fuels. Furthermore, the renewed interest in this plant is not surprising since it can contribute to producing 1,900 liters of oil per hectare versus 572 liters/ha with colza, 662 liters/ha with sunflower or 446 liters/ha with soya (Legendre, 2008).

The production of phougère is likely to expend in the regions where is it concentrated (Kita, Koulikoro, Yorosso and Garodo). In 2006, the Mali FolkeCenter developed a project targeting the production of jatropha oil destined for electricity production in the agricultural and cotton region of Garolo. Besides cotton, this region is also known for the production of peanuts and important food crops (corn, sorghhum, rice, etc.). In its project launched in 2007, Mali biocarburant SA used jatropha to produce biodiesel intended for the domestic market in the Koulikoro region. This region, which stretches over 7,000 km^2, combines the production of commercial crops (cotton, peanut and tobacco), food crops (corn, millet and rice) and truck farming given its proximity to the Niger River. In the same year, the Jatropha Mali Initiative (JMI) project was also launched in Kita in the region of Kayes. The project initially targeted the production of biodiesel. Since 2009, jatropha vegetable oil destined for the Malian industrial market has become the first output resulting from this seed transformation. Finally, in 2008, the Groupe Énergies Renouvelables, Environnement et Solidarités (GERES) implemented a jatropha production project in the Koutiala region for rural electrical distribution purposes. In light of this information, jatropha production appears to be an interesting avenue for different types of end users. However, he literature reveals little consensus in terms of its concrete economic benefits. The challenges facing policy makers are to evaluate the tradeoffs between benefits and cost of promoting the expansion of the sector.

1.2 Jatropha development: The controversy

Among the objectives most often associated with projects for developing jatropha are the advancement of women (production of soap and sale of oil), the reduction of village poverty (crop protection, sale of seeds, oil, soap), soil erosion control (planting of live shrubs) and the production of renewable energy are most often cited (Henning, 2009). Finally, impact analysis of introducing and developing this crop in rural settings on the welfare of households and communities is also beginning to generate growing interest in the current context of Millenium Development Goals (Pallière et al., 2009). Some researchers such as

Matthews (2007) see the production of biodiesel from jatropha as a means to industrialize poor countries and help them overcome poverty. Planted on a large scale, jatropha may even enable these countries to reduce their imports of petroleum products or even export to international markets. Renner (2007) summarizes the perception of many "Jatropha seems to offer the benefits of biofuels without the pitfalls."

However, others raise some doubts on the benefits of producing biofuels from agricultural products. They raise concerns over biodiversity loss (Raizon, 2009) or endangering the food sovereignty of countries that are already struggling (Luoma, 2009; Raizon, 2009; Campa and Valentin, 2009). Other concerns include the possible influence of pourghère plantations on soil fertility or the risks of diseases or parasites transmission that could annihilate not only jatropha but also other cultures (Campa et al., 2009).[12] This literature shows that two opposing views are at odds when it comes to jatropha production and promotion. Nevertheless, as Benge (2006) states, "there is no indication that any scientific studies have been conducted to prove or disprove any of the above concerns." Based on the fact that the African continent still disposes significant surface of unexploited agricultural land (approximately 58% according to GEXSI, 2008), it appears relevant in our view to contribute to this debate with a focus in economic and distributional impact which is what we propose in this case of Mali.

2 The Malian model

2.1 The model

Since the late 1990s researchers have been using CGE models to analyze the impact of policy reforms on poverty and income distribution. Three main categories of these models have been used during this period: the representative household approach (RH), the integrated multi-household approach (IMH) and the multi-household sequential approach (MHS).

The CGE-RH approach divides households into groups, choosing a representative household for each group and using that representative household in the CGE model. The variations in income of the representative agents generated with the CGE model are applied to households within their respective group from a household survey. This assumption does not allow the analyst to take into account within-group changes in income distribution, even though studies (Huppi and Ravallion 1991 and Savard 2005, for example) have shown that such changes can be greater than between-group inequality changes. Savard (2005) demonstrated that the results of poverty and income distribution analysis can be completely reversed by taking into account within-group distributional effects.

[12] The authors would like to recall the African coffee plant (arabica) introduced to the entire intertropical area by colonists and whose plantations were decimated in the early 20th century by orange rust.

To solve this problem, a second approach was proposed by Decaluwé, Dumont and Savard (1999) and applied by Cogneau and Robilliard (2000), Gørtz et al. (2000) and Cockburn (2001), namely the CGE integrated multi-household approach (CGE-IMH). This method incorporates a large number of households from a household survey (and sometimes all of them) into the CGE model. The approach takes into account within-group distributional effects and has the further advantage of providing coherence between the micro and macro parts of the model, but at a cost. First, data reconciliation can be very problematic (Rutherford, Tarr and Shepotylo, 2005); second, numerical resolution can be challenging (Chen and Ravallion, 2004).

The third approach is referred to as the CGE micro-simulation sequential method (MSS) and could be subdivided into two variants. The first, micro-accounting, was formally presented by Chen and Ravallion (2004) and has been extensively applied in recent years.[13] The second variant, proposed by Bourguignon, Robilliard and Robinson (2005), consists of integrating, at an individual level, rich micro behavior observed at a household level such as consumption or labor supply. This version introduces more heterogeneity between households with the application of a microeconometric model. The general idea of the MSS approach is that a CGE module feeds market and factor price changes into a micro-simulation household model. The main criticism leveled at this approach is that the micro-feedback effect is not fully taken into account; the question has been raised in two literature reviews of macro-micro modeling for poverty analysis (Hertel and Reimer (2005) as well as Bourguignon and Spadaro (2006)). However, Bourguignon and Savard (2008) found that the loss of information associated with using the MSS approach can be relatively small and policy conclusions were robust between the two approaches.[14] In this paper we apply the micro-accounting version of the MSS approach.[15]

The last two approaches (IMH, MSS) allow for rich analysis of income distribution and poverty because they include a large number of households in the modeling exercise. This in turn allows the modeler to apply poverty and income distribution measures and indexes following policy simulations. As already mentioned, the IMH approach is the soundest on a theoretical basis. However, with this approach, it is necessary to construct a balanced sub-matrix for household accounts in a standard social accounting matrix. On the other hand, with the CGE-MSS approach, the household income and expenditure do not require balancing. This gain in flexibility comes from the fact that the micro module is solved sequentially and that we use price percentage changes to link the CGE module to the micro household module. This constraint is one of the two reasons behind our choice to select the CGE-MSS approach for our analysis. The second argument for this approach is that some households will increase their labor supply and land use. This will involve in some cases

[13] Among early applications of this approach are Vos and De Jong (2003) and King and Henda (2003).

[14] Bourguignon and Savard's (2008) comparative analysis of the IMH and MSS approaches was applied to the Filipino economy. In this study, the labor supply was endogenous and the largest portion of the gap in the results obtained from the two approaches came from the labor supply. In our application, the labor supply will be held constant.

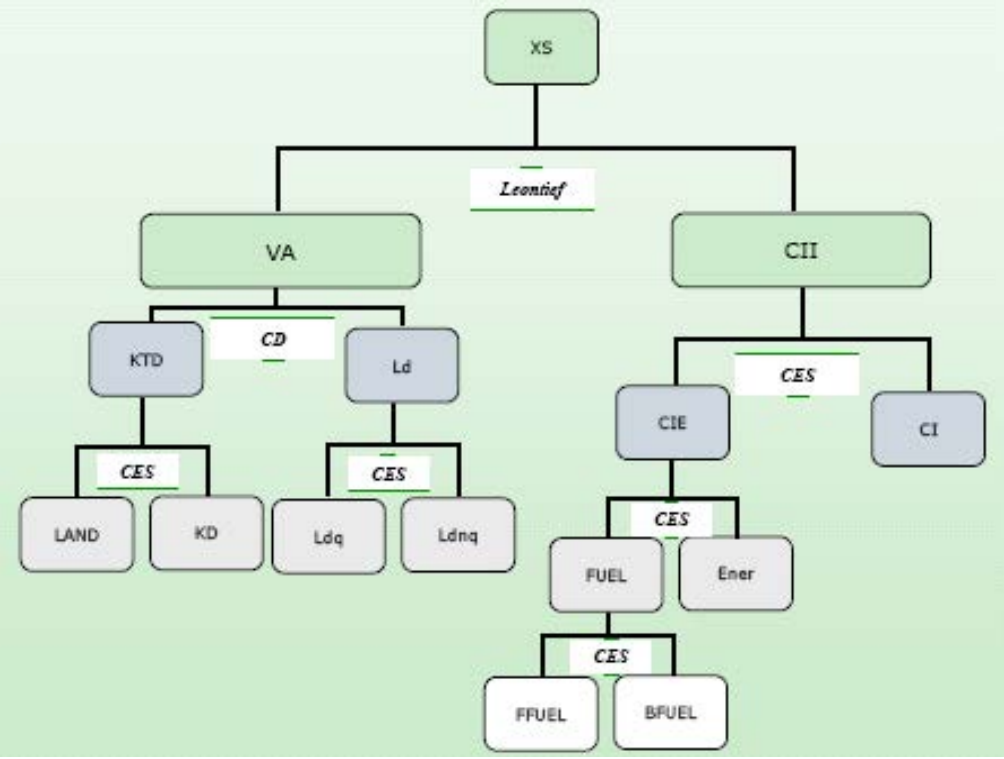
[15] The main reason for selecting this approach is the lack of adequate data to apply the microeconometric approach.

discrete changes or important increases in factor effective endowments. This type of behavior cannot be models in the IMH approach that only allows for marginal changes in factor endowments. We will refer to the household sub matrix database as the household module. To capture the impact of jatropha and biofuel policies on the welfare of individual households and distributional effects, we had to adapt a standard model to specificities of these two sectors in the Malian economy. The presentation of the model is decomposed into the CGE module and household micro household module.

2.1.1 CGE module

The CGE component of our model (hereafter referred to as the CGE module) is based on the EXTER model of Decaluwé et al. (2001), with significant adjustments, which we describe herein. The production structure is substantially modified.[16] We adopted a multilayered production structure as illustrated in Figure 1.

Figure 1: The CGE model and its structure



Starting at the top level, we have total production of the sector (*XS*), which is made up of fixed value-added shares (*VA*) and intermediate consumption (*CII*), as generally assumed in standard CGE modeling. The relationship determining the level of *VA* is a Cobb-Douglas production function between composite labor (*LD*) and total capital (*KDT*). Producers minimize their cost of generating *VA* subject to the Cobb-Douglas function. First order conditions from this process are used to determine the optimal labor demand equations.

[16] We provide the complete set of equations in the appendix.

Labor (*LD*) is then decomposed into skilled (*LDQ*) and unskilled (*LDNQ*) labor, with the combination of these two factors being determined by a constant elasticity of substitution (CES) function, once again through a process of cost minimization. This assumption implies that changes in the relative wages of the two types of labor will lead the producer to modify the ratio between the two types of workers, subject to constraints on substitution linked to his production capacities. The total capital (*KDT*) is decomposed into land (*LAND*) and capital (*KD*). The same CES function is used to link these two factors.

The capital is mobile between agricultural sectors and the land is fixed. Moving on to intermediate consumptions, we significantly enrich the EXTER model by decomposing these inputs into various sub-inputs. We first have the total intermediate consumption (*CII*) that is decomposed into energy (*CIE)* and other intermediate consumptions (*CI)*. These two sub-inputs are linked with a CES function. The *CIE* is further decomposed into fuels (*FUEL*) and electricity (*ENER*)[17]. These two inputs are linked with a CES function, therefore allowing for substitution in these inputs. The fuels are further decomposed into fossil fuels (*FFUEL*) and biofuels (BFUEL) with the same functional form (CES)[18]. Other intermediate consumption (*CI*) was modeled as fixed shares from the input/output ratios computed from the data in the SAM. Given the CES function, the market share will be gained through a reduction in price of biofuels compared to the fossil fuels. Sector-specific elasticities of substitution are used to reflect differences among sectors in determining the mix of factors in each CES function.

In the CGE model, four agents are included (government, aggregate household, firms and the rest of the world). The government draws its revenues from goods and services tax, import duties, households' and private firms' income taxes as well as from transfers from the rest of the world (budgetary assistance). Its expenditure is made up of the consumption of public services and of transfers to other agents. The aggregate private firm draws its income from capital remuneration. It spends its income by paying taxes; making transfers to other agents and saves for investment. The rest of the world is considered as an agent in a standard fashion as it is used to model economic relations between Mali and the rest of the world including imports, exports and transfers to and from agents in Mali. Finally, we include a single representative household in the CGE module.

Our hypotheses reflect the fact that Mali is a small open economy for which world prices of imports and exports are exogenous. We posit the Armington hypothesis (1969) for import demand, whereby domestic consumers can substitute domestically produced goods with imports (imperfectly) according to an elasticity of substitution that is sector specific. On the export side, producers can sell the goods on the local market or export their production and are influenced by relative prices on each market and by their respective elasticity of transformation of the good for one or the other market. We used the GDP deflator as a numeraire.

[17] Other sources of energies such wood and charcoal are included in the forestry sector.

[18] Although Mali could produce ethanol in future, we have excluded it from this analysis as this study focuses on biodiesel.

Our model's equilibrium conditions are also standard. The commodity market is balanced by an adjustment of the market price of each commodity. The labor market is perfectly segmented and balances out with an adjustment of the nominal wage on each of the respective markets (skilled and unskilled)[19]. It is therefore possible for workers to move from one sector to another, but not from one market to another. We use two closures for the labor markets in simulation. In the first option, labor supply is fixed and in the second it is endogenous. In the latter case, we use a standard wage curve as in Carneira and Arbache (2003) and Annabi et al (2005) where labor supply increases (decreases) with an increase (decrease) in real wage on each market[20]. The increase in labour can come either from the extensive margin (number of hours worked) or the intensive margin (more workers enter the market). The current account balance is exogenous, and it balances out with an adjustment of the nominal exchange rate[21]. Finally, investment is savings driven in the model, meaning that total investment equals sum of household and government savings and borrowings from the rest of the world.

2.1.1.1 The data

The social accounting matrix (SAM) necessary for the implementation of a CGE mode was constructed with the main data drawn from an input–output table with 18 productive sectors.[22] The reference year for the SAM is 2006. As noted earlier, our model for Mali covers 20 production sectors, including jatropha, biofuels, fossil fuels and other energies (mainly electricity). Jatropha and biofuels were not found in the initial SAM (Coulibaly 2009). We used information from the sectoral analysis presented in Coulibaly et al (2010) to disaggregate the sectors from crop agriculture and fuel sectors. The size of these sectors is relatively small in Mali but they present substantial potential for growth. The micro-household data base for 4494 households was constructed from the 2006 *Enquête légère intégrée auprès des ménages* (ELIM-2006) survey. The main task for constructing this database is to modify the income and expenditure structures for the households based on the nomenclature of the SAM.

2.1.2 Micro household module

In the micro household module, we include all of the 4,494 households from the survey (ELIM-2006). We have specified income and expenditure functions for the households, which are parameterized on the household-specific information found in the survey. As

[19] For a detail discussion on such labor market segmentation, the reader can consult Boeters and Savard (2012).
[20] This type of endogenous labour supply approach is based on Blanchflower and Oswald (1998). Based on Card (1995), we posit higher elasticity for the nonqualified of around 0.17 and 0.06 for the qualified workers.
[21] When performing distributional analysis, it is usually recommended to maintain the current account balance exogenous. This prevents obtaining gains in welfare through an increase current account deficit (or increase in foreign savings). This constraint imposes using either the nominal exchange rate or the price index as the adjustment variable to balance out the current account balance. Since it is the real exchange rate that is important (nominal exchange rate over the price index), fixing one of the other is irrelevant and results will be the same.
[22] The original input-output matrix was obtained from the "Direction nationale de la statistique et de l'informatique."

mentioned, the module is solved sequentially (CGE module and household module). Let us now describe this sequence. We first specify an income equation that reflects income structure for each household in the ELIM-2006 survey. We assume that the endowments of factors are exogenous and are modified exogenously when necessary. We use the factor payment variations generated by the CGE module and apply them to the factor endowments. The two wage rates are also applied to labor endowments of households.[23] As in the CGE module, we assume that the transfers from other agents to the households are exogenous. When changes in factors such as land increases in the jatropha production are necessary, we computed the number of households concerned based on shares of land involved in the simulations. From there, we isolated farm households in our sample and performed random draws of households to select the ones benefiting from the growth in land under jatropha cultivation. We applied the growth to these households[24].

This procedure provides us with the new household-specific income. We can then move on to the expenditure side. The demand functions are derived from a utility maximization process (Cobb-Douglas utility function), and this demand equation is a function of market prices and household income. The final step in the sequential resolution of the household module consists in computing the change in welfare. Implicitly, this allows us to take into account simultaneously the income and price effects on each household's welfare.[25] As in Bourguignon and Savard (2008), we use the variation of the real income to measure the change in welfare. The household-specific value shares for consumption are computed from observed figures in ELIM-2006. These shares are then used to specify a household-specific price index that is in turn used in combination with the nominal income to obtain the change in real income. It is this real income that is used to compute welfare changes.

2.1.3 Poverty and distributional analysis

After selecting our criteria for household decomposition (including rural/urban divide) we can apply any type of distributional analysis. The indices can be applied using the reference period directly from ELIM-2006 data and then for the various simulations. The indices selected for our distributive analysis are the Foster, Greer and Thorbecke[26] (F-G-T, 1984) P_α indices for poverty analysis and the Gini index for inequality changes. In addition to these indices, we applied pro-poor growth analysis with the growth incidence curves (GIC) proposed by Ravallion and Chen (2003).

[23] The survey included information that allowed us to decompose the labor into qualified and non qualified labor.

[24] We repeated this procedure a number of times and our distributional analysis was robust to this random draw procedure. This can be explained by the fact that poverty rates in rural areas are very large and the random draw produced sample of households with similar compositions.

[25] This approach is different from the endogenous poverty line proposed by Decaluwé et al. (2005) as it captures the price effect of the simulation through specific household preference and not through a basic needs approach. For a discussion of the advantages and disadvantages of the two approaches, see Ravallion (1994).

[26] FGT poverty indices are additively decomposable; as such, they are interesting within the framework of this analysis and make it possible to measure the proportion of the poor among the population but also of this poverty depth and severity. The higher the degree of poverty aversion, the greater the importance granted to the poorest. For detailed information on this index family, read Ravallion (1994).

3 Simulations

The main objective of this paper is to investigate the distributional impact of an expansion of jatropha production and associated biofuel production from jatropha in Mali. We first look at three scenarios of increasing production of jatropha. These simulations are performed by exogenously increasing the land in the jatropha sector and capital in the biofuel sector[27]. We performed a fifteen fold increase in land for jatropha production going from 3,000 to 45,000 hectares. The capital in the biofuel production sector is increased exogenously by fivefold to correspond to cultivation of jatropha in the increased lands[28]. This set of simulations can be seen as similar in nature, though larger in scale, than the extension of the biofuel industry in line with the objectives established by the ANADEB at 23,000 hectares for 2015[29].

Within this first set of simulations we perform the increase in scale with three set of assumptions. In the first case, we assume that the additional land used for cultivating jatropha comes from unused idle land (Sim1a) and in the second case; the expansion of the sector is done on arable land used to produce other agricultural products (Sim1b). These two extreme case scenarios provide us with upper and lower bounds for our comparative analysis. Additional capital used in the jatropha sector and biofuel sector is taken from other sectors of the economy exogenously[30]. For the last simulation of the first set we repeat Sim1b and introduce endogenous labor supply. For this assumption we use a standard wage curve as in Annabi et al (2005). In this scenario, the additional workers needed to produce jatropha can come from new labor (extra workers and/or more hours worked by active workers). However, if the scenario produces downward pressure on the real wage, we will observe an increase in unemployment.

In the next set of simulations, we consider a policy intervention to promote the biofuel sector. This policy consists in subsidizing biofuel market prices by 20% This policy provides an additional comparative advantage to this sector compared to fossil fuels. We fund this subsidy with a 1% tax on fossil fuels[31]. This tax rate is assumed because in simulation 2a, a

[27] We reiterate both land and capital are mobile across the agriculture sub-sectors. However, capital mobility between agriculture and other sector is assumed to be restricted. Given the increase in production of jatropha considered in the study, an increase in the number of biodiesel plants is needed to process jatropha produced. The additional capital is taken from other sector exogenously and hence the total capital in the economy is held constant.

[28] A priori, this could seem like a large increase but it represents less than 0.03% of the total capital. The large proportional increase is tied to the small initial figure. This can be interpreted as constructing 18 additional plants from 4 at the reference period.

[29] We fixed the objective to double this 23,000 hectares surface in order to generate observable changes in our CGE model. One could also consider the different interventions made by the ANADEB as enumerated in section 2 and in Coulibaly et al (2010). One example for these interventions is the education of farmers regarding the benefits of increased jatropha cultivation. According to MaliBiocarburant data, they can produce biofuel at 550FCFA per litre with no subsidy while gasoil is sold at 625FCFA per litre. However, our scenario analysis focuses only on exogenous expansion.

[30] For this assumption, the volume of capital is so small that is has little effect on other sectors since it constitutes less than 0.05% of capital of the rest of the economy. We exogenously increase the capital in the biofuel and jatropha sector and decrease the volume of capital by 0.03% in other sectors.

[31] A small tax was required to fund the subsidy given the small relative size of biofuels compared to fossil fuels. Hence, applying a small tax on fossil fuels will produce little general equilibrium effects.

1% tax on fossil fuel plus the 20% subsidy are revenue neutral. We use this level of tax for other simulations in this set for comparative analysis purpose but this level is no longer revenue neutral given other general equilibrium effects that are different in simulations 2b, 2c and 2d.

We compare 4 case scenarios. The first one (sim2a) is a 20% subsidy and the 1% fossil fuel tax without an increase in land and capital in the jatropha and biofuel sectors. This allows us to isolate the impact of the tax and subsidy from other effects of the next simulations.

For the next simulation (sim2b), we combine the tax and subsidy with a tenfold increase in land for jatropha production where the land comes from idle land. The third simulation (sim2c) in the same as sim2b but the land is taken from other agricultural sectors and the last one (sim2d) in this group is sim2c with endogenous labor supply[32].

The main challenge with performing sim1c and 2d with the endogenous labor supply is to attribute the increase in labor supply to specific households. For this procedure we randomly draw households from a group of selected households on the basis of characteristics found in the household survey. Table 1 summarizes these simulations.

Table 1: Simulation descriptions

Code	Simulations presentation
1a	15 x increase of land for jatropha using idle land in Mali
1b	15 x increase of land for jatropha using agriculture land
1c	15 x increase of land for jatropha using agriculture land with endegenous labour supply
2a	1% tax on fossil fuels & 20% subsidy to biofuel no exogenous increase in jatropha land
2b	1% tax on fossil fuels & 20% subsidy to biofuel & 10 x jatropha land with idle land
2c	1% tax on fossil fuels & 20% subsidy to biofuel & 10 x jatropha land with exploited land
2d	1% tax on fossil fuels & 20% subsidy to biofuel & 10 x jatropha land with endegenous labour supply

4 Results

We proceed with a brief description of our macro and a few sectoral results. As we focus our analysis on a distributional impact of these scenarios, we select some key variables that play an important role in this distributional impact analysis[33].

4.1 Macroeconomic and sectoral impacts

From our results presented in Table 2 below, the first general statement we can formulate is that the impact on macro variables is relatively small. This is not surprising as the two main sectors of interest are relatively small at the reference period. In the first set of simulations, the first simulation is the one with the weakest impact at the macro level. Hence, using idle

[32] For this set of simulations we used and 10 fold increase since the combination of the subsidy and 15 fold increase in land would not run as we encountered numerical resolution problems.

[33] We can highlight that we performed extensive sensitivity analysis with respect to the value of parameters for our elasticities of substitution of our production structure. In reasonable ranges of parameter values our results were robust. Quantitative differences were observed but almost all qualitative variations were unchanged with very few exceptions. The general patterns observed and analyzed hereon were robust to our sensitivity analysis. For information detailing this sensitivity analysis, the reader can consult Olinga Megada (2012).

land produces a slight positive impact on most macro variables. Both GDP and economic welfare increase under this scenario. Firms seem to be the losers since income increases for households and government while it decreases for firms because most income goes to households as labor income as jatropha is labor intensive. The first simulation produces a small appreciation of the real exchange rate which is expected given the substitution of fossil fuels by biofuels produced locally.

Table 2: Macro level results of the CGE model
% changes from the base case

Variables	Definition	Sim 1a	Sim 1b	Sim1c	Sim2a	Sim2b	Sim2c	Sim2d
Yh	Household income	0.03	-0.15	-0.16	0.07	0.07	-0.11	-0.10
w^1	qualifed w age	0.16	0.05	0.04	0.06	0.33	0.22	0.17
w^2	non qualifed w age	0.12	-0.07	-0.05	0.09	0.26	0.06	0.04
rr	rental rate of agricultural capital	-0.56	-0.39	-0.39	-0.53	-0.64	-0.46	-0.45
GDP	Gross domestic product	0.02	-0.18	-0.19	0.08	0.08	-0.12	-0.12
EV	change in w elfare	0.01	-0.03	-0.03	0.02	0.02	-0.02	-0.02
Yg	Government income	0.01	-0.14	-0.14	0.00	-0.46	-0.60	-0.60
Sg	Government savings	0.03	-0.51	-0.52	-0.01	-1.71	-2.24	-2.21
Ye	Firms' income	-0.04	-0.21	-0.21	0.07	-0.01	-0.18	-0.18
Se	Firms' savings	-0.08	-0.44	-0.44	0.14	-0.03	-0.38	-0.37
It	total investment	-0.03	-0.50	-0.51	0.01	-1.40	-1.87	-1.84
u	unemployment	na	na	0.11	na	na	na	-0.23
e	real exchange rate	-0.15	-0.24	-0.25	0.04	-0.08	-0.17	-0.17

Note: rental rate of agricultural capital refers to the return to capital in uses other than jatropha.

When the jatropha sector competes with other agricultural sectors for land, we observe a reduction in most macro variables with the exception of the qualified wage. This results clearly indicate the followings: (i) it would not be beneficial to grow jatropha for biofuels in Mali at the expense of existing agriculture lands, (ii) it would be more beneficial to grow existing crops if new lands were to cultivated provided that existing crops has a market. Note that biodiesel could have better domestic and export markets compared to that of existing agriculture crops. The endogenous labor supply assumption (sim1c) does not have a strong impact when comparing results with the sim1b given the small pressure on wages. We also reiterate that the capital required by the jatropha sector will be drawn from all other sectors. Hence, competition for inputs across agricultural sectors arises in land and capital. The jatropha sector also competes for workers in simulation 1a and 1b. In simulation 1b and 1c, the impact on the real exchange rate is almost twice as strong compared to the first simulation. For simulation 1b and 1c, the reduction in land available for other agricultural sectors that in turn reduce output for these products. The reduction in supply produces (see table 4) and increase in market price and hence produce a better returns to capital for agricultural sectors compared to simulation 1a.

The fourth simulation (2a) is interesting as it provides positive results for most variables with the exception of the rental rate of capital in agricultural sector. It is the only simulation

where we observe a depreciation of the real exchange rate. As was expected the simulation is neutral for government since the fossil fuel tax funds the subsidy to biofuels. The impact on wages is slightly positive. Simulation 2b is interesting since it produces strongest positive effects on wages and relatively strong negative impact on rental rate of agricultural capital. When comparing the government situation we notice a relatively strong deterioration in savings (larger deficits). This is a result of the strong expansion of the biofuel sector without other compensating revenue sources, which pushes the subsidy bill higher. This produces a reduction in public savings and hence in total investment in the economy.

The relatively large gap between wage and rental rate of capital should produce stronger distributional impact compared to other simulations. When comparing simulation 2b and 2c, we notice that the competition for land produces stronger negative impact on most variables and a reduction of positive effects on others. Comparing simulations 1a and 1b, there is a positive impact on both GDP and aggregate welfare when otherwise idle land is used. This is relatively intuitive, since the idle land which has a zero opportunity cost, is now brought to the production process. Although it has some crowding out effects, such as relocation of labor from other sectors to jatropha and biodiesel sectors, those effects are relatively small compared to the positive impacts of the use of idle lands. This contrasts with 1b, illustrating the negative implications of increasing production of jatropha with competition for land. This result reveals an interesting insight: producing jatropha in existing lands by replacing existing crops would not be beneficial in Mali. It would be more interesting to examine whether jatropha or other crops would have more favorable impacts to the Malian economy if they are grown in idle lands. It depends on several factors such international prices of biodiesel and food commodities and a single country model, used in this analysis, is not suitable to answer this particular question.

We can see a similar difference between 2b and 2c. However, both of these scenarios also include the production subsidy and fossil fuel tax that are introduced as a revenue-neutral combination in simulation 2a. Comparing 2a and 2b, we see that there are essentially identical increases in household income, GDP, and welfare, but the combined effect of the fiscal instruments as well as the increased availability of unused land for jatropha production significantly reduces savings and investment. In effect, the subsidy adds nothing to the real output effect of the increase idle land availability in 1b, while also worsening the overall fiscal position of the country. Conversely, if the unused land were not available, the biofuel subsidy with a revenue-neutral fossil fuel tax would have similar impacts on income and welfare.

Finally, the addition of endogenous labor supply in the model leads to an increase in unemployment in simulation 1c, and a decrease in simulation 2d when the fiscal instruments are combined with land use changes. In 1c, the higher real wage from increased competition for workers, plus competition for land, raises unemployment. The biofuel subsidy reverses the negative impact on unemployment. This is because the government subsidy drives the expansion of jatropha plantation and biodiesel production proportionately higher than that

in Scenario 1c. Higher expansion of this sector would mean higher demand for employment[34].

Moving on to the sectoral results, and recognizing once again that we have limited impacts except for the jatropha and biofuel sectors, we look first at the output/value added changes (in Table 3. The results show an interesting contrast between Scenario 2a and rest of the scenarios. If there is only a subsidy provided to promote biodiesel, jatropha sector value added increases by 20% and biofuel sector by 21%. On the other hand, jatropha sector value added increases by 10 times if land allocated to jatropha is expanded exogenously by 15 fold. Direct investment or expansion of lands for jatropha cultivation would be more powerful if the objective of the policy is to increase production of biodiesel in Mali. *However*, such as policy has significant negative implications to the overall economy unless idle land is utilized for biodiesel production.

Table 3: Value added results of the CGE model
% changes from the basecase

Variables	branches	Sim 1a	Sim 1b	Sim1c	Sim2a	Sim2b	Sim2c	Sim2d
Va (value added)	crop agriculture	0,21	-0,50	-0,51	0,22	0,17	-0,54	-0,53
	rice	0,13	-0,28	-0,29	0,18	0,23	-0,18	-0,17
	export agriculture	0,14	-0,46	-0,47	0,04	0,09	-0,52	-0,51
	jatropha	1069,18	1068,76	1068,62	20,48	729,40	729,09	729,30
	coton	-0,13	-0,93	-0,93	0,13	-0,33	-1,13	-1,12
	Livestock	0,03	-0,25	-0,26	0,14	-0,05	-0,33	-0,30
	forestry	0,25	-0,44	-0,44	0,28	0,31	-0,38	-0,38
	mining	-0,09	-0,08	-0,08	-0,01	-0,09	-0,08	-0,07
	agoindustry	-0,08	-0,08	-0,09	0,01	0,01	0,01	0,02
	textile	-0,05	-0,06	-0,07	-0,01	-0,13	-0,13	-0,11
	other industries	-0,19	-0,18	-0,18	-0,01	-0,09	-0,07	-0,06
	other energy	-0,05	-0,06	-0,06	0,00	-0,09	-0,09	-0,09
	biofuel	1089,94	1089,51	1089,37	21,39	743,56	743,25	743,47
	construction	-0,80	-0,87	-0,88	-0,03	-0,84	-0,91	-0,90
	commerce	0,02	0,00	0,00	0,00	-0,03	-0,05	-0,04
	transport	-0,02	-0,01	-0,01	0,00	-0,03	-0,02	-0,02
	services	-0,64	-0,62	-0,62	-0,01	-0,39	-0,38	-0,37
	banking & finance	-0,43	-0,50	-0,50	-0,01	-0,42	-0,48	-0,47
	public services	-0,20	-0,10	-0,10	-0,05	-0,29	-0,18	-0,16
	fossil fuels	-1,36	-1,38	-1,39	-0,03	-0,89	-0,91	-0,90

Expansion of jatropha plantation would cause a decrease in value added in most of the sectors because jatropha plantation would crowd out both labor and capital from most of the sectors. These negative impacts, however vary across sectors and across scenarios. For

[34] Although the relationships are non-linear, one can still roughly estimate that if jatropha plantation were increased by 10 folds instead of 15 folds as assumed in scenario 1C, value added of jatropha sector would have increased by 712.41% (against 1068.62% as shown in Table 3). Scenario 2d considers 20% of government subsidy on top of 10% exogenous land supply thereby causing expansion of jatropha sector value added by 729.3%. We can apply the same rule for biodiesel sector as well. In summary, Scenario 2d causes proportionately larger expansion of jatropha and biofuel sectors than Scenario 1C. This would help explain the difference on employment impacts in these two scenarios.

example, Scenario 1a and 2b does not cause a decrease in value added of existing crop sectors as the lands required for biodiesel expansion would be supplied through new or idle lands. There are some exceptions, however. The cotton sector exhibit a slight decrease in production. The primary reason for this reduction is the crowding out effects, such as reallocation of labor from cotton sector to jatropha sector, both sectors are very labor intensive. It is also interesting to note that unskilled labor currently engaged in construction and service sectors might go back to agriculture sector due to expansion of jatropha plantation.

In the second and third simulations (1b and 1c), drawing land from other sectors has a negative impact on these agricultural sectors and effects on other sectors are quite similar to simulation 1a. However, the transport and commercial sectors are not negatively affected by this scenario. In these two simulations, the two sectors most negatively affected are the fossil fuels, cotton and construction sector. For the second set of simulations, we note that the subsidy is very inefficient in generating an increase in output for the jatropha sector and biofuel sectors, which were both increased by around 20% in simulation 2a, whereas corresponding outputs increase by more than 7 folds in other scenarios.

The price effects follow a similar trend with weak effects in general for all sectors but jatropha and biofuels. As we can see from Table 4, the strongest impact is on jatropha with decreases in price between 23 to 29% for all simulations with increase in land use for the sector. The price of biofuels decreases in all simulations given the surge in output. However, these price decreases are small considering the very high increase in supply on the market.

Table 4: Market price results of the CGE model
% changes from the basecase

Variables	branches	Sim 1a	Sim 1b	Sim1c	Sim2a	Sim2b	Sim2c	Sim2d
Pq (market price)	crop agriculture	-0,19	0,31	0,30	-0,15	-0,27	0,22	0,23
	rice	-0,10	0,13	0,13	-0,10	-0,07	0,16	0,16
	export agriculture	0,12	0,47	0,47	0,03	0,12	0,47	0,47
	jatropha	-29,58	-29,71	-29,72	33,08	-23,33	-23,48	-23,47
	coton	-0,19	0,00	-0,01	-0,05	-0,52	-0,33	-0,33
	Livestock	-0,02	0,04	0,05	-0,06	0,02	0,08	0,07
	forestry	-0,22	0,23	0,23	-0,18	-0,22	0,23	0,24
	mining	-0,06	-0,19	-0,19	0,05	0,01	-0,12	-0,12
	agoindustry	0,09	-0,05	-0,05	0,07	0,21	0,07	0,06
	textile	0,11	-0,07	-0,07	0,08	0,14	-0,04	-0,05
	other industries	-0,10	-0,23	-0,23	0,05	-0,01	-0,14	-0,14
	other energy	0,04	-0,18	-0,19	0,08	-0,07	-0,29	-0,28
	biofuel	-3,45	-3,65	-3,65	-0,08	-2,86	-3,06	-3,06
	construction	-0,43	-0,65	-0,65	0,05	-0,45	-0,67	-0,67
	commerce	0,83	0,41	0,40	0,10	0,20	-0,22	-0,19
	transport	0,23	0,08	0,07	0,06	0,14	-0,02	-0,01
	services	0,15	-0,10	-0,10	0,07	0,04	-0,20	-0,19
	banking & finance	-0,04	-0,26	-0,27	0,06	-0,06	-0,28	-0,29
	public services	0,21	0,05	0,04	0,06	0,24	0,08	0,06
	fossil fuels	-0,28	-0,48	-0,48	0,06	-0,27	-0,47	-0,47

The strong price decreases for jatropha has a positive impact on the biofuel sector. It is also very interesting to note that the subsidy to biofuel (Scenario 2a) has a positive effect on jatropha production and price. This is because this is the only scenario where the policy shock is applied to biodiesel (i.e., consumption of biodiesel is subsidized) and not to jatropha cultivation, whereas land expansion for jatropha cultivation is considered in the rest of the scenarios. The subsidy also allows for a low decrease in price of biofuel in combination with a more than 20% increase in output by the sector. When we combine this simulation 2a with the increase in land for jatropha production (sim2b), we greatly reduce the demand side pressure on jatropha with the supply effect and we observe a strong decrease in the price of jatropha (-23%). It is also interesting to highlight that the market prices of other agricultural goods all increase when jatropha competes with these sectors of land and these prices decrease for most sectors when there is no competition (sim1a and sim 2b). These differentiated effects will play an important role in determining the distributional impact of these simulations.

The results for changes in the rental rate of capital for the non-agricultural sectors are presented in Table 5. Since the capital is fixed, each sector has a specific rental rate of capital. Not surprisingly the biofuel sector experiences a very strong increase in returns in all simulations since all scenarios are favorable to this sector. In the first simulation (sim1a), the fossil fuels, the construction and service sectors exhibit decreases around or above 2%.

Table 5: Rental rate of capital results of the CGE model
% changes from the basecase

Variables	branches	Sim 1a	Sim 1b	Sim1c	Sim2a	Sim2b	Sim2c	Sim2d
r (rental rate of capital)	mining	-0,37	-0,39	-0,40	0,02	-0,19	-0,21	-0,21
	agoindustry	0,01	-0,15	-0,15	0,09	0,39	0,22	0,22
	textile	0,08	-0,11	-0,11	0,07	0,08	-0,11	-0,10
	other industries	-0,46	-0,58	-0,58	0,07	0,07	-0,05	-0,06
	other energy	-0,01	-0,23	-0,24	0,08	-0,14	-0,36	-0,35
	biofuel	437,25	436,04	435,98	45,69	1530,65	1526,93	1527,18
	construction	-2,37	-2,78	-2,78	-0,01	-2,38	-2,78	-2,77
	commerce	1,14	0,61	0,59	0,12	0,26	-0,27	-0,22
	transport	0,35	0,31	0,31	0,05	0,34	0,30	0,30
	services	-1,94	-2,08	-2,07	0,06	-0,98	-1,12	-1,12
	banking & finance	-0,97	-1,25	-1,26	0,04	-0,77	-1,05	-1,06
	fossil fuels	-4,24	-4,42	-4,44	-0,04	-2,53	-2,71	-2,72

This simulation has some sectors benefiting, namely the commerce and transport sectors. The competition from the biofuels toward fossil fuels is clearly observed in all simulations. Moreover, in all simulations, the transport sector benefits from the lower fuel prices. The subsidy (sim2a) produces a positive impact on the biofuel sector but with a much smaller impact compared to the first three simulations. The trends within each set of simulations are quite similar (with the exception of sim2a). We only observe a few qualitative differences within each set of simulations such as in the textile, commerce and other industries sectors.

We complete the section with a brief description of the market penetration of biofuel in the context of our simulations. In the first set of simulation, the exogenous expansion of the jatropha production allows biofuel to take up just over 3.7% of market share compared to fossil fuel from an initial share of just over 0.3%. The simulation 2a which is a policy intervention without exogenous growth of the jatropha sector produces an increase in market share to 0.38%. On the other hand, the 10 fold increase in land use for jatropha production (sim 2b to 2d), allows biofuels to achieve a market share of 2.65%. One important caveat that can be drawn from this result is that policy instruments like subsidy do not help much to increase the share of new energy technology (e.g., biofuels, wind, solar) in a general equilibrium setting, at least in the relatively nearer term. However, the subsidy policy does not have unfavorable macroeconomic and welfare impacts. On the other hand, large scale investment or forced mandate to substantially increase share of jatropha biodiesel would have adverse impacts on the overall economy and welfare.

Table 6: Market penetration of biofuel

Market penetration of biofuel in % of share	
Reference	0,31
sim1a	3,74
sim1b	3,74
sim1c	3,73
sim2a	0,38
sim2b	2,65
sim2c	2,65
sim2c	2,65

We will follow this section with the distributional analysis. It will be important to keep in mind the variations presented in the previous tables.

4.2 Distributional impacts

In this section, we present and analyze poverty and income distribution changes following the different scenarios. We perform this analysis at the national level and also present a rural-urban decomposition analysis. It is important to restate that the CGE model does not take into account this household decomposition. The decomposition is performed at the distributional analysis level. The CGE-microsimulation model allows us to compute changes in real income and equivalent variations for each 4,494 household in the model. Table 7 presents the share of households as well as average per capita expenditure for each of the two groups. We observe that 31.70% of Malian households live in urban area and 68.3% in the rural zone. The average per capita expenditure of urban households is more than double (631 064 Fcfa) compared to what is observed for rural households (225 416 Fcfa).

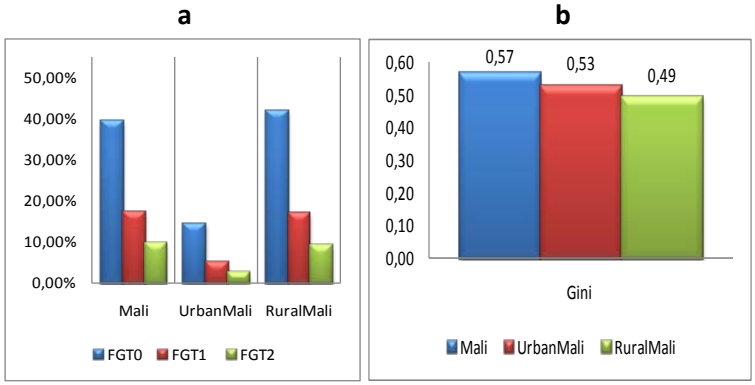
Table 7: Descriptive statistics for groups

	% of households	Mean of *per capita* expenditure (Fcfa)
Urban	31.7%	631064.8
Rural	68.3%	225416.8
Mali	100%	377035.72

Sources: Elim, 2006

Let us begin with the analysis of poverty and inequality for the reference period at the national level and for the two groups of interest (Figure 2).[35] While poverty at the national level is slightly below from 40%, the rural area exhibits a poverty rate slightly higher at 42% while the poverty rate is much lower in urban zones at 14.5%. When analyzing the poverty depth (FGT1) and severity (FGT2), the indices for rural areas are just below the national level and the urban zones have much lower levels for these two indices. Mali is a country with relatively high level of inequality with a Gini value of 0.57 for the country. However, the decomposition analysis reveals lower inequality within the two zones at 0.53 for the urban areas and even lower in rural Mali at 0.49.

Figure 2: Poverty and inequality analysis for Mali and the groups



Source: Resutlts obtained by authors with DASP 2.1

For the distributional impact analysis for national poverty (see Table 8), we see that the country would experience a decrease in poverty for all indices and all simulations. In the first set of simulations, the one with the weakest positive impact is sim1b. Looking at poverty serverity, we observe the strongest reduction for the first simulation (sim1a) , while sim1c exhibits the highest reduction in poverty depth index. In the second set of simulations, the sim2a seems to be the most interesting in terms of the three poverty indices and the subsidy using idle land (sim2b) is the second best option. The sim2c produces the weakest positive results. The positive effects are a the results of increasing wages in most simulations and the decrease in price of key goods for poor households (food prices, forestry, fuel, manufactured goods). The returns to agricultral capital and land are qualitatively different between simulations and hence in some cases it will attenuate the positive effects of other variables and in other it will amplify the positive effects of other variables. The two simulations with endogenous labor supply contribute to significantly improving the situation of the

[35] The welfare indicator used is the annual expenditures after private net transfers (monetary and non monetary), expressed per capita. The literature shows that income transfers between households can be considered a source of poverty reduction as well as a means to attenuate inequalities between households (Adams and He, 1995). Coulibaly (2010) shows that in the absence of transfers, poverty would be much higher in Mali and its regions. It is also worth noting that the national threshold chosen is the one suggested by the World Bank, based on the basic needs methodology. The poverty threshold is different in the two zones. The "Institut National de Statistique du Mali" computed 18 poverty lines that are decomposed between urban and rural areas for the 9 departments of the country. We computed rural and urban lines with the weighted averages on the nine rural and nine urban zones. This gave us a poverty line of 148 152 Fcfa for the urban and 120 091 Fcfa for the rural areas.

households benefiting from new or more work (sim1c versus sim1b and sim2d versus sim 2c).

Table 8: Variation of poverty indices by groups[36]

		Mali	UrbanMali	RuralMali
Référence	FGT0	39,72%	14,54%	42,05%
	FGT1	17,42%	5,10%	17,03%
	FGT2	9,96%	2,67%	9,14%
Sim 1a	Δ % FGT0	-0,05%	0,18%	*-0,31%*
	Δ % FGT1	*-0,24%*	*0,54%*	*-0,44%*
	Δ % FGT2	*-0,34%*	*0,39%*	*-0,51%*
Sim 1b	Δ % FGT0	*-0,11%*	0,41%	-0,13%
	Δ % FGT1	*-0,23%*	-0,07%	*-0,28%*
	Δ % FGT2	*-0,25%*	-0,03%	*-0,31%*
Sim 1c	Δ % FGT0	*-0,18%*	-0,63%	-0,20%
	Δ % FGT1	*-0,25%*	-0,20%	*-0,30%*
	Δ % FGT2	*-0,28%*	-0,08%	*-0,31%*
Sim 2a	Δ % FGT0	*-0,44%*	-0,25%	*-1,02%*
	Δ % FGT1	*-0,77%*	*0,13%*	*-1,00%*
	Δ % FGT2	*-0,85%*	*0,13%*	*-1,01%*
Sim 2b	Δ % FGT0	-0,05%	0,18%	-0,26%
	Δ % FGT1	*-0,28%*	*0,42%*	*-0,48%*
	Δ % FGT2	*-0,38%*	*0,30%*	*-0,56%*
Sim 2c	Δ % FGT0	*-0,11%*	-0,16%	-0,13%
	Δ % FGT1	*-0,21%*	-0,05%	*-0,27%*
	Δ % FGT2	*-0,23%*	0,00%	*-0,29%*
Sim 2d	Δ % FGT0	*-0,18%*	-0,39%	-0,20%
	Δ % FGT1	*-0,26%*	-0,18%	*-0,28%*
	Δ % FGT2	*-0,26%*	-0,06%	*-0,29%*

When analyzing the impact of the simulations on the two groups, we observe quite intuitive results where the rural households on an aggregate basis, benefit in all simulations for all indices while urban households benefit in some simulations and for some indices. In fact, the positive results observed for urban households are insignificant (standard errors are greater than the variation of the indices). We observe significant negative impact for urban households for simulations 1a, 2a and 2b. In none of the cases do we have a significant result for the headcount index (FGT0) for urban households. For rural households all simulations produce significant results for depth and poverty indices. However, for the headcount index, only sim1a and sim2a produce significant results.

It is interesting to observe that the strongest positive effects overall for the country and rural households is the tax and subsidy option (sim2a). In simulations with an expansion of jatropha production, we have two opposing effects being confronted namely the increase in income from new production but the increase in supply decreases the prices and returns on factors.

[36] We present complete poverty analysis for each group. However, we indicate significant results (at 0.05%) in italic character. When variations are not in italic, it indicates that the results are not significant.

Table 9 presents the variation of the inequalities. Only one option produces a reduction in inequality for the country and the two groups, namely sim1c. Two simulations produce across the board increase in inequality (sim2c and sim2d). Other simulations (sim1a, sim1b and sim2a) produce benefits to one group and for the national level. Finally, in one simulation (sim2b), we observe a reduction of inequality at the national level but not for subgroups.

Table 9: Variation of Gini index by groups

	Mali	UrbanMali	RuralMali
Gini	0,57	0,53	0,49
Δ% Gini - Sim 1a	-0,090%	0,019%	-0,057%
Δ% Gini - Sim 1b	-0,002%	0,004%	-0,036%
Δ% Gini - Sim 1c	-0,033%	-0,137%	-0,041%
Δ% Gini - Sim 2a	-0,155%	-0,033%	0,156%
Δ% Gini - Sim 2b	-0,015%	0,018%	0,320%
Δ% Gini - Sim 2c	0,154%	0,248%	0,762%
Δ% Gini - Sim 2d	0,123%	0,107%	0,072%

In terms of the effects on the groups, the positive results obtained for poverty in rural areas do not translate in reduction in inequality in all simulations. It is only the case for simulations of the first set while all simulations in the second set increase inequality in that zone. For urban zones, the negative results for poverty translate into increase in inequality for most simulations.

4.3 Pro-poor analysis

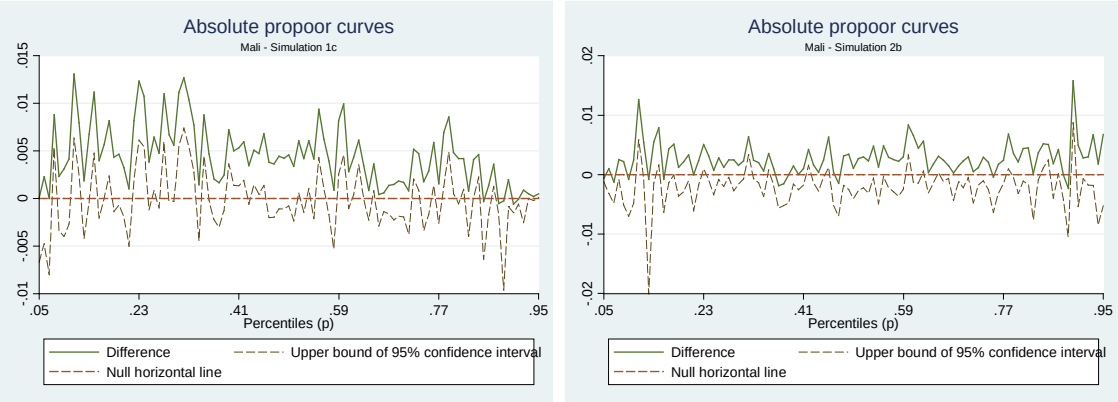
To complete our distributional impact analysis, we examined whether the simulations can be classified as pro-poor or pro-rich. To conduct this analysis, we used the growth incidence curve (GIC) developed by Ravallion and Chen (2003). This analysis allows us to see whether the variation in real income (or expenditure) generated by the model is distributed across the distribution. The curve represents the change in real income for each percentile of the sample of households. Hence, a negatively sloped curve represents a pro-poor policy and a positively sloped curve a pro-rich simulation.

Figure 3 panel a depicts the GIC for Mali for sim1c. The curve exhibit a slight negative slope and hence this simulation is more favorable to poorer households (below 60th percentile) compared to households above this 60th percentile. We recall that this simulation produce a reduction for the three poverty indices and a reduction in the Gini index at the national level and for the two subgroups. In Figure 4, panel b, the GIC curve for sim2b reveals a proportional impact since we cannot identify a slope for the curve while poverty indices

decrease and the Gini index at that national level also decreased albeit this decrease was extremely small.

Figure 3: Growth incidence curve for Mali

(a) Simulation 1c **(b) Simulation 2b**

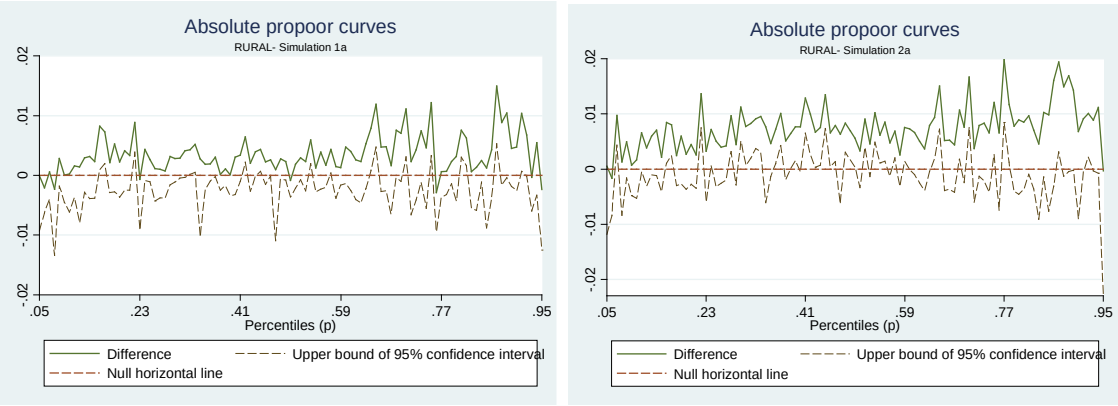


Source: Computed by authors from ELIM 2006 with DASP package

Figure 4 depicts the GIC for the rural households for simulation 1a (panel a) and simulation 2a (panel b). In panel a, we have a relatively horizontal curve with the exception of the two tails where the poorest are just below the 0 line and households between the 80th and 93rd percentile are the winners of this simulation. On the other hand, the simulation 2a consisting of taxing fossil fuels and subsidizing biofuel has a very slight positive slope. Interestingly, this simulations was the most efficient to reduce poverty in rural areas. The positive slope is coherent with the increase in inequality measured with the Gini index (+0.16).

Figure 4: Growth incidence curve for Rural

(a) Simulation 1a **(b) Simulation 2a**



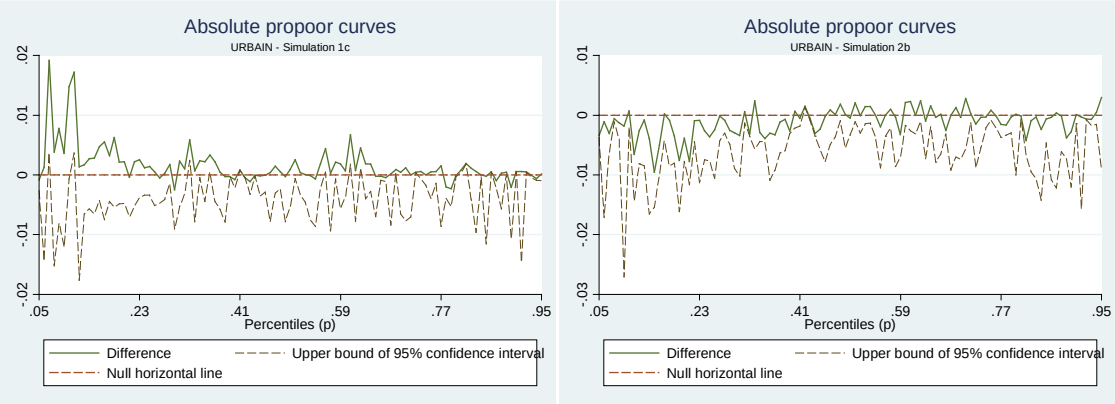
Source: Computed by authors from ELIM 2006 with DASP package

The other curves presented were computed for urban households for simulations 1c and 2b. These two curves are interesting insofar as the trend observed is not consistent through the entire distribution. For sim1c (panel a) we have a negative slope from the bottom of the distribution up to the 30th percentile and a flat curve to the top of the distribution. Hence,

this simulation is favorable to the poorest households with little distributional impact for the richest 70% of the population in urban areas. On the other hand, the sim2b (panel b) is slightly positively sloped below the 50th percentile and slightly negatively sloped above this 50th poverty line. In this case, the simulation is most favorable to the center of the distribution (between the 40th to the 70th percentile.

Figure 5: Growth incidence curve for Urban

(a) Simulation 1c **(b) Simulation 2b**



Source: Computed by authors from ELIM 2006 with DASP package

We complete the pro-poor analysis with a presentation of results from the Ravaillon and Chen (2003), Kakwani and Son (2003) and Kakwani and Pernia (2001) indices. Results are presented in Table 10 where PPG is used for pro-poor growth, PRG for pro-rich growth, PPR for pro-poor recession, PRR for pro-rich recession and PSPPG for non-strictly pro-poor growth[37].

[37] For Kakwani and Pernia (2001), when growth is positive and when $\psi>1$, it indicates that poor benefit proportionally more from growth compared to the rich. When $\psi<-1$ growth is pro-rich. For $0<\psi<1$, the growth is non strictly pro-poor and with $-1<\psi<0$ growth is non strictly pro-rich. For Kakwani and Son (2003), the equation of growth rate equivalent to poverty implies that growth will be pro-poor (pro-rich) if γ^* is greater (smaller) than γ. If γ^* takes a value between 0 and γ, growth will be accompanied by an increase in inequality but with a decrease in poverty (this is when we use NSPPG). For further explanation of these indices, the reader can consult Boccanfuso and Menard (2009).

Table 10: Pro-poor numerical analysis

	Pro-poor measure	Mali	Urban	Rural
Sim 1a	Growth	+	-	+
	Ravaillion & Chen (2003) - g	PPG	PRR	PRG
	Kakwani & Son (2003) - g	PRG	PRR	PPG
	Kakwani & Pernia (2001)	PRG	PPG	PPG
Sim 1b	Growth	+	+	+
	R&C (2003)	PRG	PRG	PPG
	K&S (2003)	PPG	NSPPG	PPG
	K&P (2001)	PPG	NSPPG	PPG
Sim 1c	Growth	+	+	+
	R&C (2003)	PRG	PRG	PRG
	K&S (2003)	NSPPG	NSPPG	PPG
	K&P (2001)	NSPPG	NSPPG	PPG
Sim 2a	Growth	+	+	+
	R&C (2003)	PPG	PRG	PRG
	K&S (2003)	PPG	NSPPG	PPG
	K&P (2001)	PPG	PPG	PPG
Sim 2b	Growth	+	-	+
	R&C (2003)	PRG	PRR	PRG
	K&S (2003)	NSPPG	PRR	NSPPG
	K&P (2001)	NSPPG	PPR	NSPPG
Sim 2c	Growth	+	+	+
	R&C (2003)	PRG	PRG	PRG
	K&S (2003)	NSPPG	NSPPG	PPG
	K&P (2001)	NSPPG	NSPPG	PPG
Sim 2d	Growth	+	+	+
	R&C (2003)	PRG	PRG	PRG
	K&S (2003)	NSPPG	NSPPG	PPG
	K&P (2001)	NSPPG	NSPPG	PPG

These results tend to confirm the graphical pro-poor analysis we have presented where no clear pattern can be extracted from this. The only simulation producing pro-poor growth with all indices is simulation 2a. For the rural zone, the simulation 1b is the only one generating pro-poor growth for the three indices and simulation 1a and 2a are the only one with at least one index to be pro-poor growth for the urban area. The Ravaillion and Chen (2003) index seem to generate pro-rich growth in most scenarios. Kakwani and Pernia (2001) generate 10 occurrences of pro-poor growth which Kakwani and Son (2002) eight cases of pro-poor growth.

5 Conclusions and final remarks

In this paper, we construct a CGE model and a microsimulation model to analyze the macroeconomic as well as distributional impact of the expansion of jatropha based biodiesel

industry in Mali. We considered two types of land for jatropha plantation: (a) idle land, which is not used for agriculture purpose nor is protected as a natural forest, and (b) land that has already been used for agriculture. In line with existing government plans, we considered scenarios where lands allocated to jatropha are increased by fifteen-fold and the capacity of biodiesel refineries is expanded accordingly. The study finds that the expansion of biodiesel industry (i.e., both farming and oil conversion activities), would increase GDP, though slightly, if idle lands are utilized for jatropha cultivation. However, the expansion of jatropha would cause a slight loss in GDP if the existing agriculture land is used for jatropha cultivation. From the macroeconomic perspective, expansion of jatropha based biodiesel industry would be beneficial to the country only if the plantation of jatropha is carried out on idle lands instead of existing agriculture lands.

The distributional results are slightly different. The study finds that rural poverty would decrease no matter whether idle lands or existing agricultural lands are used for jatropha plantation, although the percentage reductions in rural poverty are higher in the former compared to the latter case. This is because jatropha plantation would provide higher returns to land and rural labor. The urban households are the losers from the expansion of jatropha based biodiesel as these households face price increases for other food staples and do not get the benefits from the increase of jatropha based biodiesel outputs. At the national level, the distributional impacts are more favorable as the share of rural households is much higher compared to that of urban households. On the other hand, since the returns do not pass to the urban poor, they do not get any benefits of expanding jatropha based biodiesel industry. These results imply that a policy to expand jatropha based biodiesel industry in Mali should be implemented along with some safeguard measures to protect the urban poor from potential negative consequences.

This analysis can be extended for improved distributional analysis. The small size of the sector at the reference period constrains us in the size of the expansion of the sector. Converting the model into a sequential dynamic CGE model would help us introduce incremental growth of the sector. However, performing distributional analysis with a dynamic CGE model presents important challenges as one needs to determine who will benefit from the growth and depreciation of production factors. Very few authors have proposed a convincing methodology to perform such an analysis. Another interesting extension of this model would be to introduce some endogeneity in the agricultural households' behavior allowing them to switch from one crop to the other. The exogenous land endowment limits this type of behavior. This type of application will require some further investigation on household behavior at the micro level for which we lack adequate databases.

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Appendix

The detailed CGE model developed for the study

Definition of variables, parameters and sets

Endogenous variables

M_{im} : imports

Q_i : composite good

XS_i : sectorial output

Va_i : value added

CII_i : Total intermediate consumption

CI_i : Total intermediate consumption excluding energy

CIE_i : Total energy intermediate consumption

$Fuel_i$: Total fuel input

$Energ_i$: Non fuel energy input

$FFuel_i$: Fossil fuel input

$BFuel_i$: Biofuel input

Ex_e : exports

D_i : Interior supply for domestic production

$Di_{i,j}$: Intermediate consumption of non energy inputs

Dit_i : Total demand of intermediate inputs

$Ldnq_i$: Non qualified labor demand

Ldq_i : Qualified labor demand

Ld_i : Composite labor demand

Kdt_i : Composite capital of land and regular capital

$Land_i$: Demand for land

Kd_{ag} : Capital demand

w^1 : qualified wage

w^2 : non qualified wage

r_m : sectorial price of capital

rr : price of agricultural capital

pt_{ag} : price of land

pkt_i : composite price of land and capital

pii_i : price of total intermediate consumption excluding energy

pci_i : price of total intermediate consumption

pce_i : price of total energy composite input

pca_i : price of composite fuel input

w_i : sectorial composite wage

Ym_h : household income

Sm_h : household savings

Ydm : household disposable income

Ye : revenu des entreprises

Se : épargne des entreprises

Ti_m : indirect taxes

Tim_{im} : import duties

Tie_e : export taxes

Td_h : household income tax

Tde : firms income tax

Yg : government revenues

Sg : government savings

$C_{h,i}$: household expenditure matrix

Ctm_h : discretionary expenditure of household

Inv_i : investissement demand

Cg_i : sectoriel government consumption

Pe_e : domestic price of exports

Pm_{im} : domestic price of imports

Pq_i : composite market price

Pd_i : domestic price of locally produced good including tax

Pl_i : domestic price of locally produced good excluding tax

P_i : producer price

Pv_i : value added price

e : nominal exchange rate

It : total investment

Exgoneous variables

Kd_{nag} : non agricultural capital stock

Kdo_{ag} : agricultural capital stock at reference period

$Ldhq_h$ *:* dotation de travail formel des ménages

$Ldhnq_h$ *:* dotation de travail formel des ménages

Div : Dividend

G : total public consumption

$Pindex$: price index (GDP deflator)

$Dldw$: foreign qualified labor endowment

Sr : Current account balance or foreign savings

Tgm_h : government transfers to household

$Term$: dividend paid to rest of world

Tge : government subsidies to firms

Tme : household transfers to firms

$Trme$: rest of world transfers to firms

$Trmm_h$: rest of world transfers to household

$Tmrm_h$: household transfers to other household

Pwm_{im} : world price of imports

Pwe_e : world price if export

Trg : rest of world transfers to government

Tgr : government transfers to rest of world

Definition of Parameters

δ_{im}^{m} : distributive parameter of CES for imports

σ_{im}^{m} : elasticity of substitution of CES for imports

B_{im}^{m} : Scale parameter of CES for imports

ρ_{im}^{m} : parameter of the CES function for imports

B_e^e : scale parameter of CET for exports

δ_e^e : distributive parameter of CET for exports

ρ_e^e : parameter of the CET function for exports

σ_e^e : elasticity of transformation of CEt for exports

δ_i^l : distributive parameter of CES for labor

σ_i^l : elasticity of substitution of CES for labor

B_i^l : Scale parameter of CES for labor

ρ_i^l : parameter of the CES function for labor

δ_{ag}^K : distributive parameter of CES for land and capital

σ_{ag}^K : elasticity of substitution of CES for land and capital

B_{ag}^K : scale parameter of CES for land and capital

ρ_{ag}^K : parameter of the CES function for land and capital

δ_i^{ii} : distributive parameter of CES for total intermediate inputs

σ_i^{ii} : elasticity of substitution of CES for total intermediate inputs

B_i^{ii} : scale parameter of CES for total intermediate inputs

ρ_{energi}^{ie} : parameter of the CES function for total intermediate inputs

δ_{energi}^{ie} : distributive parameter of CES for composite energy input

σ_{energi}^{ie} : elasticity of substitution of CES for composite energy input

B_{energi}^{ie} : scale parameter of CES for composite energy input

ρ_{energi}^{ie} : parameter of the CES function for composite energy input

δ_i^{fu} : distributive parameter of CES for composite fuel

σ_i^{fu} : elasticity of substitution of CES for composite fuel

B_i^{fu} : scale parameter of CES for composite fuel

ρ_i^{fu} : parameter of the CES function for composite fuel

λ_h^{ka} : agricultural capital income share of households

λ_h^{Land} : land capital income share of households

λ_h^{knag} : non agricultural capital income share of households

λ_f^{ka} : agricultural capital income share of firms

λ_f^{Land} : land capital income share of firms

λ_f^{knag} : non agricultural capital income share of firms

λ_g^{ka} : agricultural capital income share of government

λ_g^{Land} : land capital income share of government

λ_g^{knag} : non agricultural capital income share of government

λ_{row}^{ka} : agricultural capital income share of firms

λ_{row}^{Land} : land capital income share of firms

λ_{row}^{knag} : non agricultural capital income share of firms

v_i : Leontief coefficient of value added

io_i : Leontief coefficient of total intermediate inputs

A_m : Scale parameter of Cobb-Douglas function

α_m : value share of labor of the Cobb-Douglas function

aij_{ij} : input-output coefficient

tx_i : indirect tax rate

tm_{im} : import duties tax rate

tye : firms' income tax rate

tym_h : households' income tax rate

$\gamma_{h,j}$: non discretionary expenditure by households

$\beta^{c}_{i,h}$: value share of discretionary household expenditure

ψ_{h} : marginal propensity to save of households

μ_{i} : value share of investment demand

β^{g}_{i} : value share of government expenditure

β^{v}_{i} : value share of sectoral value added

Defining sets

i,j : all sectors
m : tradable sectors
snm : non-tradable sectors (public sector)
im : import sectors
nim : non import sectors
e : export sector
ne : non export sector
ag : agricultural sectors
nag : non agricultural sectors
energi : energy sectors
nenergi: non energy sectors
h : household categories

Defining sub-sets

elec : other energies or electricity (i) and (energy)
biof : biofuel (i) and (energy)
carb : fossil fuel (i) and (energy)

Model Equations

Production

A. 1. $$Xs_i = \frac{Va_i}{v_i}$$

A. 2. $$CII_i = io_i Xs_i$$

A. 3. $$Va_m = A_m Ld_m^{\alpha_m} Kdt_m^{1-\alpha_m}$$

A. 4. $$Va_{snm} = Ld_{snm}$$

A. 5. $$Ld_m = \frac{\alpha_m Pv_m Va_m}{w_m}$$

A. 6. $$Ld_{snm} = \frac{P_{snm} Xs_{snm} - \sum_j Di_{j,snm} Pq_{snm}}{w_{snm}}$$

A. 7. $$Ld_i = B_i^l \left[\delta_i^l Ldnq_i^{-\rho_i^l} + \left(1-\delta_i^l\right) Ldq_i^{-\rho_i^l} \right]^{-\frac{1}{\rho_i^l}}$$

A. 8. $$Ldnq_i = \left[\left(\frac{\delta_i^l}{1-\delta_i^l} \right) \left(w^1 / w^2 \right) \right]^{-\sigma_i^l} Ldq_i$$

A. 9. $Kdt_{ag} = B_{ag}^{K}\left[\delta_{ag}^{K} Kd_{ag}^{-\rho_{ag}^{k}} + \left(1-\delta_{ag}^{K}\right) Land_{ag}^{-\rho_{ag}^{K}}\right]^{-\frac{1}{\rho_{ag}^{K}}}$

A. 10. $Land_{ag} = \left[\left(\frac{\delta_{ag}^{K}}{1-\delta_{ag}^{K}}\right)\left(rr \Big/ pt_{ag}\right)\right]^{\sigma_{ag}^{K}} Kd_{ag}$

A. 11. $Kdt_{nag} = Kd_{nag}$

A. 12. $CII_{i} = B_{i}^{ii}\left[\delta_{i}^{ii} Cie_{i}^{-\rho_{i}^{ii}} + \left(1-\delta_{i}^{ii}\right) Ci_{i}^{-\rho_{i}^{ii}}\right]^{-\frac{1}{\rho_{i}^{ii}}}$

A. 13. $Cie_{i} = \left[\left(\frac{\delta_{i}^{ii}}{1-\delta_{i}^{ii}}\right)\left(pii_{i} \Big/ pce_{ii}\right)\right]^{\sigma_{i}^{ii}} Ci_{i}$

A. 14. $CIE_{energi} = B_{energi}^{ie}\left[\delta_{energi}^{ie} Fuel_{energi}^{-\rho_{energi}^{ie}} + \left(1-\delta_{energi}^{ie}\right) Energ_{energi}^{-\rho_{energi}^{ie}}\right]^{-\frac{1}{\rho_{energi}^{ie}}}$

A. 15. $CIE_{nenergi} = Fuel_{nenergi}$

A. 16. $Fuel_{energi} = \left[\left(\frac{\delta_{energi}^{ie}}{1-\delta_{energi}^{ie}}\right)\left(pq_{elec} \Big/ pca_{energi}\right)\right]^{\sigma_{i}^{ii}} Energ_{energi}$

A. 17. $Fuel_{i} = B_{i}^{fu}\left[\delta_{i}^{ie} FFuel_{i}^{-\rho_{i}^{fu}} + \left(1-\delta_{i}^{fu}\right) BFuel_{i}^{-\rho_{i}^{fu}}\right]^{-\frac{1}{\rho_{i}^{fu}}}$

A. 18. $FFuel_{i} = \left[\left(\frac{\delta_{i}^{fu}}{1-\delta_{i}^{fu}}\right)\left(pq_{biof} \Big/ pq_{carb}\right)\right]^{\sigma_{i}^{ii}} BFuel_{i}$

A. 19. $Di_{m,j} = aij_{m,j} CI_{j}$

Income and savings

A. 20. $$Ym_{h} = w^{1} Ldhq_{h} + w^{2} Ldhnq_{h} + Tgm_{h} + Trmm_{h} + Tmrm_{h} + Div_{h} + \lambda_{h}^{ka} rr\left(\sum_{ag} Kd_{ag}\right) + \lambda_{h}^{Land}\left(\sum_{ag} pt_{ag} Land_{ag}\right) + \lambda_{h}^{knag}\left(\sum_{nag} r_{nag} Kd_{nag}\right)$$

A. 21. $Ydm_{h} = Ym_{h} - Td_{h} - Tmrm_{h} - Tme$

A. 22. $$Ye = Tge + Trme + Tme + \lambda_{e}^{ka} rr\left(\sum_{ag} Kd_{ag}\right) + \lambda_{e}^{Land}\left(\sum_{ag} pt_{ag} Land_{ag}\right) + \lambda_{e}^{knag}\left(\sum_{nag} r_{nag} Kd_{nag}\right)$$

A. 23. $Sm_{h} = \psi_{h} Ydm_{h}$

A. 24. $Se = Ye - \sum_{h} Div_{h} - Tde - Term$

Government income and savings

A. 25. $$Yg = \sum_{im} Tim_{im} + \sum_{h} Td_{h} + \sum_{m} Ti_{m} + Tde + Trg + \lambda_{gov}^{ka} rr\left(\sum_{ag} Kd_{ag}\right) + \lambda_{gov}^{Land}\left(\sum_{ag} pt_{ag} Land_{ag}\right) + \lambda_{gov}^{knag}\left(\sum_{nag} r_{nag} Kd_{nag}\right)$$

A. 26. $Sg = Yg - G - \sum_{h} Tgm_{h} - Tgr - Tge$

A. 27. $Ti_{im} = tx_{im}\left(Pl_{im} D_{im}\right) + tx_{im}\left(1 + tm_{im}\right) ePwm_{im} M_{im}$

A. 28. $Ti_{nim} = tx_{nim}\left(Pl_{nim} D_{nim}\right)$

A. 29. $Tie_{ex} = te_{ex} pe_{ex} EX_{ex}$

A. 30. $Tim_{im} = tm_{im} ePwm_{im} M_{im}$

A. 31. $Tde = tyeYe$

A. 32. $Td_h = tym_h Ym_h$

Forgien trade

A. 33. $M_{im} = \left[\left(\frac{\delta_{im}^m}{1-\delta_{im}^m} \right) \left(\frac{Pq_{im}}{Pm_{im}} \right) \right]^{\sigma_{im}^m} D_{im}$

A. 34. $Q_{im} = B_{im}^m \left[\delta_{im}^m M_{im}^{-\rho_{im}^m} + \left(1-\delta_{im}^m\right) D_{im}^{-\rho_{im}^m} \right]^{-\frac{1}{\rho_{im}^m}}$

A. 35. $Xs_e = B_e^e \left[\delta_e^e Ex_e^{\rho_e^e} + (1-\delta_e^e) D_e^{\rho_e^e} \right]^{\frac{1}{\rho_e^e}}$

A. 36. $Ex_e = \left[\left(\frac{1-\delta_e^e}{\delta_e^e} \right) \left(\frac{Pe_e}{Pl_e} \right) \right]^{\sigma_e^e} D_e$

A. 37. $Q_{nim} = D_{nim}$

A. 38. $Xs_{ne} = D_{ne}$

Interior demand

A. 39. $C_{h,i} = \gamma_{h,i} + \beta_{h,i}^c \left[\frac{Ctm_h - \sum_j Pq_j \gamma_{h,j}}{Pq_i} \right]$

A. 40. $Ctm_h = Ydm_h - Sm_h$

A. 41. $Dit_m = \sum_j aij_{m,j} CI_j$

A. 42. $Inv_i = \frac{\mu_i It}{Pq_i}$

A. 43. $Cg_i = \frac{\beta_i^g G}{Pq_i}$

Prices

A. 44. $Pm_{im} = (1 + tx_{im})(1 + tm_{im}) ePwm_{im}$

A. 45. $Pv_i = \frac{P_i Xs_i - \sum_j Di_{j,i} Pq_j}{Va_i}$

A. 46. $r_{nag} = \frac{Pv_{nag} Va_{nag} - w_{nag} Ld_{nag}}{Kd_{nag}}$

A. 47. $Kd_{ag} = \frac{Pv_{ag} Va_{ag} - pt_{nag} Land_{nag}}{rr}$

A. 48. $w_i = \frac{w^1 Ldq_i + w^2 Ldnq_i}{Ld_i}$

A. 49. $pkt_{ag} = \frac{pt_{ag} Land_{ag} + rrKd_{ag}}{Kdt_{ag}}$

A. 50. $$pkt_{nag} = \frac{pt_{nag} Land_{nag} + r_{nag} Kd_{ag}}{Kdt_{nag}}$$

A. 51. $$Pe_e = \frac{Pwe_e e}{1 + te_e}$$

A. 52. $$Pq_{im} = \frac{Pd_{im} D_{im} + Pm_{im} M_{im}}{Q_{im}}$$

A. 53. $$Pq_{nim} = Pd_{nim}$$

A. 54. $$pci_i = \frac{pce_i CIE_i + pii_i CI_i}{CII_i}$$

A. 55. $$pce_i = \frac{pca_i Fuel_i + pq_{elec} Energ_i}{CIE_i}$$

A. 56. $$pca_i = \frac{pq_{carb} FFuel_i + pq_{biof} BFuel_i}{Fuel_i}$$

A. 57. $$pii_i = \frac{\sum_j pq_j CI_{j,i}}{CII_i}$$

A. 58. $$Pd_i = Pl_i (1 + tx_i)$$

A. 59. $$P_i = \frac{Pl_i D_i + Pe_i Ex_i}{Xs_i}$$

A. 60. $$Pindex = \beta_i^v Pv_i$$

Equilibrium conditions

A. 61. $$Sr = \sum_{im} Pwm_{im} M_{im} + \tfrac{1}{e}(Term + Tgr) + \tfrac{1}{e} sDldw - \sum_e Pwe_e Ex_e - \tfrac{1}{e}(Trme + Trg + \sum_h Trmm_h) + \lambda_{row}^{ka} rr(\sum_{ag} Kd_{ag}) + \lambda_{row}^{Land}(\sum_{ag} pt_{ag} Land_{ag}) + \lambda_{row}^{knag}(\sum_{nag} r_{nag} Kd_{nag})$$

A. 62. $$Q_i = C_i + Dit_i + Inv_i + Cg_i$$

A. 63. $$It = Se + Sg + eSr$$

A. 64. $$\sum_h Ldhnq_h = \sum_i Ldnq_i$$

A. 65. $$\sum_h Ldhq_h + Dldw = \sum_i Ldnq_i$$

A. 66. $$\sum_{ag} Kdo_{ag} = \sum_i Kd_{ag}$$