BEFS

Bioenergy and Food Security Project

An Economic Assessment of Alternative Production Pathways for Peruvian Biofuels Production

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IFPRI

Bioenergy and Food Security Project

Introductory Note

Using a Computable General Equilibrium (CGE) Model to analyze the effects of biofuel polices in Peru

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Introduction

In 2007 a blending policy was established in Peru imposing the following mandates:

Biodiesel:

- obligatory 2% (B2)blending starting in 1 January 2009
- obligatory 5% (B) blending starting in 1 January 2011 to replace B2

Ethanol:

- obligatory 7.8% starting in 1 January 2009.

The two main objectives of the biofuel blending mandate are i) to diversify energy sources and ii) to create growth and employment opportunities. It is this second objective that has provoked much interest within the policy machinery of Peru. A key question is how the biofuel mandates in Peru should be implemented to optimize the social benefits that could potentially emerge. There are of course many avenues through which biofuels can be developed. However, specific biofuel pathways may potentially offer greater social and economic benefits compared to others. Thus, the BEFS project in Peru commissioned a Computable General Equilibrium (CGE) analysis in order to quantify the economy-wide impacts of implementing particular biofuel pathways. The advantage of the CGE approach is its ability to measure the ultimate impact of a policy or a number of policies on aggregate welfare by quantifying the change in the income and consumption of various groups who may be affected by the policy either directly or indirectly.
In the context of the Peruvian biofuel mandate, the CGE model simulates the expansion of biofuels production by predicting changes in consumer prices and household incomes. This is then used to estimate changes in poverty, both at the national level and for different households groups (e.g., rural/urban). The CGE analysis in Peru considered nine alternative production scenarios or pathways to explore the impact of developing the biofuel sector on the economy of Peru[1].

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[1] Five analyze the impact of ethanol production and four analyze the impact of biodiesel production. Ethanol and biodiesel are produced using a variety of technological pathways using two feedstocks for

Constructing a CGE model for an analysis of biofuel policy on development variables

In using CGE models to analyse any developmental impacts of biofuels policy the set-up of a model becomes quite critical. The set-up refers to the characteristics of the model and the assumptions used to define the model. CGE models can be country, regional or globally based. Since the BEFS project was interested in looking only at impacts within Peru a one-country CGE model was developed. A number of assumptions have been made with respect to employment, technology and other key parameters. Generally speaking assumptions should relate to the economy under consideration but in all cases they can be relaxed or made more stringent depending on the kinds of questions that a policy-maker want to answer. Sometimes assumptions are made for analytical simplicity and do not alter the outcome of the results generated by the model.

The distinction between static and dynamic models is an important one in CGE analysis. The use of a particular type of model depends on the kind of policy impacts a government is interested in analysing. In some cases a static model may serve the policy purpose and in other cases a dynamic model is more useful.

A **static** or **comparative-static** CGE model considers the effects on an economy of a policy change of the economy **at only one point in time**. From a policy analysis point of view, these results show the difference (usually reported in percent change form) between two alternative future states (with and without the policy shock). The process of adjustment to the new equilibrium is not explicitly represented in such a model. However, while a static model provides a one-time snapshot of policy impacts some policymakers may be interested in seeing what happens during the period of transition. For example, there may be unemployment and poverty effects during adjustment which are not captured by the analysis. Secondly, social benefits from a particular policy may take time to take effect. A static model may only partially capture full effects. In addition, any negative shorter term effects may be offset in the longer term and vice-versa. For this reason policy-makers may prefer a dynamic analysis.

By contrast, a **dynamic** CGE models explicitly traces each variable through time—often at annual intervals. These models are more realistic, but more challenging to construct and solve—they require for instance that future changes are predicted for all exogenous variables, not just those affected by a possible policy change.

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each biofuel. Sugarcane and molasses produce ethanol, and palm oil and jatropha produce biodiesel. For both biofuels, feedstock production in most cases (except for molasses and one of the palm oil producing scenarios) is a 60/40 share between large scale commercial farms and smallholders, respectively.

As time constraints did not permit for a dynamic analysis, the CGE analysis used in Peru uses a static model that assumes full employment of production factors. Whilst this assumption is quite limiting, the static model provides a preliminary basis for raising awareness on some policy and methodological issues. However, given that the static model measures impacts only at one point in time it is clear that a future analysis should be based on a dynamic model to show the trajectory of impacts. Moreover, some of the assumptions of the static model can be changed to allow for sensitivity analyses in order to shows how impacts change depending on the assumptions and model specifications.

The Peru CGE analysis- a starting point for future analysis

The Peru analysis has been carried out using the Standard Static IFPRI model. This was used to quantify the effects of developing the biofuel sector in Peru and its impact on sectoral and economy-wide productivities, resource allocation, and welfare. The analysis to date should be seen as an exploratory analysis to illustrate how CGE models can be used to consider outcomes from specific biofuel pathways. As with any analysis, there is always an opportunity to enrich the way a model is constructed to allow for a more in depth consideration of specific effects.

Thus the results of this analysis must not be seen as definitive or predictive in any sense. Rather, the model illustrates some important issues that would require a more comprehensive CGE analysis set in a dynamic framework without the full employment assumption. This would allow for a better examination of development effects over time and specifically to capture growth and employment effects. The static model full-employment model is constrained by only allowing redistributive effects to take place. The assumption of full-employment means that the growth effects from biofuels policy cannot be fully captured.

A further direction for future analysis relates to the household sector. In the current analysis this is divided into rural and urban households. A future analysis may well consider rural/urban, regional, and poverty status. Thus households could be disaggregated for example as:

urban/poor and urban/non-poor
Selva/poor and Selva/non-poor
Coastal/poor and Coastal/non-poor

Such a classification would capture better the rural dimension of poverty in Peru. Depending on government priorities other decisive household characteristics may be included within the model such as female-headed households or indigenous households.

The CGE analysis in Peru to date presents a generalized and preliminary consideration of the impacts biofuel policy on the Peruvian economy. For the government wanting to use CGE analysis further, negotiations will be required between the policy machinery and CGE analysts in order to determine the precise nature of what is to be analysed. On the basis of this, a model that reflects the areas of interest of any impacts from a policy change can be set up. In addition negotiations are a necessary part in gaining consensus in how to define the key characteristics of the economy so that the final model reflects the reality and to allow for specific impacts to be identified.

It is a serious mistake to use CGE analyses as an economic crystal ball. Results generated by CGE models are **not** forecasts but relate to how one set of results differs from the benchmark equilibrium of the model. In other words, how do the results of a particular biofuel pathway compare to the identified benchmark of no biofuel mandates in Peru? It should be noted that the strength of CGE analyses for policy purposes does **not** lie in their predictive accuracy, but in their ability to shed light on the economic mechanisms through which price adjustments are transmitted in markets.

CGE models are often used to consider "what if "scenarios. Indeed, in Peru the CGE analysis asks: what if feedstocks are produced through a 60-40 partnership of large farms and smallholders, what are the impacts on the economy. These impacts however should to be analyzed in terms of the **dynamics** of the economic interactions that generate them. This means, critically, one needs to distinguish to what extent results are generated by the characteristics and assumptions of the model. CGE analysis often does not account for these linkages. Thus, sensitivity analysis plays an important role in examining the extent to which results are driven by the model characteristics. The Peru analysis carried out a number robustness tests to show the impacts of changes in assumptions.

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Executive Summary

This study explores the potential impact of the biofuel promotion policies implemented in recent years by the Government of Peru on the country's macro economy, sectoral production and welfare. The study uses a single country static Computable General Equilibrium Model (CGE), the appropriate analytical tool when quantifying the economy-wide effects of policy changes. The CGE model relies on the 2002 Social Accounting Matrix (SAM) for Peru, as the main database and simulates the effects of various scenarios reflecting the government mandatory blending policy under alternative assumptions. Relying on a static model and assuming full employment of production factors, this study does not aim to capture exhaustively all the growth mechanisms associated to the biofuel policies. It should be considered as an exploratory work that raises awareness on important policy and methodological issues.

The biofuel policy is being implemented under blending policy mandates for biodiesel and ethanol production. Nine production scenarios are analyzed based on the different sources of feedstock and production (smallholders and/or commercial farms)[3]. Four types of feedstock are considered: sugar cane ethanol, molasses from sugarcane, palm oil, and jatropha. Four land markets are considered to reflect differences between two regions (coastal and jungle), and two farm technologies (smallholder and commercial farms) are used to produce the feedstock used for biofuel production. Within this framework, it is assumed that the effects of a mandatory blending policy would lead to the consumption of 3,600 barrels of petroleum equivalent per day (BPD) of biodiesel and 1,100 BPD of ethanol by 2015. Initially, the production of biofuels is assumed to be zero and trade is not allowed to take place.

On one hand, the results indicate that the ethanol mandatory policy based on sugar cane has no significant effects on the Peruvian real GDP, and the biodiesel mandate leads to a minimal efficiency cost (up to 0.07% of real GDP) if palm oil is used. On the other hand, using only molasses for the production of fuel ethanol would be more costly, in particular if they are currently used efficiently by other industries, if no demand exists for the additional sugar production, or if the sugar sector (and sugar mills) remains located in the coastal area where land is scarce.

Under the assumption of constant taxation of fuel, using biofuels would increase the cost of the fuel for both, intermediate users –i.e. the transportation sector - and final users – i.e. the consumer - thus leading to a decline in fuel consumption. This effect is very limited when sugar ethanol is used, however, when molasses and jatropha are used as feedstock, prices can rise, in the most adverse case, by up to 20% and 9%, respectively. Under a mandatory policy, consumers bear the cost of such a policy. Given their pattern of consumption, urban households will suffer net real income losses from such a policy. However, in the case of subsidies or tax reduction – not considered in this study – urban households, that are the main taxpayers, may also suffer a similar cost.
Agricultural value added increases significantly (more than 1%) only under the biodiesel scenarios due to the land expansion. Similar results are found when molasses is used for ethanol production because sugar cane production has to increase on a much larger scale when molasses is used than when sugar cane juice is used directly. Non-biofuel agricultural production

[3] These represent the central case for the model's results. They are not to be confused with results that stem from the different robustness checks performed further on.

is not impacted when expansion takes place in the jungle area as there is no competition for land amongst the crops. When molasses is used for ethanol production, land competition and macroeconomic downturns lead to a fall in production of nearly 1% in both, cereal and livestock production. When sugar cane expansion takes place in the coastal area, the production of crops, other than sugarcane, declines by about 0.2%.

In general, rural household income expands as a result of the biofuel mandates, except under the molasses and the low-yield jatropha scenarios. Gains to rural households come at the expanse of urban households who incur higher costs as a result of higher fuel prices. More specifically, when sugarcane is used directly in ethanol production, income of rural households increases by 12 million soles (0.04%) in jungle area and 22 million of Soles (0.08%) in coastal areas. Under the biodiesel mandate, the increase in income for rural households ranges between 16 (0.06%) and 47 (0.17%) million Soles, respectively, the latter attributable to jatropha being supplied by high-yield smallholders. These results suggest that a biofuel policy that aims to benefit rural households and smallholders[4] would do so to the disadvantage of urban households who would stand to lose more than 500 million Soles. Only ethanol policies may have positive or neutral overall outcomes on both the rural and urban households.

The results from this exploratory analysis are quite significant: first, imposing a blending target on biodiesel when Peru's comparative advantage is in the production of ethanol, makes it a relatively inefficient tool to redistribute income and reduce poverty in rural areas. Second, coupled with the upward trend in diesel use, a blending target on biodiesel would lead to high economic costs. Finally, the high cost of fuel for road transportation may also lead to adverse consequences for the most remote locations and the poor regions across Peru by increasing transportation costs nationwide.

In order to provide a more comprehensive analysis of complementary policy considerations to Peru's biofuel strategy, the authors test for robustness by introducing alternative assumptions. Three checks for robustness are conducted: introducing alternative assumptions to the land market (the supply of land increases to balance demand, and smallholders are also allowed access to the new lands); liberalizing trade; and freeing the markets of feedstock for fuel blenders.

The first test of robustness highlights the role of the land market in Peru. Relaxing the land constraints in the coastal areas leads to positive results and even the large losses incurred under the molasses scenarios are eliminated. Similarly, giving smallholders access to more land will mitigate the increase in their production costs under the jatropha scenarios - where smallholder participation is greater and land requirements are higher than in palm oil production - and consequently, reduces the total cost of the biodiesel policy.

Removing trade barriers leads to more trade in ethanol and biodiesel. Local production of biodiesel disappears, since no feedstock appears to be competitive, and ethanol production and exports increase. Trade liberalization, under biodiesel promotion, leads to a worse outcome than under the autarkic strategy that uses palm oil.

[4] By imposing the biodiesel mandate.

When fuel blenders are allowed to choose the most cost effective feedstock the most efficient production process for ethanol is the one that uses sugarcane grown in the jungle and that for biodiesel it is the use of palm oil as a feedstock in a 60/40 production mix between large firms and smallholders.

Introduction and Background

The economy of Peru mirrors its geographic characteristics, and is currently split between a modern sector in the coastal area, and less-developed inland areas of the Sierra and Selva regions. Extreme poverty continues to be higher in the Sierra and Selva regions in particular in rural areas. As of 2001, about 61% and 41% of the population in these regions, respectively, did not have enough income to cover their essential food needs. Although the share of the agricultural sector in GDP has generally been following a downward trend, the main income source for rural households continues to be from agriculture, directly and indirectly. Consequently, it is important for governments to consider strategies for rural development. This project analyzes whether biofuel development may be considered an instrument toward this objective.

For Peru the main crops for biofuel production are sugar cane (including molasses), palm oil and jatropha. A blending policy was established in 2007 imposing a mandate for biofuel blending. Starting January 1st of 2009, there is an obligatory biodiesel of 2% (B2) that would rise to a 5% blending by January 1st, 2011. Ethanol has an obligatory blending of 7.8% that starts in January 1st, 2009. The objective behind the biofuel blending mandates is to diversify the energy sources and create growth and employment opportunities for the Peruvian economy. Biofuel development is also seen as part of the country's anti-narcotics initiatives, where the development of biofuel feedstocks, especially in the Amazon region, is viewed as an alternative to drug cultivation.

The objective of the study is to analyze, within a general equilibrium framework, the economy-wide effects from the development of the biofuel industry in Peru. Alternative scenarios and technologies are assumed to illustrate the cost and benefits of different options.

The main database used for the Peru Biofuel Model is the 2002 Social Accounting Matrix (SAM) for Peru. Other data is included to supplement the SAM data for the production and prices of key sectors in the economy. Detailed cost structures for each feedstock production process, as well as for ethanol and biodiesel production, are also used to complement the data. There are four land markets, land for commercial farms and land for smallholders in both the coastal and jungle areas of Peru. In order to discuss more comprehensively the impact of the biofuel policy on rural livelihoods and welfare, the household sector is divided into rural and urban households who have different demand and income structures and consequently would be affected differently by these policies. The SAM also distinguishes between skilled, semi-skilled and unskilled labor.

This study uses a single country static CGE model adapted for Peru to analyze the biofuel promotion policies implemented by the Government of Peru. Two types of feedstock - sugar cane ethanol and molasses from sugar cane – are considered for ethanol production and two feedstocks - palm oil and jatropha- are considered for biodiesel production. Initially, the production of biofuels is assumed to be zero and trade is not allowed to take place. Within this framework, it is assumed that the effects of a mandatory blending policy would lead to the consumption of 3,600 barrels of petroleum equivalent per day (BPD) of biodiesel and 1,100 BPD of ethanol by 2015.

The Peru Biofuel Model operates under the full employment assumption to analyze nine production scenarios that differ based on the different feedstocks and production technologies used to produce ethanol and biodiesel[5]. For each type of biofuel under consideration, the model distinguishes between the production pathway of commercial farmers who operate at a high level of technology (inputs, fertilizer, etc.) and that of smallholders who operate at a more traditional level. In all but one scenario, the feedstocks are grown and supplied to the fuel blenders under a fixed ratio of 60% originating from commercial farms and 40% from smallholders, according to the mandate set by the Government of Peru to ensure smallholder participation in the national biofuel policy. Results from the nine scenarios are compared to the baseline case of no biofuel mandate, highlighting the effects on Peru's macro economy, sectoral production and welfare.

In order to provide a more comprehensive analysis of complementary policy considerations to Peru's biofuel strategy, three robustness checks are conducted. The results of these robustness checks shed light on future research that may be needed to enrich the current exploratory work. The first robustness check introduces alternative land assumptions in order to highlight the role of the land market in Peru and the second check involves removing trade restrictions from the model by allowing new exports and imports to take place. The final robustness check allows fuel blenders to choose the most cost effective feedstock for the production of the relevant mandated biofuel.

The report is structured as follows: Chapter II discusses the general CGE methodology used and the adaptations introduced to the standard CGE model to represent the Peruvian economy and the biofuel sector. Chapter III presents the database used for the model: the 2002 SAM for Peru. Chapter IV discusses simulation results from nine biofuel promotion scenarios. Chapter V discusses the different robustness checks undertaken, and finally, Chapter VI concludes, highlighting the different policy options available as a result of this exploratory undertaking.

[5] These represent the central case for the model's results. This is not to be confused with results that stem from the different robustness checks performed further on.

CGE Methodology[6]

Standard CGE Model Assumptions

A static computable general equilibrium (CGE) model is the appropriate tool to capture the economic relationships and links between the macro and micro sectors of the Peru economy, with a specific focus on the Biofuel sector. This CGE model is used to quantify the effects of developing the biofuel sector in Peru and its impact on sectoral and economy-wide productivities, resource allocation, and welfare. One advantage of CGE models is that they capture the price and resources allocation effects of policy changes after market adjustment in a consistent macroeconomic framework. Typically, a CGE model consists of set of linear and non linear equations that are solved simultaneously, and the resultant solution is a general equilibrium in all markets providing a complete and consistent picture of the “circular flow” in an economy, and at the same time accounting for all market-based interactions among economic agents (Robinson 1989). The behavior of commodity and factor markets is based on standard microeconomic theory where households maximize utility from consumption under budget constraints, and producers maximize profits given the existing technology. The model traces the impact of an exogenous shock on growth and income distribution through its effect on factor wages and employment which in turn affect the incomes and expenditures of the various household groups given their initial structure of factor ownership. CGE models portray the household level impacts of policy changes by having a representative household (RH) that represents all the individuals in a particular class or group.

The model used for Peru follows the IFPRI Standard static CGE model (Lofgren et al. 2002). The model has been extended to explicitly include disaggregated agricultural and food processing sectors, accounting for different technologies in the production of crops that provide feedstocks to the Peru’s biofuel sector. The model simulates various scenarios that aim to quantify the magnitude and direction of alternative biofuel policy directives on the Peruvian economy. The following sections describe four key components of the model in Lofgren et al. (2002): (1) activities, production, and factors; (2) institutions; (3) markets; and (4) model closures or macroeconomic balances.

Activities, Production, and Factors

Each production sector (activity) is assumed to maximize profits subject to constraints from the assumed production technology and factor market employment rigidities. The technology structure is shown in Figure 1, where it is represented by nested CES (constant-elasticity-of-substitution) and Leontief (fixed-coefficient) functions.

At the top level, the technology is specified by a Leontief function that would determine the mix between quantities of value added and aggregate intermediate input. Value added is itself a CES function of primary factors[7] whereas the aggregate intermediate input is a Leontief function of disaggregated intermediate inputs.

Each activity produces one or more commodities according to fixed yield coefficients and any commodity may be produced by more than one activity. For instance, the activity ‘Sugar’ produces, both, the ‘Sugar’ and the ‘Molasses’ commodities and the ‘Ethanol’ commodity is produced by 5 activities; ‘Ethanol1’, ‘Ethanol2’, ‘Ethanol3’, ‘Ethanol4’ and ‘Ethanol5’. Similarly biodiesel can be produced by ‘Biopalm6’, ‘Biopalm7’, ‘Biojatropha8’ and ‘Biojatropha9’ activities, each one representing

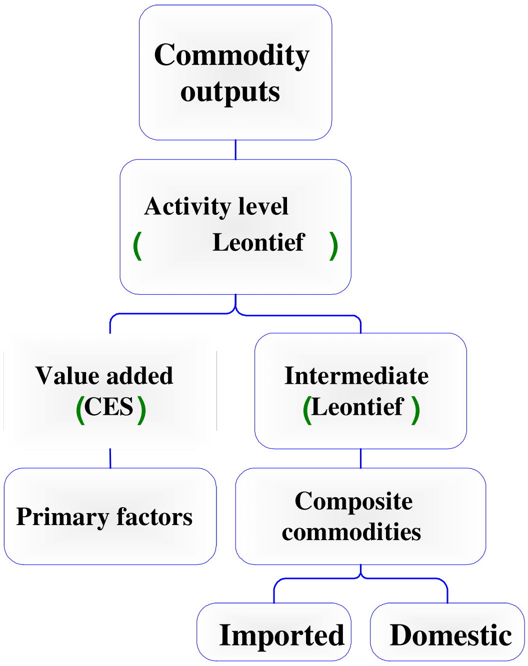
[6] The structure of this section follows Lofgren et al, 2002.
[7] With a value of 0.8 for all sectors

a different technology, including fixed ratio combinations of feedstocks produced by smallholders and large farms.

The revenue of the activity is defined by the level of the activity, yields, and commodity prices at the producer level. As part of its profit-maximizing decision, each activity uses a set of factors up to the point where the marginal revenue product of each factor is equal to its wage[8]. For agricultural sectors, the model allows returns by unit of land to differ among crops.

Full employment of the production factors is assumed. Labor and capital supplies are fixed and these factors are perfectly mobile across sectors but land is not, remaining only in the agricultural sector.

Figure 1: Production Technology



Source: Lofgren et al, 2002

Institutions: Households, Government, and Rest of the World (RoW)

Households receive their incomes from factor earnings, and transfers from other institutions. More specifically, each household receives fixed shares of income flowseither from factors, the government or the rest of the world. Households use their income to pay direct taxes, save, consume, and make transfers to other institutions. It is assumed that direct taxes, and transfers to other domestic institutions are defined as fixed shares of household income whereas the savings share is flexible for selected households. Remaining income, after taxes, savings, and transfers to other institutions is spent on consumption. Household consumption is for marketed commodities purchased at market prices adjusted for commodity taxes. Household consumption is allocated across different commodities according to Linear Expenditure System (LES) demand functions, derived from the maximization of a Stone-Geary utility function[9].

[8] Unless additional factor-related constraints are imposed.
[9] For details, see Dervis et al. 1982.

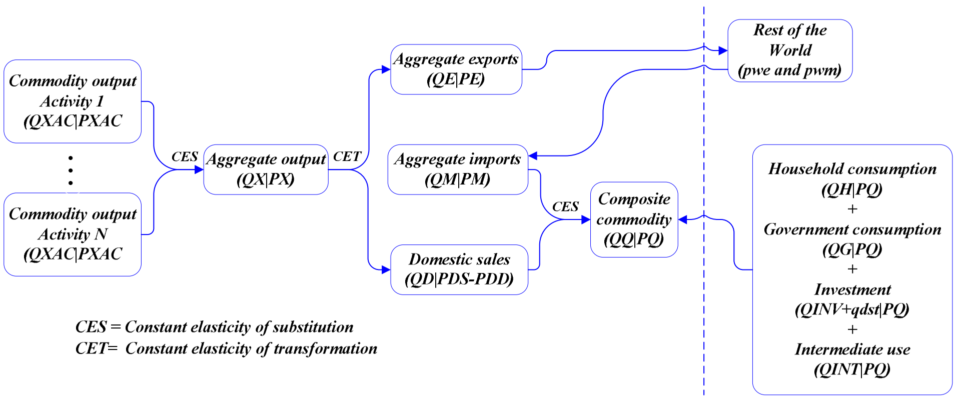
The government collects taxes (or pays subsidies) and receives transfers from other institutions. The model by default assumes that all taxes are at fixed ad valorem rates. The government uses this income for its own consumption, and for transfers to other institutions. Typically, government consumption is assumed fixed in real (quantity) terms whereas government transfers to domestic institutions (households and enterprises) are CPI-indexed. Government saving is the difference between government income and spending in the model.

The rest of the world represents the foreign sector. Transfer payments from the rest of the world to domestic institutions and factors are all fixed in foreign currency. Foreign savings (or the current account deficit) is the difference between foreign currency spending and receipts. Commodity trade with the rest of the world is discussed in the following section.

Commodity Markets

Figure 2 shows the physical flows for marketed commodities along with the associated quantity and price variables as defined in the model equations discussed in *Lofgren et al (2002)*[10]. Domestic output may be sold in the market or consumed at home. For marketed output, aggregated domestic output (QX) for each commodity is computed as the composite output of different activities that produce the commodity (QXAC). These outputs are imperfect substitutes because of differences in timing, quality, and location between different activities. A Constant-Elasticity-of-Substitution (CES) is used as an aggregation function. The demand for the output of each activity is derived from minimizing the cost of supplying a given quantity of aggregated output subject to a CES function. Activity-specific commodity prices (PXAC) clear the implicit market for each disaggregated commodity.

Figure 2: Flow of Marketed Commodities.



Source: Lofgren et al, 2002

The model relies on the Armington specification to allow imperfect substitutability between domestically produced and imported commodities. That is, imports (QM) and the demand for domestically produced goods (QD), within the same sector are treated as differentiated goods whose demand is characterized by a specified constant elasticity of substitution. The same Armington specification is applied to domestic output (QX). It is assumed that there is imperfect transformability of domestic output (QX) to exports (QE) and to domestic supply of domestically produced goods (QD). The degree of transformability is the elasticity of transformation.

[10] Modified equations for this study are presented in appendix B.

Under the small country assumption, Peru's imports have an infinitely elastic world supply and its exports face an infinitely elastic world demand, thus world prices of imports *pwm* and of exports *pwe* are exogenously determined. The domestic prices of imported and exported products are given by:

$$PM = pwm\ (\ 1 + tm\ )\ EXR$$

and

$$PE\ = pwe\ (\ 1\ -\ te\ )\ EXR$$

respectively, where EXR is the exchange rate (domestic currency per unit of foreign currency), and *tm* and *te* are the implicit tariff and export tax rates that account for legal tariffs and export taxes, as well as any quantitative trade restrictions and direct price controls that affect the disparity between the domestic and border prices of traded goods.

The Armington assumption implies that consumers face commodities that are composite goods (QQ), and their demand is a constant elasticity of substitution (CES) aggregation function of imports (QM) and domestic sales (QD), with a specified substitution elasticity. Consumers maximize utility, which in the model is the same as maximizing consumption (QQ), so that the desired ratio between (QM) and (QD) is a function of their relative prices. Similarly, producers provide a composite commodity (QX) that is a constant elasticity transformation (CET) function of exports (QE) and domestic output (QD) and maximize profits so that their desired ratio is a function of their relative prices.

$$\left(\frac{QM}{QD}\right) = CES^{*}\left(\frac{PM}{PDD}\right)$$

and

$$\left(\frac{QE}{QD}\right) = CET^{*}\left(\frac{PE}{PDS}\right)$$

Where CES* and CET* refer to the first-order conditions for utility maximization and profit maximization. Sectoral composite good prices are the weighted averages of the domestic prices of their component products:

$$PQ\ = \frac{(PDD \cdot QD + PM \cdot QM\ )}{QQ} = CES\ (PDD,\ PM)$$

and

$$PX\ = \frac{(PDS \cdot QD + PE \cdot QE\ )}{QX} = CET\ (PDS,\ PE)$$

where the CES and CET functions refer to cost functions that relate composite prices to their component prices. They reflect the first-order conditions described above.

The assumptions of imperfect transformability and imperfect substitutability permit the model to more appropriately reflect the realities of most countries. The assumptions used give the domestic price system a degree of independence from international prices and prevent unrealistic export and import responses to economic shocks. At the disaggregated commodity level, these assumptions allow for a continuum of tradability and two-way trade, which is commonly observed even at very fine levels of disaggregation[11].

This model specification determines the role of the exchange rate in achieving equilibrium. The model specifies a functional relationship between the balance of trade and the real exchange rate – i.e., the relative price of tradable and semi-tradables.

Macroeconomic Balances

Macroeconomic balances or “System constraints” are constraints that have to be satisfied by the economic system, but are not considered in the optimizing decision of any micro agent (Robinson 1989). There are three macroeconomic balances: the (current) government balance, the external balance (the current account of the balance of payments, which includes the trade balance), and the savings-investment balance. The mechanism by which the model satisfies these constraints is referred to as the “closure rules.” It is worth noting that the choice of a closure rule has no effect on the base-line solution generated by the current CGE model but would typically influence the results for other policy simulations.

The Government closure assumes that government savings are a flexible residual with all tax rates fixed for domestic institutions.

The presence of the rest of the world in the model requires an explicit treatment of how foreign exchange outflows and inflows are equilibrated. Typically, the real exchange rate, defined as the relative price of traded to non-traded goods, is the equilibrating variable, an assumption that is followed for Peru.

The closure rule adopted for the model is an investment-driven saving investment balance which assumes that investment demand is fixed and the value of savings adjust (a “Johansen” closure). A “Johansen” closure assumes no link between the macro variables and aggregate employment, as a result, in the presence of the full employment assumption[12], a shock introduced to the system would affect the composition of aggregate demand, but not GDP.

[11] Robinson and Lofgren (2005) note that introducing a degree of substitutability and transformability is theoretically consistent with the Salter-Sawn model which assumes a rigid dichotomy between tradable and non-tradable commodities.

[12] It is assumed that smallholders, who are of great interest for the Government of Peru, are not unemployed.

Modeling the Biofuel Sector

Technological pathway for Ethanol and Biodiesel Productions

The FAO and the Government of Peru are interested in analyzing nine alternative production scenarios to explore the impact of developing the biofuel sector on the economy of Peru (see Table 1). Of the nine scenarios, five analyze the impact of ethanol production and four analyze the impact of biodiesel production. Ethanol and biodiesel are produced using a variety of technological pathways using two feedstocks for each biofuel. Sugarcane and molasses produce ethanol, and palm oil and jatropha produce biodiesel. For both biofuels, feedstock production in most cases (except for molasses and one of the palm oil producing scenarios) is a 60/40 split[13] between large scale commercial farms and smallholders, respectively.

As a working assumption in this study, we consider that without the mandatory policy, no production of ethanol or biodiesel takes place. All the biofuel technologies are considered as latent technology in the model.[14]

[13] A ratio set by the Government of Peru.

[14] However, for calibration purpose, we will assume that an infinitesimal production exists for each technology initially.

Table 1: Production Matrix for Biofuel Production in Peru and Resultant Policy Scenarios

Scenario	Feedstock	Biofuel Production	Other Production	Feedstock Production	Level of Technolog y	Feedstock considerations
1	Sugarcane	Ethanol* coast	Co-generated electricity	Smallholder/ Commercial	High	-
2	Sugarcane	Ethanol* coast	Co-generated electricity	Commercial	High	-
3	Sugarcane	Ethanol Jungle	Co-generated electricity	Smallholder/ Commercial	Medium	-
4	Molasses	Ethanol	Sugar	Smallholder/ Commercial	High	Opportunity cost high
5	Molasses	Ethanol	Sugar	Smallholder/ Commercial	High	Opportunity cost low
6	Palm Oil	Biodiesel	Edible oil	Smallholder/ Commercial	Medium/ High	-
7	Palm Oil	Biodiesel	Edible oil	Commercial	High	-
8	Jatropha	Biodiesel	-	Smallholder/ Commercial	Medium	Low yield
9	Jatropha	Biodiesel	-	Smallholder/ Commercial	Medium	High Yield

Source: FAO, 2010

Ethanol Production

There are five possible pathways to produce ethanol either directly through the sugarcane feedstock, or, indirectly through its derivative, molasses (Table 1). As for other sectors, each biofuel technology will combine inputs, including feedstocks and value added. We assume Leontieff technology to maintain the physical yield constant during the simulations. In addition, for each technology, the Leontieff parameters will also allow us to define the share of one feedstock, e.g. sugar cane, supplied by different types of agents (commercial farms or small holders). Each of these pathways is analyzed in the scenarios undertaken. For the first three scenarios where ethanol is produced directly from sugarcane, electricity is a generated co-product.

The first two scenarios assume that sugarcane production takes place in the coastal region using higher level technology. The first scenario uses the 60/40 production split between commercial farmers and smallholders and the second assumes that only commercial producers produce sugarcane in the Coastal region. The choice of the Leontieff functional form ensures that the 60/40 production ratio between commercial farmers and smallholders is maintained. In the absence of this 'forced' relationship, the production of biofuel feedstocks would be overtaken by the commercial farms due to their more competitive cost and yield structures. In the coastal regions, total costs incurred in growing sugarcane for commercial farms are US$12.32 per hectare, for smallholders it is US$26 per hectare. Yields are also higher for commercial farms than smallholders. The former have yields of 140 tons per hectare vis a vis 130 tons per hectare for smallholders (see Production Cost Tables in the Annex). As a result, a leontief function ensures the imposed commercial/smallholder mix is maintained and yields are constant. In scenario 3, the sugarcane is produced in the Selva region again maintaining the 60/40 production split in production. The last two scenarios considered for ethanol production use molasses. Molasses, a product of the food processing sector, is currently only used for human consumption and for animal feed. In scenario 4, a higher opportunity cost for production is assumed and in scenario 5, a lower opportunity cost is used. Opportunity costs are modeled through a change in the price of each unit of molasses used.

For example, a high opportunity cost in scenario 4 means a higher price per unit of molasses used[15] due to an additional mark-up. It is important to keep in mind that the high opportunity cost does not reflect a change in the energy content of the molasses or an increase in the share of wasted molasses. Physical yields are not modified.

Biodiesel Production

Biodiesel production in Peru may be produced either using palm oil or jatropha. Currently in Peru, palm oil is an edible oil and jatropha is a new feedstock that has not yet been produced. For each of these feedstock options, two scenarios are explored. For palm oil, scenario 6 assumes the same 60/40 production split between commercial farmers and smallholders but scenario 7 assumes that only commercial producers grow the oil palm. For jatropha production, both scenarios (8 and 9) assume the 60/40 production split, however, the former assumes a yield of 4 tons per hectare for smallholders whereas scenario 9 assumes a higher yield of 6.5 tons per hectare. One of the co-products of biodiesel production from jatropha is glycerol. The model does not explicitly consider a market for glycerol, instead it is aggregated with the Oil and Fat sector (sectoral disaggregation of the model will be discussed in the data section).

Biofuels and Fuels blending

All different types of ethanol are merged, i.e. blended, into one generic ethanol sector assuming a CES technology with very large degree of substitution across products (elasticity of substitution equals to 20). The same methodology is applied to biodiesel.
Finally, a fuel sector blends fossil fuel, ethanol and biodiesel. Here, we assume a leontieff technology among inputs (the different type of fuels) and does not consider value added for this sector. The leontieff technology allows us to represent explicitly the mandate and to have consumption targets independent of the relative prices of the different fuels.

Capital Market

For the biofuel processing sectors the rate of return of capital may differ between alternative technological pathways. In the production of ethanol, the highest return to capital is assumed to accrue to processing plants that use feedstock supplied only from the commercial farms in the coastal areas (Scenario 2). The lowest return to capital is from the production of ethanol using high opportunity cost molasses. Given that we assume the same price of ethanol for all technological pathways, profit margins are reduced for technology associated with higher cost of intermediate inputs.

Feedstock Production

Agricultural feedstocks for biofuels

There are four feedstocks considered for the production of the biofuels; sugarcane, molasses, palm oil and jatropha. For each feedstock, production can take place in one or two regions, involving commercial farms and/or small holders.

For all but the last feedstock, production is active and is re-directed from their original use to the production of biofuels. In the baseline, palm oil is used only in the food production industry and sugarcane is used for the production of sugar and molasses. Molasses is used to produce, both, ethanol for human consumption and feedstuff for the livestock industry. For jatropha, the model assumes that the technology for jatropha production exists, however, it is not activated until the mandates become

[15] This price gap generates rent for all households.

effective. In other words, jatropha production is close to zero in the baseline but increases as a result of the biofuel development scenarios which use it as feedstock for producing biodiesel (scenarios 8 & 9).

Land Market

There are four land markets portrayed in the model. In both regions (coastal and jungle) there are two markets: one for smallholders and one for commercial farms. In the jungle region, all land allocated to the production of new biofuel feedstock is assumed to be endowed to commercial farms. Smallholders, on the other hand, do not receive any new allocations of land in the central cases. At equilibrium the land market insures that the total demand for land by the different activities is equal to the total supply of land for each region and for each type of land user/owners. Land supply in the Jungle region is not fixed and land extension is allowed in the scenarios. Due to the Leontieff technology assumed in the production of feedstock and the initial assumption of land distribution among crops and regions (see data section), this mechanism is needed to allow the production expansion in the jungle region for which the initial amount of land is insufficient to expand feedstock production.

Differences in land quality exist between the two regions consequently determining the average price of land in each region. The price of land in the coastal areas is roughly 6.5 times higher than the average price of land in the jungle areas. Within each region returns to land are differentiated according to the different agricultural activities. For instance, the returns to land from planting high value crops such as fruits, vegetables and legumes are assumed to be three times higher than the average returns per region. Returns from “Other Crop” activities are assumed to be twice as much as the average regional land prices. Cereals as a crop are assumed to bring in a lower return to land of slightly less than half the return to land for the two regions.

Finally, and in order to highlight the important role of the land market on the overall biofuel policy, a land market robustness check is introduced analyzing two variations. The first variation assumes that the relative price of land for commercial farms and smallholders is constant. In the second variation, the amount of land needed to maintain the real price of land at this initial level is endogenized to equilibrate the land market. [16]

Trade

In the central case, no trade occurs so all the increase in demand is assumed to be satisfied by domestic production. In addition, the world prices of ethanol and biodiesel are assumed constant, i.e. no growing demand from large importers like the US and/or the EU for instance. Therefore, the simulated biofuel mandates would lead to increases in imports if trade is allowed. Relative to the baseline which assumes no production or trade of biofuels, the policy shocks would increase domestic demand and the production prices of ethanol and biodiesel. Since world prices remain constant, an increase in the cost of production leads to an erosion of Peru’s competitiveness for ethanol and biodiesel and an increase in imports. For fuel ethanol, this result may appear unrealistic since Peruvian export costs are nowadays below the domestic price of ethanol for several trade partners (at least the EU). In this situation, the model was unable to explain why, in the reference situation, Peru does not produce and export ethanol. To correct for this, an additional export cost is introduced in the baseline in order to explain the initial equilibrium.

[16] Each region is assumed to have an infinite land supply elasticity.

As a further robustness check, trade is allowed to take place and the previously imposed trade cost on ethanol is removed. It is also important to note that the model does not assume any learning curve nor does it assume a reduction in production costs through the amortization of fixed costs. Indeed, "nascent industry" consideration in a dynamic model may lead to a decline in production cost and the domestic mandate may help to boost exports on the long run by developing a local market to ensure economies of scale for the local industry. In our static model, the technology is assumed to be "mature"[17] and we assume perfect competition for all sectors. We exclude the possibility of economies of scale.

In this situation, the flows of exports/imports would be impacted by the domestic mandates (e.g. the biodiesel mandate could be reached through imports instead of domestic production).

[17] Based on the Product life cycle theory, a technology is considered to be mature if it reaches the stage where changes in production cost are only associated with changes in factor prices.

The Model's Database: Peru 2002 Social Accounting Matrix (SAM)

A SAM is a comprehensive, complete, flexible, and consistent system for organizing the social and national accounts of a nation over a period of time, usually a year (Declauwe et. al. 1999). It is comprehensive in that it covers all transactions within the domestic economy and between the domestic economy and the rest of the world. It is complete in that all incomes and outlays in the economy are accounted for; i.e. every payment, receipt, and every transfer. It is also flexible as it can focus on a particular region, commodity, institution, or policy issue. It can be aggregated or disaggregated to any level depending on the requirements of the research issue at hand and the availability of data. It is a consistent structure as the total receipts (income) and expenditures of each account must balance (equal row and column sums). The construction of SAMs in general is driven by three motivations. First, it displays information in a manner that exhibits the structure of an economy in an illuminating way. Secondly, by exposing inconsistencies between data from different sources, it contributes to improvements in data. Thirdly, it provides all or at least a major part of the data needed for different types of models, most importantly fixed-price SAM-multiplier models and computable general equilibrium (CGE models) (Round, 2003).

A typical SAM includes accounts for production (activities), commodities, factors of production, other actors (institutions), and the rest of the world, which receive income and demand goods. According to its structure, each account is represented by a row and a column account, where typically, incomes and receipts are shown along a row while expenditures or outlays are shown down a column. Activities pay for intermediate inputs, factors of production, and taxes, while they receive payments for sales to commodities. The commodity account buys goods from activities (producers), the rest of the world (imports) and pays tariffs to the government – an institution – and sells commodities to activities (intermediate inputs), final demanders (households, government, and investment), and exports to the rest of the world. Gross domestic product (GDP) at factor cost (payments by activities to factors of production) equals gross domestic income and also equals GDP at market prices (consumption plus investment plus government demand plus exports minus imports) minus taxes.

The SAM accounts are disaggregated appropriately to address the policy questions explored by the underlying model. For example, a relatively disaggregated household accounts is desirable in order to analyze income distribution issues. In theory there is no limit to the level of disaggregation, however, in practice data availability and the effort involved in constructing a SAM are a constraint. In this report, the disaggregation of production sectors, households, and the government has been motivated by the objective of exploring the impact of developing the biofuel sector in Peru on the economy.

Peru SAM, 2002

The Peru CGE model is based on the 2002 Peru SAM[18] and follows its disaggregation of activities, commodities, factors, institutions and taxes. The main body of data used is the 2002 SAM, other major information sources are the 2007 production and price data for the key sectors in the economy; sugarcane, palm oil, molasses, oil and fat sector[19]. Furthermore, Peru farm budget costs were provided by FAO experts, for smallholders and the commercial farms, as well as the costs of production for the biofuel sector for each technological pathway.

A first step in implementing the model is the SAM calibration process. Technically, this means that the model solution should replicate the SAM, a solution that is typically called the "base" solution which represents a "benchmark" equilibrium for the purpose of carrying out comparative static analysis; comparing other equilibrium states generated by the model after accounting for a policy shock.

The Aggregated SAM

The aggregated SAM for Peru presents a summary of the Peru SAM that aggregates the main accounts. Table 2 shows that aggregation. There are 8 accounting categories. Accounts 1, 2, and 3 are single accounts aggregating the activity, commodity, and factor accounts, respectively. Domestic institutions (households and the government) are shown in accounts 4 and 5, respectively. Account 6 is the rest of the world account, which records international trade and Account 7 is the saving-investment account which balances the income and expenditures flows. The tax/subsidy account, account 8, collects the taxes in the economy and pays them to the government. The last account is the total account.

[18] Thurlow et al, 2009.
[19] FAOSTAT Online.

Table 2: Peru Aggregated SAM, 2002 (Billions of Soles)

	Activities	Commodities	Factors of Production	Households	Government	ROW	S-I	Institution Tax	Tariffs	Commodity Tax	Total
Activities		325.423									325.423
Commodities	146.163	23.447		143.808	20.234	32.652	37.359				403.663
Factors of Production	179.260										179.260
Households			179.260	64.203	8.445	1.895					253.803
Government						-3.469		7.749	2.483	17.908	24.672
ROW		34.402									34.402
S-I				38.043	-4.007	3.324					37.359
Institution Tax				7.749							7.749
Tariffs		2.483									2.483
Commodity Tax		17.908									17.908
Total	325.423	403.663	179.260	253.803	24.672	34.402	37.359	7.749	2.483	17.908	

Source: Peru CGE Model, 2010

Peru SAM

In the Peru SAM used for the model, we have 49 activities: 16 accounts for the agricultural sectors and 33 for the non agricultural sectors. Within the agricultural sector, there are 9 biofuel feedstock producing activities. In the non agricultural sectors, there are 12 fuel and biofuel producing activities and one feedstock producing sector, molasses.

There are four land markets. Land 1 refers to land owned by commercial farms in the coastal regions and Land 2 refers to land owned by smallholders in the same region. Land 3 refers to land owned by commercial farms in the jungle region (Selva) and Land 4 refers to smallholder land in that region too. Table 3 lists all these SAM accounts.

Table 3: Activities, Factors and Institution in the Peru SAM

Agriculture (16)			
Cereals	Fruit	Palm1	Palm2
Vegetables	Legumes	Jatropha1	Jatropha2
Sugarcane1	Sugarcane2	Jatropha3	Other Crops
Sugarcane3	Sugarcane4	Livestock	Forest
Non Agriculture (33)			
Fishing	Petroleum refinery	<u>Ethanol1</u>	<u>Ethanol2</u>
Crude Oil Extraction	Minerals	<u>Ethanol3</u>	Ethanol4
<u>Sugar & Molasses</u>	Mining	Ethanol5	Ethanol *
Food Production	Oils and Fats	Biodiesel*	<u>BioJatropha8</u>
Beverage and Tobacco	Textiles and Clothing	BioPalm6	<u>BioJatropha9</u>
Wood Products	Chemicals	BioPalm 7	
Machinery and Equipment	Other Manufacturing	Finance and Trade	Services
Electricity and Water	Construction	Government Services	
Transportation	Fuel*		
Factors (5)			
Skilled Labor	Semi-Skilled Labor	Unskilled Labor	
Capital			
Land1	Land2	Land3	Land4
Institutions (5)			
Households – Rural and Urban			
Enterprises			
Government			
Rest of the world			

Source: Peru CGE Model, 2010

Note: Blending sectors are indicated with an asterisk. Underline activities indicate activities with multi product outputs.

Biofuel Sectors in the Peruvian SAM

In the Agricultural Sector

The agricultural sector includes feedstock crops (sugarcane, palm and jatropha) and other crop and livestock activity. The different feedstocks used for biofuel production are individually modeled. All feedstock production is active in the baseline, except for production of sugarcane by smallholders in the jungle region and the production of jatropha. Production for these two different feedstocks is close to zero and is activated after the mandate is enforced. *Sugarcane1* and *Sugarcane2* represent farm activity in the Coastal regions for commercial farms and smallholders, respectively, and *Sugarcane3* and *Sugarcane4* represent farm activity of commercial farms and smallholders in the Jungle region. All biodiesel feedstock; oil palm and jatropha, are grown in the jungle region of Peru. *Palm1* and *Palm2* are commercial and smallholder production, respectively, of oil palm. *Jatropha1* represents commercial farm activity, *Jatropha2* high-yield smallholder production, and finally, *Jatropha3* represents low-yield smallholder production in the jungle.

Non Agricultural Sectors

Ethanol1 through *Ethanol5*, *Biopalm6* and *Biopalm7*, and, *Biojatropha8* and *Biojatropha9* are the activity sectors that represent the production technologies employed in producing the commodities Ethanol and Biodiesel. Finally, the Fuel sector is a only a blending sector that mixes ethanol and biodiesel produced with gasoline and diesel, respectively, according to the respective mandate enforced There is no value added attributed to this sector, all value added is generated in the nine activity sectors mentioned above.

Structure of the Economy

In Peru in 2002, private consumption made up 72% of GDP at market value and government consumption 10% and exports and income were close, each making up slightly over 16% of GDP and GDP at factor cost reached 90% of its market value equivalent (Table 4).

Table 4: GDP Composition

	% of GDP
Absorption	100.87
Private Consumption	72.03
Fixed Investment	18.71
Government Consumption	10.13
Exports	16.35
Imports	-17.23
GDP at Market Value	100
Net Indirect taxes	10.21
GDP at Factor Cost	89.79

Source: Peru CGE Model, 2010

Table 5, summarizes the sectoral structure of the Peruvian economy portrayed in the model's base year, 2002. It also shows the relative importance of the agricultural sector in terms of its contribution to value added, production and employment. The agricultural sector contributed less than 7% to the economy's value added, output and employment in 2002. Furthermore, trade activities accounted for a mere 4% emphasizing the relatively minor role the sector played in the Peruvian economy's macro structure in 2002. The sector with the largest contribution to value added, production and consequently employment is the finance and trade sector with shares of 36, 30 and 32%, respectively in 2002. As for trade, the mineral extraction sector contributes more than one quarter of Peru's exports, followed closely by the Mining sector (16.7%) and then by exports of the Food production sector (12%). Imports, on the other hand are more than 25% for the machine and equipment sectors, followed by imports in the Chemicals sectors and then Finance and trade, 15% and 13.17% respectively.

Table 5: Sectoral Structure in Peru, 2002, (%)

Sector	VA by activity	Production by goods/services	Employment by activity	Exports	Exports to Output	Imports	Imports to Demand
Cereal	0.90	0.60	0.80	0.05	0.70	3.60	30.30
Fruit	1.00	0.80	0.60	0.90	6.90	0.20	3.30
Vegetables	2.20	1.70	1.20	1.40	6.90		
Legumes	0.50	0.30	0.30	0.20	1.30	0.20	5.50
Other Crops	0.90	0.60	0.50	1.40	10.30	0.70	8.40
Livestock	1.00	1.30	0.90				
Forest	0.10	0.10	0.08				
Fishing	0.70	0.60	0.70	1.60	23.10	0.20	2.70
Crude oil	0.60	0.50	0.20	5.50	100.00	3.90	100.00
Mining	4.00	3.80	2.50	27.10	63.50	0.20	1.60
Sugar	0.01	0.30	0.10	0.20	8.10	0.50	19.30
Molasses		0.03					
Oil & Fats	0.10	0.20	0.20	0.09	4.90	3.30	56.60
Beverage and Tobacco	0.70	1.00	0.60	0.20	2.00	0.40	3.70
Fuel		1.30					
Wood and Paper Products	1.40	2.20	1.20	1.70	7.30	3.40	15.30
Chemicals	2.40	3.00	1.50	2.70	8.90	15.20	36.40
Petroleum Refined	0.50	1.10	0.20	3.40	30.00	3.80	33.70
Machines and Equipment	0.80	1.40	0.60	1.00	6.90	25.20	66.40
Other Manufacturing	0.70	0.90	0.40	0.30	3.90	2.50	23.20
Electricity and Water	2.00	1.60	1.60				
Construction	6.50	7.30	9.80				
Transportation	8.30	9.10	7.70	6.50	7.20	9.60	10.80
Services	10.70	8.90	8.10	0.50	0.60	2.40	2.80
Government Services	8.20	6.20	17.20				
Finance and Trade	36.40	29.70	32.90	9.20	3.10	13.20	4.60
Mining	2.10	4.20	1.90	16.70	36.60	6.10	20.70
Textiles and Clothing	2.20	3.40	3.10	7.50	22.20	3.70	12.80
Food Production	4.90	7.50	4.90	11.90	15.90	1.60	2.60
Total	**100.00**	**100.00**	**100.00**	**100.00**	**9.40**	**100.00**	**10.80**
Agriculture	6.80	5.70	4.60	3.90	4.30	4.80	7.50
Non Agriculture	93.20	94.30	95.40	96.10	9.70	95.20	11.00
Total	**100.00**	**100.00**	**100.00**	**100.00**	**9.40**	**100.00**	**10.80**

Source: Peru CGE Model, 2010

The Finance and trade sector, as well as the Government services sector together provide 50% of Peru's employment, with the former alone contributing 33%.

As already discussed, some feedstock and biofuel sectors are introduced into the model with a baseline production close to zero to deal with latent technology. This treatment is useful to calibrate the model parameters easily. These infinitesimal production levels will eventually rise when the scenarios analyzing biofuel promotion (Scenarios 1-9) are introduced into the model.

Labor Markets and the Household Sector

The household sector is divided into two: rural and urban so as to emphasize the role of the national biofuel initiative on the Peruvian people. This disaggregation is important so as to isolate the effect of the biofuel promotion policies on these two groups and to assess the policies' welfare impacts. From Table 6 (below), over a period of four years (2004 to 2007), rural poverty was, on average, over two thirds and poverty in the Selva region was, on average, 55%. Urban and coastal poverty, on the other hand, were under 33% of the population.

Table 6: Poverty Headcount, % of Total Population

	2004	2005	2006	2007
Urban	37.1	36.8	31.2	25.7
Rural	69.8	70.9	69.3	64.6
Coastal	35.1	34.2	28.7	22.6
Selva	57.7	60.3	56.6	48.4

Source: Instituto Nacional de Estadistica e Informatica

Labor income (semiskilled and unskilled) only makes up 25.4% of total income to rural households (Table 7 below). The majority of their income accrues from the enterprise sector (61%) and only 10.64% accrues from land rent[20]. They receive no transfers from the rest of the world and receive less than 3% of their total income from the government (Table 7 upper half). Urban households exhibit some different characteristics, 55% of their total income is labor income followed by 35.2% from the enterprise sector, 6.5% from government transfers and under 3% from abroad. Appropriately, the lowest accruals to income coming to the urban households are from land rent, 0.6% (Table 7 upper half).

Table 7 (lower half) shows also the returns of factors of production to rural and urban households. Urban households are the sole contributors to the skilled labor market; they also receive over 95% of the returns to semi-skilled labor and 73.7% of the returns to the unskilled labor in Peru. The rural households, on the other hand, receive 26.3% and fewer than 5% of the returns to unskilled labor and semi-skilled labor, respectively. Rural households receive 80% of total land rents in Peru. Urban households receive close to three quarter of enterprise income, over 90% of government transfers and all income accruing from abroad.

[20] Rural households receive 80% of all the land rents in the system.

Table 7: Sources of Income and Contribution to Factors of Production (%)

	Skilled Labor	Semi-Skilled Labor	Unskilled Labor	Land2	Land4	Enterprises	Government	ROW	Total
Sources of Income									
Rural HH		7.00	18.40	10.60	0.04	61.00	2.90		100
Urban HH	14.30	29.70	11.00	0.60	0.00	35.20	6.50	2.80	100
Total	11.80	25.70	12.30	2.30	0.01	39.70	5.90	2.30	100
Returns to Factors of Production									
	Skilled Labor	Semi-Skilled Labor	Unskilled Labor	Land2	Land4	Enterprises	Government	ROW	Total
Rural HH		4.80	26.30	80.00	80.00	26.90	8.60		17.50
Urban HH	100.00	95.20	73.70	20.00	20.00	73.10	91.40	100.00	82.50
Total	100	100	100	100	100	100	100	100	100

Source: Peru CGE Model, 2010

Table 8 below shows households' expenditure on selected items in 2004, the base year. Close to 60% of consumption expenditures of the rural households are on food items and 28% are on services. Urban households, on the other hand spend more than half their expenditures on services, a quarter on food and 4% on fuel. The latter figure will be very important since it means that urban households spend as a percentage of their total income more than 50% more than rural households on fuel. Therefore, they will be much more sensitive to a change in this price.

Table 8: Selected Household Expenditure Shares (%)

	Rural	Urban
Food	57.50	25.16
Fuel	2.60	4.10
Services	28.07	52.32
Industrial Goods	1.48	4.24
Total Consumption	100.00	100.00

Note:
Food includes; agricultural crops, livestock, fisheries, beverage and tobacco, sugar, oil and fat and food processing commodities.
Services include; transportation services and finance and trade.
Industrial goods include; machines and equipment and other manufacturing goods.
Source: Peru CGE Model, 2010

Peru CGE Model Results

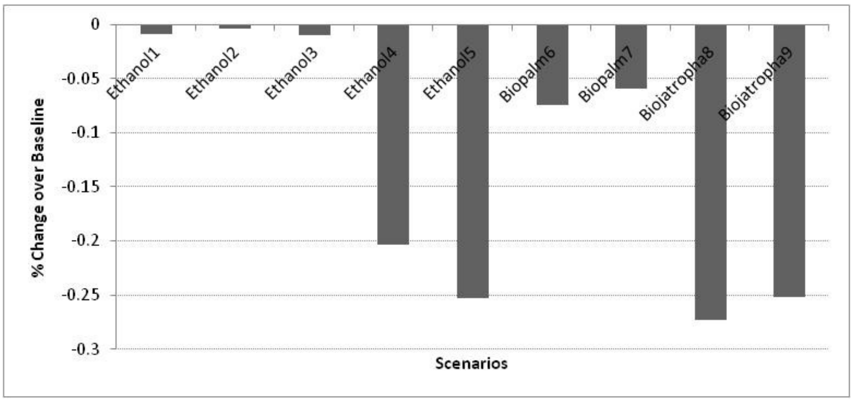
In this section, the results of the various policy simulations will be discussed It is worthwhile to note that throughout the scenarios, the Peru CGE model is a static model that assumes full employment of its factors of production. In this context we do not expect to see large change in real income and GDP since there is no dynamic gains or job creation. We only focus on the efficiency consequences of the policy and its redistributive consequences.

Let's remind you that there are nine technology/policy scenarios(Table 1): five for ethanol and four for biodiesel. Each policy scenario is conducted individually by assuming a mandate of 7.8% mix for ethanol or a 5% mix for biodiesel by 2011 as set by the authorities in Peru. Based on the projections of the Ministry of Mines and Energy, the demand of biodiesel is expected to reach 3,600 barrels of petroleum equivalent per day (BPD) of biodiesel and 1,100 BPD of ethanol by 2015. When the scenarios are implemented, we target these volumes figures instead of the percentage mix. Indeed, we believe that the demand of fuel in 2015 is better estimated by the Ministry of Mines and Energy than by our static model.

The commercial/smallholder mix for feedstock production is a 60/40 ratio using several technological pathways to produce the feedstocks used for ethanol and biodiesel production. It is important to keep in mind that the ethanol and the biofuel mandates are estimated independently as each technological pathway is studied one at a time.
In the following sections we discuss the macro economic impacts, the sectoral effects and finally, the distributional consequences of the nine policy scenarios introduced.

Impact on Gross Domestic Product

Figure 3: Real GDP



Source: Peru CGE Model, 2010

The model is a one period model that assumes full employment in the factor markets with fixed labor and capital supplies and perfect mobility across sectors. Consequently, the effect on GDP is not expected to be significant since only land will expand as a factor of production (Figure 3). At the same time, the mandate plays the role of a policy constraint that alters the efficient allocation of resources in an economy driven by market signals. This loss in economic efficiency leads to economic net losses economy-wide.

In the case of the mandate on ethanol, the scenario Ethanol3 (sugarcane grown in the jungle) does not lead to any losses since the economic costs of the distortive policy, i.e. the mandate, are compensated by the economic expansion in the jungle region (new lands activated for economic uses). However, despite that, it is clear from Figure 3 that scenarios Ethanol4 and Ethanol5 – using molasses as a feedstock for ethanol production – bring about a reduction in real GDP of -0.2 to -0.25% respectively. Relatively, these last results are very strong. Molasses is initially used efficiently as it is not wasted thus receiving a normal market price. When molasses is used to produce ethanol, molasses it has to be diverted from other sectors, for instance, the production of ethanol for human consumption. In that case, additional sugar has to be produced to generate more molasses in order to satisfy the demand that had existed for that displaced ethanol. This leads to a reduction in potable ethanol production and a fall in its exports by 80%. At the same time, additional sugar needs to be processed in order to generate more molasses and with the saturation of the domestic market, it has to be sold on the world market at an even lower price (exports increase by more than 320%). This shift in the production and export pattern of molasses is costly for Peru since it moves its economy far from the optimal allocation, thus altering several sectors. However, another effect dominates the previous one. In the current approach, using molasses implies a shock to the sugar sector and an increase in the production of this sector. Since the existing sugar industry almost exclusively relies on sugarcane produced in the coastal area, the impact is a significant shock to the agricultural sector. Indeed, due to the low yield of ethanol production per unit of sugarcane when molasses are used to produce ethanol, the amount of sugar needed to satisfy the mandate rises significantly. That is especially true for scenarios Ethanol4 & Ethanol5 more than for scenarios Ethanol1 or Ethanol2. At the same time, for these two scenarios (Ethanol4 & Ethanol5) the increase in ethanol production has not relied on a reallocation of the existing sugarcane areas from the sugar industry to the ethanol industry. The increases in ethanol production are channeled through the sugar sector. This significant impact on the coastal area agricultural market leads to a heightened competition for land whose prices balloon and other factor income fall. The result is a reduction in the other factors' rate of return and an overall decline in GDP.

The mandate for biodiesel also reduces real GDP by -0.25 to -0.27% since the amount of biodiesel produced is larger than the ethanol mandate, despite Peru's reduced efficiency in producing biodiesel. The largest reductions in real GDP occur when jatropha is the feedstock used for biodiesel production since in terms of yield and costs, it is the least efficient.

To sum up, if the ethanol mandate using sugarcane has no significant effects on the Peruvian real GDP, the biodiesel target may be reached with a minimal efficiency cost (up to 0.07% of real GDP) if palm fruit is used. However, using only molasses for the production of fuel ethanol would be more costly, in particular if; molasses is currently used efficiently by other industries, no demand exists for the additional sugar production, and, if the sugar sector - and sugar mills - remain located in the coastal area where land is scarce.

Sectoral Production

The impact on the production sector is displayed in Table 9. For non agricultural sectors, the effects may be summarized through four channels. Firstly, the use of biofuels will displace the current use of fossil fuel. Under ethanol production, the sector for refined oil witnesses a production decline of 2.5%, on average, when sugarcane is used for ethanol production. This decline is more than twice more when molasses is used to produce ethanol. Declines in the refined oil sector are far greater when biodiesel is produced and may reach up to 9% when jatropha is used as the feedstock for biodiesel. One reason for this is that the mandate for biodiesel represents a larger volume than its ethanol counterpart. However, this drop in sectoral production may also be explained by a price effect. The mandate forces the blender to use the biofuel whose price is higher than the fossil fuel price. Since the tax on fuel is not endogenized in the model, nor does the model introduce a new subsidy, the pump price of fuel increases, and will increase more when inefficient feedstocks are used (jatropha or molasses) as a response to the higher biofuel prices. This increase in the price of fuel adversely impacts consumers and other sectors in the economy, such as the transportation sector. These declines in production in the transportation sector - up to -1.2% under the molasses scenarios - and the consequent price increases, reduces consumers' demand for fuel. Finally, there are indirect effects that take place through the factor markets and the demand for inputs. This last effect in particular is important for the manufacturing sectors in the molasses scenarios. There, production factors freed by other sectors, due to the shock e.g. fossil fuel activities, will be absorbed by the other manufacturing sectors. Overall, the cogeneration of electricity has insignificant effects on the production of electricity (less than -0.04%) and is absorbed by the economy.

Table 9 : Sectoral Production – % Change compared to the Baseline

	Eth1 Sugarcane	Eth2 Sugarcane	Eth3 Sugarcane	Eth4 Mol	Eth5 Mol	BioDies6 Palmoil	BioDies7 Palmoil	BioDies8 Jat	BioDies9 Jat
Cereal	-0.04	0.02	0.01	-0.70	-0.88	0.03	0.02	-0.08	-0.02
Fruit	-0.22	-0.04	-0.03	0.00	0.39	-0.07	-0.05	0.13	0.00
Vegetables	-0.21	-0.03	-0.02	0.14	0.61	-0.04	-0.04	0.17	0.06
Legumes	-0.14	-0.02	-0.01	-0.09	0.15	-0.03	-0.02	0.09	0.03
Other Crops	-0.20	-0.02	-0.02	-0.61	-0.58	-0.02	-0.01	0.03	-0.03
Livestock	0.02	0.03	0.03	-0.89	-1.29	0.04	0.03	-0.23	-0.15
Forest	0.04	0.03	0.02	-0.37	-0.53	0.04	0.03	-0.07	-0.01
Fishing	0.03	0.03	0.01	-0.87	-1.18	0.04	0.05	-0.34	-0.26
Sugar	0.00	0.09	0.09	37.80	35.26		0.00	0.00	0.65
Oils & Fats	0.38	0.39	0.38	0.00	0.00	-0.04	0.00	-11.14	-10.93
Bev & Tobacco	0.00	0.10	0.09	-7.49	-10.14	0.00	0.00	0.01	0.70
Fuel	-0.12	-0.10	-0.01	-7.21	-8.52	-1.41	-1.45	-5.13	-3.82
Refined Oil	-2.60	-2.59	-2.53	-7.76	-8.64	-6.18	-6.21	-9.08	-8.08
Other Manufacturing	0.03	0.02	-0.01	2.51	3.17	0.22	0.16	0.71	0.93
Electricity & Water	-0.04	-0.04	-0.04	0.02	-0.01	0.01	0.03	-0.08	-0.11
Transportation	-0.01	-0.01	-0.01	-1.00	-1.25	-0.17	-0.19	-0.67	-0.50
Food Products	0.01	0.03	0.02	-0.81	-1.14	0.02	0.02	-0.22	-0.16

Note: Production changes for sectors without initial production (biofuels and jatropha) are not displayed since their relative changes are not significant.
Source: Peru CGE Model, 2010

The impact on the agricultural sectors from developing the ethanol sector, is shown in Tables 9 and 10 (production changes for biofuels and their feedstocks). Imposing the ethanol mandate in Peru and using molasses as the feedstock (Scenarios 4 and 5) leads to the largest negative impacts on that sector. The only two sectors that stand to gain from using molasses as a feedstock are the sugarcane and the sugar sector (about +35%). When sugarcane is used directly for fuel ethanol production, its production increases by 7%.

The impacts on sectoral production of enforcing the biodiesel mandate in Peru - scenarios 6 through 9 – differ across the agricultural sector. Other crops, including sugarcane, are weakly affected since the land extensions for palm oil and jatropha are in the jungle area and so do not compete with land used for the production of the other agricultural activities. Under scenarios Biopalm 6 and 7, palm fruit production rises more than three times its baseline production (+800,000 tons). When jatropha is the feedstock producing biodiesel in Peru (458,000 tons), the production of palm fruit, and consequently, oils and fats falls by more than 11% as both perennial crops compete for the same land.

It is estimated that the mandates will lead to the production of 64 million liters of ethanol and 124 million liters of biodiesel.

Table 10 : Sectoral Production of Biofuels and their Feedstocks – Volume Changes Compared to the Reference Situation

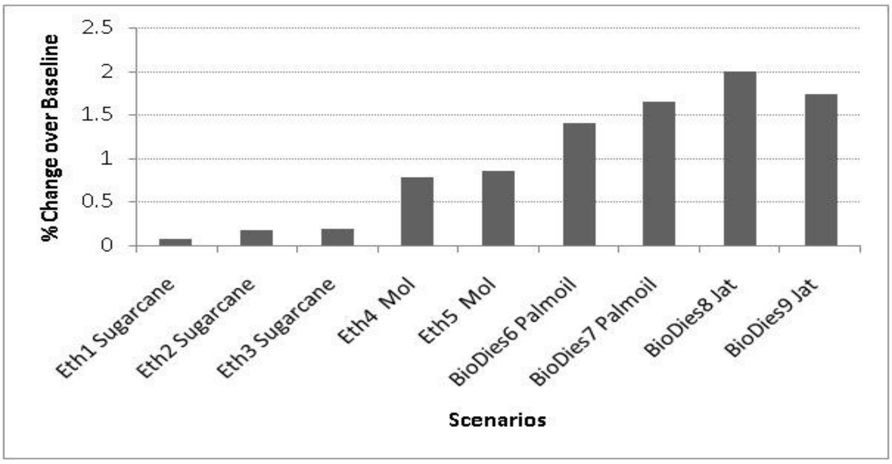
	Sugarcane	Palm Fruit	Jatropha	Ethanol for road transportation	Biodiesel for road transportation
	1000 Tons	*1000 Tons*	*1000 Tons*	*Million liters*	*Million liters*
Reference	8,969	238	0	0	0
Eth1 Sugarcane	9,623	239	0	64	0
Eth2 Sugarcane	9,631	239	0	64	0
Eth3 Sugarcane	9,631	239	0	64	0
Eth4 Mol	12,359	238	0	64	0
Eth5 Mol	12,132	238	0	64	0
BioDies6 Palmoil	8,969	1,046	0	0	129
BioDies7 Palmoil	8,969	1,046	0	0	129
BioDies8 Jat	8,969	212	458	0	129
BioDies9 Jat	9,028	212	458	0	129

Source: Peru CGE Model, 2010

Farm Value Added

Figure 4 shows the impact on farm value added from promoting the biofuel sector in Peru. The overall effect on value added remains limited for the sugarcane ethanol scenarios (up to 0.3%) as even with the ethanol mandate, sugarcane production constitutes only 3% of overall agricultural production. When molasses is the feedstock for ethanol, however, the effects on agricultural value added are three times as large than when sugarcane is directly used for the production of ethanol. Other crops, on the other hand, are negatively affected. The scenario with the largest positive impact on farm value added is the low-yield jatropha technology. Farm value added rises by 2% as higher jatropha production leads to more land extension - a result of the higher cost of producing this crop to produce biodiesel - a large share of the value added remains in agricultural sector.

Figure 4 : Farm Value Added



Source: Peru CGE Model, 2010

Table 11 displays the value added per hectare that would accrue to the agricultural sector from producing ethanol in Peru. Producing ethanol from molasses clearly brings about the largest value added per hectare. As already discussed, the molasses scenarios lead to a significant pressure on the existing land resources and drastically increase the value of each hectare in the sugarcane industry as well as in the other agricultural sectors. The other ethanol scenarios produce modest positive impacts in value added per hectare across most activities in the agricultural sector. For activities located in the jungle, the scenario Ethanol3 leads to the extension of activities within this region and the amount of new lands allocated to production reduces the average value by hectare, however, total value added still expands.

Table 11 : Value Added per Hectare (Ethanol Production), % Change over Baseline

	Eth1 Sugarcane	Eth2 Sugarcane	Eth3 Sugarcane	Eth4 Mol	Eth5 Mol
Cereal	0.30	0.06	0.07	-3.72	-5.64
Fruit	0.39	0.09	0.08	-3.97	-6.07
Vegetables	0.40	0.09	0.08	-3.99	-6.10
Legumes	0.39	0.09	0.08	-3.98	-6.07
Sugarcane1	0.98	-4.21	-4.20	667.91	1096.25
Sugarcane2	0.66	0.15	0.14	-4.42	-7.07
Sugarcane3	n.a.	n.a.	-10.23	-26.96	-79.92
Sugarcane4	n.a.	n.a.	-0.11	-1.80	27.52
Palm1	n.a.	n.a.	-11.39	-29.73	-88.55
Palm2	n.a.	n.a.	-0.30	-0.53	72.59
Jatropha1	n.a.	n.a.	n.a.	n.a.	n.a.
Jatropha2	n.a.	n.a.	n.a.	n.a.	n.a.
Jatropha3	n.a.	n.a.	n.a.	n.a.	n.a.
Oth Crops	0.39	0.09	0.08	-3.97	-6.06
Livestock	0.04	0.00	0.03	-3.23	-4.62

Source: Peru CGE Model, 2010

Table 12 : Value Added per Hectare (Biodiesel Production), % Change over Baseline

	BioDies6 Palmoil	BioDies7 Palmoil	BioDies8 Jat	BioDies9 Jat
Cereal	-0.20	-0.23	-1.53	-0.84
Fruit	-0.17	-0.20	-1.73	-0.97
Vegetables	-0.17	-0.20	-1.74	-0.98
Legumes	-0.17	-0.20	-1.73	-0.98
Sugarcane1	-3.64	-3.37	-77.22	-77.13
Sugarcane2	-0.07	-0.12	-1.94	-0.99
Sugarcane3	1.27	-0.58	369.76	159.81
Sugarcane4	n.a.	n.a.	n.a.	n.a.
Palm1	1.45	-0.61	411.76	177.96
Palm2	-0.39	0.62	14.37	368.59
Jatropha1	n.a.	n.a.	264.66	114.41
Jatropha2	n.a.	n.a.	7.31	n.a.
Jatropha3	n.a.	n.a.	n.a.	107.12
Oth Crops	-0.17	-0.20	-1.72	-0.97
Livestock	-0.30	-0.31	-1.26	-0.77

Source: Peru CGE Model, 2010

Producing biodiesel using jatropha provides a more consistent increase in the value added per hectare for all crops in the jungle area (Table 12). The reasoning is that through the model solution, the jungle region, whether smallholder or commercial farm, is the one impacted by the biodiesel scenarios and coupled with the fact that when smallholders have high yield, they manage to generate high rents from the land they use (+107%). Lastly, the use of new land in the jungle area initially allowed for jatropha crop growth can be used, after market clearing, by sugarcane producers thus reducing the pressure on land used by commercial farms for sugarcane production in the coastal region.

Income effects and welfare

The model is used to calculate the consumer's equivalent variation (EV) as a proxy for measuring welfare. EV measures the minimum payment that would be required to give/take from the consumer such that he/she are well off before the change[21] as after. Table 13 provides results for the overall household sector and for the breakdown between rural and urban households in millions of Soles. It is clear that the Ethanol producing scenarios 4 and 5 are the most adverse, as discussed in the GDP section. Overall though, rural households benefit poorly from the biofuel mandates. For them, the most favorable outcomes are reached when jatropha is used and they have high yields (+0.17%), when palm fruit is used and they are included in the production process (+0.12%), and, under the sugarcane scenario when production is by, commercial/smallholder mix in the coastal areas. However, urban households are negatively affected under all the scenarios except under the sugarcane ethanol scenarios - 2&3. These results are mainly driven by the increase in the price of fuel as a result of the mandate. Interestingly, for urban households the outcome is worse when smallholders are involved in the production of the biofuel feedstocks (scenarios 1 and 6). They are less productive thus their involvement leads to a higher increase in the production costs of biofuels ultimately resulting in an increase in the production costs of gasoline and diesel and thus the overall price of fuel. As

[21] For more details on the methodology see Blonigen et al, 1997.

discussed earlier, domestic taxation on fuel is not adjusted and so it is expected that the results indicate that consumers are paying the price of mandate policy. We may consider a policy where the increased production cost of the fuel, for the blenders, is compensated by a tax decrease and/or a subsidy. However, this policy would have cost implications for the taxpayer. Depending on the differences between the household distribution in terms of fuel consumption and of tax contribution, results from Table 13 may change. However, it is still realistic to think that most of the burden will be paid by urban households given their higher spending on fuel (4.1% of total consumption spending) vis a vis their rural counterparts (1.48% of total consumption spending).

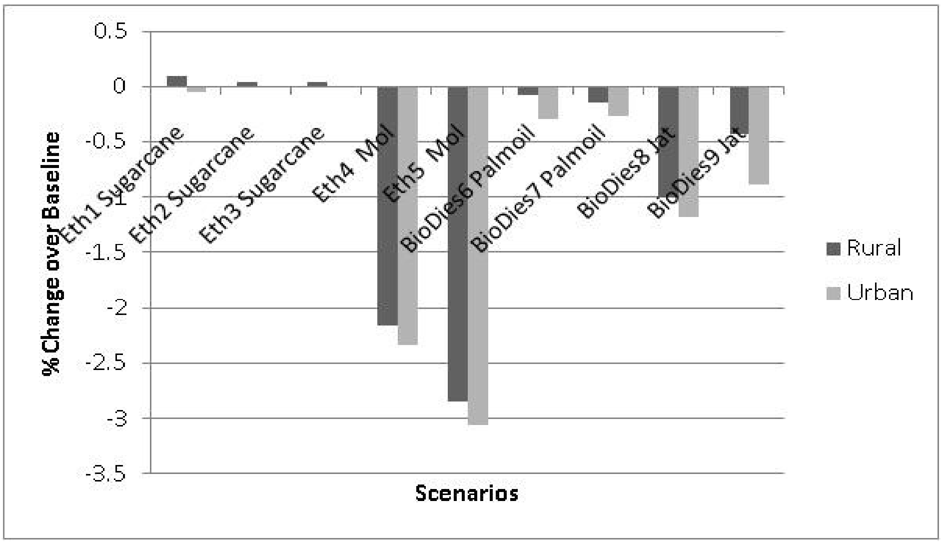
Table 13 : Equivalent Variation, Value, Millions Soles

	Rural		Urban		Total	
Eth1 Sugarcane	22.12	*0.08%*	-20.09	*-0.02%*	2.03	*0.00%*
Eth2 Sugarcane	13.6	*0.05%*	5.6	*0.00%*	19.2	*0.01%*
Eth3 Sugarcane	12.41	*0.04%*	13.63	*0.01%*	26.04	*0.02%*
Eth4 Mol	-214.79	*-0.76%*	-1436.55	*-1.08%*	-1651.35	*-1.02%*
Eth5 Mol	-294.24	*-1.04%*	-1865.26	*-1.40%*	-2159.5	*-1.34%*
BioDies6 Palmoil	33.1	*0.12%*	-162.22	*-0.12%*	-129.12	*-0.08%*
BioDies7 Palmoil	15.57	*0.06%*	-135.38	*-0.10%*	-119.81	*-0.07%*
BioDies8 Jat	-23.47	*-0.08%*	-630.96	*-0.47%*	-654.42	*-0.41%*
BioDies9 Jat	47.2	*0.17%*	-503.02	*-0.38%*	-455.82	*-0.28%*

Source: Peru CGE Model, 2010

Figure 5 displays similar results to Table 13 with one important difference: percentage changes in household income are computed before the redistribution of profits by the firms to the households. Since the role of commercial farms is important - at least 60% of the biofuel production- and given the uncertainties about the structure of their shareholders, it may be interesting to look at household income before profit redistribution. Indeed, if we assume that current firm ownership follows the average pattern of the economy, there may be a case where numerous investments are undertaken through foreign direct investment and/or joint ventures. In this case, a large share of the profits may be repatriated abroad, hence reducing overall gains for the Peruvian economy. These results appear in Figure 5 where all household categories are worse off, with only the ethanol scenarios (1 to 3) positively impacting rural households.

Figure 5 : Household Income (Before Redistribution of Firm Profits)

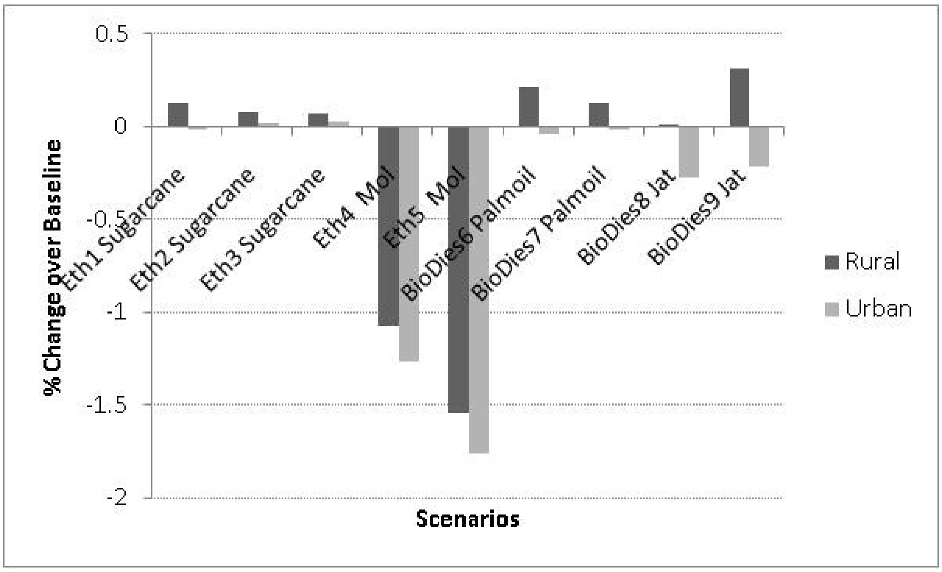


Source: Peru CGE Model, 2010

Household income is falling across all scenarios with the most significant reductions occurring when molasses is the feedstock used in ethanol production. The reduction in household income follows the general reduction pattern in factor income. The negative impacts on rural households are slightly mitigated, compared to their urban equivalents, as 80% of land rents accrue to rural households which may be seen in Figure 5.

Household consumption, computed by the model, may be another proxy to welfare and distribution effects. Figure 6 shows the impact of biofuel promotion on food consumption.

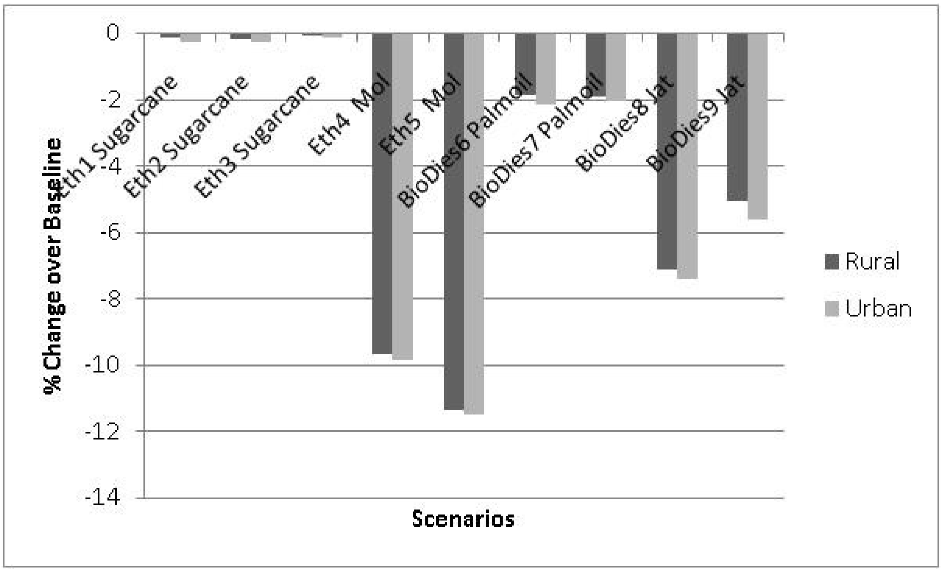
Figure 6 : Household Food Consumption



Source: Peru CGE Model, 2010

From Figure 6, the most significant impact (a fall by more than 1%) on household food consumption occurs when molasses is used to produce ethanol as this coincides with the significant reductions in income shown in Figure 5. For the other sugarcane ethanol scenarios, food consumption increases slightly (up to +0.13% for rural household in scenario 1). For biodiesel scenarios, the palm fruit production with smallholder participation and high-yield jatropha production increases food consumption in the rural areas (+0.2 and +0.3%, respectively). However, the jatropha scenarios also have adverse effects on urban households (at least -0.2%). It is important to note that these overall changes in food consumption are limited and mainly represent the changes in real income (driven by the changes in factor income and more importantly, the price of fuel). The competition for land and the potential increase in agricultural prices is quite limited and not relevant in this analysis.

Figure 7 : Household Fuel Consumption



Source: Peru CGE Model, 2010

A more detailed focus on household fuel consumption (Figure 7) shows that it falls across all scenarios, and more significantly so under the Ethanol4 and Ethanol5 scenarios, followed by the Biojatropha8 and 9. That pattern of consumption mimics the pattern of increasing fuel prices where the commodity price of fuel increases by over 19% and 16% over the baseline under the Ethanol5 and the Ethanol4 scenarios, respectively.

Robustness Checks

In order to add robustness as well as some comprehensiveness to the results of the model, a series of robustness checks were conducted. The first addresses the assumption on the land markets, the second allows trade and, finally, the third allows the freedom to choose amongst the different feedstocks available to produce biofuels.

Land Robustness Check

In this analysis, two assumptions on the land market are relaxed. One allows land supply flexibility[22] in order to maintain the average price of land in each region constant and the other allows smallholders access to the new lands available for feedstock production[23].

Assuming land supply is flexible, the amount of land needed to stabilize land prices is presented below in Table 14. The largest amount of land needed under this assumption is for jatropha (up to +82,000 ha). Interestingly, these figures appear to be below the existing projection of land extension.

Table 14 : Additional Land Needed to Stabilize Land Rends in Real Terms, 1,000 Ha

	Coastal Area	Jungle
Eth1 Sugarcane	5	0
Eth2 Sugarcane	5	0
Eth3 Sugarcane	0	6
Eth4 Mol	27	2
Eth5 Mol	27	2
BioDies6 Palmoil	0	34
BioDies7 Palmoil	0	32
BioDies8 Jat	-3	82
BioDies9 Jat	-4	64

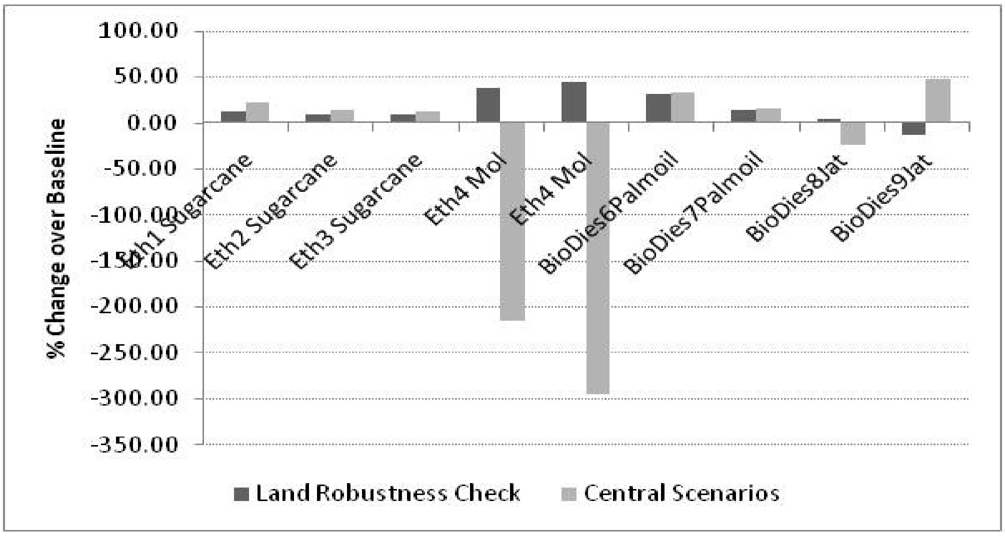
Source: Peru CGE Model, 2010

For ethanol production, adding this flexibility leads to large increases in value added across all the scenarios when sugar production is in the coastal area, i.e. scenario 1, and the molasses scenarios 4 and 5. For the molasses scenarios, value added gains in agriculture are doubled (from +0.7% to +1.4%). These results show the constraint that the land market assumption, under the central case, places on the model when considering different scenarios for biofuel production. Indeed, with the standard land market assumption, commercial farms have very limited capacity to extend their land endowment in the coastal areas since they cannot rent lands to smallholders and no new lands are available for them.

Figure 8 : Rural Household Welfare, Robustness Checks for Land Markets

[22] Land supply is assumed to be infinitely elastic

[23] All other assumptions in the central case hold for this check.



Source: Peru CGE Model, 2010

Finally, as shown in Figure 8, the impact of relaxing assumptions on the land markets is quite significant for the real income changes of the rural households and may, indeed, reverse the results reached under the central scenarios. Land assumptions in the central scenarios limit the income gains from the sugarcane juice scenarios since land expansion mitigates the increase in land rents, which are a source of income for rural households. The largest changes take place under the molasses scenarios where the model reaches an improved allocation of land between smallholders and commercial farms who can now "rent" their lands from smallholders and so add 27,000 Ha to the land supply. Sugar production - aimed at increasing molasses production – can now expand at reasonable cost increases without adversely impacting the factor markets thus reducing the competitiveness of the price of ethanol and thus protecting the economy from alternative adverse effects.

For biodiesel production, the changes are not uniform, especially with respect to the jatropha scenarios. The correlation of land rents amongst users (commercial firms and smallholders) plays an important role on the outcomes of the model. In the case of the low-yield smallholders for instance, they alone bear the cost of this inefficiency as they face a market price of jatropha that is driven by the scale of the commercial farms, however, their low-yield technology allows them to suffer losses. Contrary to the previously mentioned land market structure, land competition between commercial farms and smallholder farms and the ensuing land price correlation, allows smallholders to benefit, indirectly, from higher land rents[24]. For urban households, allowing more flexibility to the land markets, and in particular, allowing smallholders to have access to new land, will reduce the adverse costs of biofuel policies. Not only will these adverse effects be neutralized for the molasses scenarios, slightly positive gains also ensue. Similarly, losses will be reduced by 50% for the biofuel jatropha scenarios.

Overall, linking markets between smallholders and commercial farms and allowing the former to compete for additional land (and not granting a monopoly to commercial firms) reduces the pressure on land prices and thus limits fuel price increases.

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[24] it's emphasized that only the average price of land is kept constant. So, land price of smallholders can increase more than in the central case whereas land price of commercial firms increases less.

Trade Robustness Check

This introduction allows trade in the biofuel sector, which allows decision makers to explore the impacts behind the domestic promotion of the biofuel sector.

The model shows that allowing trade without any border protection leads to massive imports of both ethanol and biodiesel in order to fullfill the domestic mandate. Domestic production of ethanol would still take place in some cases (e.g. sugarcane from the jungle) however, it is more limited (less than 6 million liters) and may be exported to third markets (such as the US) and ethanol imported from other sources (e.g. Brazil) can be used to satisfy the domestic market requirement. For biodiesel, domestic production disappears.

The consequences in terms of welfare are quite the opposite. Allowing trade in ethanol leads to a slight increase of 0.28% in welfare, whereas for biodiesel, welfare falls by 0.38%. In the latter case, the large imports will lead to a negative shock to the current account and, with the current model closure, a real depreciation in the exchange rate. Having a policy that increases the demand of a good for which the economy is not competitive, and allowing trade, leads to a deterioration in Peru's terms of trade and consequently leads to significant costs to the economy. Interestingly, the liberalisation scenario on biodiesel leads to a worse outcome than an autarkic strategy using palm oil.

The effects of the domestic mandate with trade liberalisation on agricultural value added are close to zero.

As expected, the rural households are better off than urban households with trade liberalization in ethanol and the reverse is true for the biodiesel case.

Optimal Feedstock Allocation Robustness Check

The last set of robustness checks allows the model to choose the optimal allocation, i.e. the most economical, of feedstocks and the production process to produce both ethanol and biodiesel. Contrarily to previous simulations, each technology is available for use in reaching the ethanol and biodiesel targets.

For the ethanol mandate, more than 99% would be produced using sugarcane provided by commercial farms (scenario 3). The remaining production will be based on the low opportunity cost molasses. In this case, agricultural value added increases by 0.2% without any significant cost in the country's real GDP.

For the biodiesel mandate, the palm fruit feedstock is preferred. However, in this case, the mix 60/40 between smallholders and commercial firms appears to be the best outcome. It leads to an increase in agricultural value added by 1.4% but a fall in real GDP by 0.08%.

Conclusion

This study uses a single country static Computable Equilibrium Model (CGE) adapted to study the impact of the biofuel promotion policies implemented by the Government of Peru on the country's macro economy, sectoral production and welfare. Assuming the full employment of existing production factors and no dynamic gains, e.g. economies of scale, our analysis will focus on the efficiency costs of such policies and their redistributive impacts. At the same time, we do not consider all the dynamic gains of such policies or the existing costs, monetary and environmental, of putting new land into cultivation. Four land markets are considered to reflect differences between two regions (coastal and jungle), and two farm technologies (smallholders and commercial farms). Four types of feedstock are considered: sugar cane ethanol, molasses from sugar cane, palm oil, and jatropha. Initially, the production of biofuels is assumed to be zero and trade is not allowed to take place. Within this framework, it is assumed that the effects of a mandatory blending policy would lead to the consumption of 3,600 barrels of petroleum equivalent per day (BPD) of biodiesel and 1,100 BPD of ethanol by 2015. The model is an exploratory undertaking to formally quantify the impact of the different policy alternatives on the Peruvian economy.

On one hand, the results indicate that the ethanol mandatory policy based on sugar cane has no significant effects on the Peruvian real GDP, and the biodiesel mandate leads to a minimal efficiency cost (up to 0.07% of real GDP) if palm oil is used. On the other hand, using only molasses for the production of fuel ethanol would be more costly, in particular if they are currently used efficiently by other industries, if no demand exists for the additional sugar production, or if the sugar sector (and sugar mills) remains located in the coastal area where land is scarce.

Under the assumption of constant taxation on fuel, using biofuels will increase the cost of the fuel for the final consumer and for intermediate users (transportation sectors) leading to a decline in fuel consumption. This effect is, in general, very limited except when molasses and jatropha are the biofuel feedstocks used. In those two cases, price increases can reach 20% in the most adverse case, and 9%, respectively. With a mandatory policy, it is customary that consumers bear the cost of such a policy and if the model considers a subsidy or tax reduction, taxpayers would suffer a similar cost. The model shows clearly that the tax policy on biofuels that may be a complement or a substitute to the mandate policy is a critical element in assessing the final redistributive outcomes of the biofuel strategy.

Agricultural value added increases - more than 1% - under the biodiesel scenarios as a result of the land expansion and when molasses is used for biofuel production. The latter case may be explained by the fact that sugarcane production has to increase on a much larger scale when molasses is used than when sugarcane is used directly for biofuel production. Agricultural production of non-biofuel feedstock is not impacted when the expansion takes place in the jungle area as there is no land competition taking place. However, under the molasses scenarios, both, land competition and macro economic downturns lead to a fall in production of nearly 1 % for cereal and livestock production. Under the other scenarios where sugarcane expansion takes place in the coastal area, the production of different crops declines by about 0.2%.

Rural household incomes, in general, rise as a result of the biofuel mandates, except when molasses and low-yield jatropha are used as feedstock for biofuel production. These gains to the rural households are paid for by the urban households where the resultant rise in fuel prices adversely affects their welfare. Under the sugarcane ethanol scenarios, the income increases for rural households range from 12 million Soles (0.04%, with expansion in jungle area) to 22 million (0.08%, with expansion in the coastal area). Under the biodiesel scenarios, increases in rural household income range from 16(0.06%) to 47(0.17%) million Soles attributable to the high-yield jatropha technology used by smallholders. The latter example shows that the most efficient policy that increases rural household income whilst at the same time benefitting smallholders adversely affects urban households. They incur losses of more than 500 million Soles resulting in net losses in overall household incomes as a result of the biofuel policy. Only ethanol producing policies may have positive or neutral overall outcomes on welfare.

The results from this exploratory analysis are quite significant: first, imposing a blending target on biodiesel when Peru's comparative advantage is in the production of ethanol, makes it an inefficient tool to redistribute income and reduce poverty in rural areas. Second, coupled with the upward trend in diesel use, a blending target on biodiesel would lead to high economic costs. Finally, the high cost of fuel for road transportation may also lead to adverse consequences for the most remote locations and the poor regions across Peru by increasing transportation costs nationwide.

In order to provide a more comprehensive analysis of complementary policy considerations to Peru's biofuel strategy, the authors test for robustness by introducing alternative assumptions. Three checks for robustness are conducted: introducing alternative assumptions to the land market (the supply of land increases to balance demand, and smallholders are also allowed access to the new lands); liberalizing trade; and freeing the markets of feedstock for fuel blenders.

The first test of robustness highlights the role of the land market in Peru. Relaxing the land constraints in the coastal areas leads to positive results and even the large losses incurred under the molasses scenarios are eliminated. Similarly, giving smallholders access to more land will mitigate the increase in their production costs under the jatropha scenarios - where smallholder participation is greater and land requirements are higher than in palm oil production - and consequently, reduces the total cost of the biodiesel policy

Removing trade barriers leads to more trade in ethanol and biodiesel. Local production of biodiesel disappears, since no feedstock appears to be competitive, and ethanol production and exports increase. Trade liberalization, under biodiesel promotion, leads to a worse outcome than under the autarkic strategy that uses palm oil.

Finally, when fuel blenders are allowed to choose the most cost effective feedstock the most efficient production process for ethanol is the one that uses sugarcane grown in the jungle and that for biodiesel it is the use of palm oil as a feedstock in a 60/40 production mix between large firms and smallholders.

Results from the current model may be complemented and enhanced by including a more medium term time horizon, in particular modeling the dynamic learning effect in the industry (nascent industry argument). Furthermore, including a more microeconomic focus through micro-simulations would provide more detailed analysis about household welfare. The role of trade, and in particular the growing demand in markets where Peru benefits from preferences may also be critical and would need to be studied. In this context, the competition between high value exports and a domestic target will need to be investigated carefully. The integration of both these features would serve to provide the policy maker with a deeper, more time cognizant, and overall, a more comprehensive picture of the macro and micro dynamics underlying the Peruvian economy in order to formulate a sustainable national biofuel policy.

Annexes

Tables and Figures

Consumption for Fuel for Transport, 1000 Petroleum Equivalents per Day

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Diesel 2 (MBPD)	60.7	61.8	61.5	62.8	62.2	63.7	65.1	66.6	68.2	69.9
Biodiesel Requirements			1.3	1.3	3.3	3.3	3.4	3.5	3.6	3.7
Gasoline (MBPD)	19.4	18.7	18	16	15.5	14.9	14.4	13.9	13.5	13
Ethanol Requirement				1.4	1.3	1.3	1.2	1.2	1.1	1.1

Sources:
Ministry of Energy and Mines
Plan Referencial de Hidrocarburos 2007-2016

Scenario 1: Ethanol 1
Costs of Sugarcane Production
Costa Commercial/Small holder

Commercial Production	**US$/ha**	**US$/t**
Labour	196.25	1.40
Machinery	143.35	1.02
Land costs***	60.00	0.43
Supplies	575.88	4.11
Others**	483.00	3.45
Transport costs*	266.00	1.90
Total Costs		12.32
Yield****		***140***
Profit Margins	1,724.48	13.68

Smallholder Production	**US$/ha**	**US$/t**
Labour	555.28	4.27
Machinery	142.50	1.10
Land costs	0.00	0.00
supplies	278.50	2.14
Others**	285.49	2.20
Transport costs*	350.00	2.69
Total costs		26.00
Yield****		***130***
Profit Margins		14

Scenario 2: Ethanol 2

		US$/t
Yield	60/40 Partnership	***18***

Notes:
this is transport of sugarcane from field to milling/refinery
*** Other cost includes admnistrative and financial expenses*
**** Purchase of marginal lands*
***** Ton per hectare*
Supplies may include fertilizers, chemicals, fuel, irrigation
Sugar content 14 %
Source:
General Memorandum of Informacion Ethanol Mega-Project in Peru

Scenario 3: Ethanol 3
Costs of Sugarcane Production
Selva Commercial/Smallholder Partnership

Commercial Production	**US$/ha**	**US$/t**
Labour	280.00	1.5
Machinery	150.00	0.8
Land costs*	166.67	0.9
Supplies	1,055.99	5.7
Others	501.55	2.7
Transport costs	93.70	0.5
Total costs		12.13
Yield		***185***
Profit Margin		***13.87***

Smallholder Production	**US$/ha**	**US$/t**
Labour	418.67	6.70
Machinery	37.50	0.60
Land costs**	83.33	1.33
Supplies	163.52	2.62
Others	245.54	3.93
Transport costs	154.00	2.47
Total costs		26.00
Yield		***62***
Profit Margin		***8.35***

		US$/t
Scenario 3:	60/40 Partnership	***19***

Note:
Sugar Content is 10%
Direct cost includes
Source:
SNV socio economic impact analysis in the production of biofuel in the peruvian amazon

Scenario 6: Palm Oil 6
Costs of Oil Palm Production
Commercial/Smallholder Partnership

Commercial Production	**US$/ha**	**US$/t**
Labour	65	2.62
Machinery	160	6.40
Land costs		0.00
Supplies	128	5.11
Others	152	6.06
Transport costs	3	0.13
Total costs	507.98	20.32
Yield		***25***
Profit Margin		***72.18***

Smallholder Production	**US$/ha**	**US$/t**
Labour	195.50	8.89
Machinery		0.00
Land costs		0.00
Supplies	321.52	14.61
Others	316.67	14.39
Transport costs	200.00	9.09
Total costs	1,033.68	92.50
Yield		***22***
Profit Margin		***45.51***

		US$/t
Scenario 6:	60/40 Partnership	***49***

Scenario 7: Palm Oil 7
Costs of Oil Palm Production
Selva Commercial

	US$/ha	***US$/t***
Labour	65	2.62
Machinery	160	6.40
Land costs		0.00
Supplies	128	5.11
Others	152	6.06
Transport costs	3	0.13
Total costs	507.98	20.32
Yield		***25***

Scenario 8: Jatropha 8
Costs of Jatropha Production

Selva Commercial	**US$/ha**	**US$/t**
Labour	524.00	68.95
Machinery		0.00
Land costs	60.00	7.89
Supplies	305.83	40.24
Others	274.67	36.14
Transport costs	111.33	14.65
Total costs	1,275.84	167.87
Yield*		***7.6***

Smallholder	**US$/ha**	**US$/t**
Labour	350.00	87.50
Machinery		0.00
Land costs		0.00
Supplies	140.00	35.00
Others	379.74	94.94
Transport costs	21.00	5.25
Total costs	890.74	250.01
Yield*		***4***
Profit Margin**		***27.32***

		US$/t
Yield	60/40 Partnership	***201***

Note:
** Tons per Hectare*
*** According to reports by Grupo Tello they are willing to pay 250 US$ per ton for raw material.*

Scenario 9: Jatropha 9
Costs of Jatropha Production
Selva Commercial/Smallholder Partnership

Commerical	**US$/ha**	**US$/t**
Labour	524.00	68.95
Machinery		0.00
Land costs	60.00	7.89
Supplies	305.83	40.24
Others	274.67	36.14
Transport costs	111.33	14.65
Total costs	1,275.84	167.87
Yield*		***7.6***
Profit Margin		***11.96***

Smallholder	**US$/ha**	**US$/t**
Labour	597.50	91.92
Machinery		0.00
Land costs		0.00
Supplies	347.46	53.46
Others	160.63	24.71
Transport costs	63.33	9.74
Total costs		179.83
Yield*		***6.5***
Profit Margin		***70.17***

		US$/t
Yield	*60/40 Partnership*	***173***

Note:
** Tons per Hectare*

Ethanol: Production Costs of Processing, US$ per Liter

US$/LSales price ETOH

-	Ethanol 1	Ethanol 2	Ethanol 3	Ethanol 4	Ethanol 5
Raw Materials	0.2211	0.1531	0.2496	0.3800	0.1896
Utilities	0.0239	0.0239	0.0038	0.0626	0.0626
Labour	0.0027	0.0027	0.0228	0.0108	0.0108
Maintenance	0.0099	0.0099	0.0303	0.0197	0.0197
Operating Charges	0.0007	0.0007	0.0057	0.0027	0.0027
General Plant Costs	0.0063	0.0063	0.0266	0.0153	0.0153
General and Administrative costs	0.0212	0.0157	0.0271	0.0393	0.0241
Capital depreciation a	0.0542	0.0542	0.1456	0.1068	0.1068
Co-product for ferti irrigation	0.0024	0.0024	0.0033	0.0000	0.0000
Total Production Cost	***0.3425***	***0.2690***	***0.5147***	***0.6372***	***0.4316***
Energy Sales from Electricity Co-Generation*	0.0899	0.0899	0.0437	0.0000	0.0000
Net Production Cost*	***0.2526***	***0.1791***	***0.4710***	***0.6372***	***0.4316***
Profit					

Employment Generation

Type of Labour	**per shift (3 shifts)**	**per shift (3 shifts)**	**per shift (1shift)**	**per shift (2 shifts)**	**per shift (2 shifts)**
Operator	17	17	6	17	17
Superivsor	2	2	1	2	2
Total	**57**	**57**	**7**	**38**	**38**

Note:

** The assumed feeding tariff for electricity to the national grid is 70 cents US/kWh, ** Net of Revuenue from Electricity Co-Generation*

, 1MT Ethanol = 1270 liters ; 6,320 TM with value of US$ 5.6 millions

Price of ethanol paid to Grupo Romero in Dec 2009 was US$0.697 per liter

Scenarios

Ethanol 1: Coastal Commercial/Smallholder Partnership

Ethanol 2: Coastal Commercial Production

Ethanol 3: Selva Commercial/Smallholder Partnership, Hydrated Ethanol

Ethanol 4: Commercial/Smallholder, High Opportunity Cost Molasses

Ethanol 5: Commercial/Smallholder, Low Opportunity Cost Molasses

Source: FAO

Biodiesel: Production Costs of Processing, US$ per Liter

US$/L   Sales price biodiesel

-	Biodiesel 6	Biodiesel 7	Biodiesel 8	Biodiesel 9
Raw materials	0.1756	0.1664	0.5739	0.6227
Service fluids	0.0167	0.0167	0.0008	0.0008
Labour	0.0027	0.0027	0.0179	0.0179
Maintenance	0.0014	0.0014	0.0059	0.0059
Operating charges	0.0007	0.0007	0.0045	0.0045
General plant costs	0.0020	0.0020	0.0119	0.0119
General and administrative costs	0.0159	0.0152	0.0492	0.0531
Capital depreciation a	0.0219	0.0219	0.0844	0.0844
Total Production Cost	***0.2369***	***0.2270***	***0.7485***	***0.8012***
*Co-Product Raw Glycerol			0.0954	0.0954
Net Production Cost	***0.2369***	***0.2270***	***0.6531***	***0.7058***

Employment Generation

Type of Labour	per shift (2shifts)	per shift (2 shifts)	per shift (2shifts)	per shift (2 shifts)
Operator	17	17	17	17
Superivsor	2	2	2	2
Total	**57**	**57**	**38**	**38**

Note:

** Assume a 0.33 USD/kg price (half of what is the market price for Colombia)*

*** Net of Revuenue from Electricity Co-Generation*

Biodiesel 6: Palm Oil Commercial/Smallholder Partnership

Biodiesel 7: Palm Oil Commercial Production

Biodiesel 8: Jatropha Commercial/Smallholder Partnership High Yield

Biodiesel 9: Jatropha Commercial/Smallholder Partnership Low Yield

Source:

FAO

Standard Model in Mathematical Notation

The appendix presents the Peru CGE model equations in a mathematical form. The model equations are divided into four blocks: prices, production and commodities, institutions, and system constraint block. Table B1 lists all the model sets, parameters, variables, and equations. The naming convention for parameters and variables follows a simple notational principle, quantities start with a q, prices start with a p, and factor prices start by w. All model parameters are in lower case letters, and variables are in upper case letters[25].

[25] A more detailed description of the model equation may be found at Lofgren et al. (2002).

Table B.1. Mathematical Summary Statement for the Standard CGE Model

SETS

Symbol	Explanation	Symbol	Explanation
$a \in A$	activities	$c \in CMN(\subset C)$	commodities not in *CM*
$a \in ACES(\subset A)$	activities with a CES function at the top of the technology nest	$c \in CX(\subset C)$	commodities with domestic production
$a \in ALEO(\subset A)$	activities with a Leontief function at the top of the technology nest	$c \in CT(\subset C)$	domestic trade inputs (distribution commodities)
$c \in C$	commodities	$f \in F$	factors
$c \in CD(\subset C)$	commodities with domestic sales of domestic output	$i \in INS$	institutions (domestic and rest of world)
$c \in CDN(\subset C)$	commodities not in *CD*	$i \in INSD(\subset INS)$	domestic institutions
$c \in CE(\subset C)$	exported commodities	$i \in INSDNG(\subset INSD)$	domestic non-government institutions
$c \in CEN(\subset C)$	commodities not in *CE*	$h \in H(\subset INSDNG)$	households
$c \in CM(\subset C)$	imported commodities		

PARAMETERS

$cwts_c$	weight of commodity c in the CPI	$\overline{qg}_c$	base-year quantity of government demand
$dwts_c$	weight of commodity c in the producer price index	$\overline{qinv}_c$	base-year quantity of private investment demand
ica_{ca}	quantity of c as intermediate input per unit of activity a	$shif_{if}$	share for domestic institution i in income of factor f
$icd_{cc'}$	quantity of commodity c as trade input per unit of c' produced and sold domestically	$shii_{ii'}$	share of net income of i' to i (i' ∈ INSDNG'; i ∈ INSDNG)
$ice_{cc'}$	quantity of commodity c as trade input per exported unit of c'	ta_a	tax rate for activity a
$icm_{cc'}$	quantity of commodity c as trade input per imported unit of c'	te_c	export tax rate
$inta_a$	quantity of aggregate intermediate input per activity unit	tf_f	direct tax rate for factor f
iva_a	quantity of aggregate intermediate input per activity unit	$\overline{tins}_i$	exogenous direct tax rate for domestic institution I
$\overline{mps}_i$	base savings rate for domestic institution I	$tins01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates
$mps01_i$	0-1 parameter with 1 for institutions with potentially flexed direct tax rates	tm_c	import tariff rate
pwe_c	export price (foreign currency)	tq_c	rate of sales tax
pwe_c	export price (foreign currency)	tq_c	rate of sales tax
pwm_c	import price (foreign currency)	$trnsfr_{if}$	transfer from factor f to institution i
$qdst_c$	quantity of stock change	tva_a	rate of value-added tax for activity *a*

PARAMETERS

α_a^a	efficiency parameter in the CES activity function	δ_c^t	CET function share parameter
α_a^{va}	efficiency parameter in the CES value-added function	δ_{fa}^{va}	CES value-added function share parameter for factor *f* in activity *a*
α_c^{ac}	shift parameter for domestic commodity aggregation function	γ_{ch}^m	subsistence consumption of market commodity c for household h
α_c^q	Armington function shift parameter	γ_{ach}^h	subsistence consumption of home commodity c from activity a for household h
α_c^t	CET function shift parameter	θ_{ac}	yield of output c per unit of activity a
β_{ach}^h	marginal share of consumption spending on home commodity c from activity a for household h	ρ_a^a	CES production function exponent
β_{ch}^m	marginal share of consumption spending on market commodity c for household h	ρ_a^{va}	CES value-added function exponent

δ_a^a	CES activity function share parameter	ρ_c^{ac}	domestic commodity aggregation function exponent
δ_{ac}^{ac}	share parameter for domestic commodity aggregation function	ρ_c^q	Armington function exponent
δ_c^q	Armington function share parameter	ρ_c^t	CET function exponent

EXOGENOUS VARIABLES

$\overline{CPI}$	consumer price index	$\overline{MPSADJ}$	savings rate scaling factor (= 0 for base)
$\overline{DTINS}$	change in domestic institution tax share (= 0 for base; exogenous variable)	$\overline{QFS}_f$	quantity supplied of factor
$\overline{FSAV}$	foreign savings (FCU)	$\overline{TINSADJ}$	direct tax scaling factor (= 0 for base; exogenous variable)
$\overline{GADJ}$	government consumption adjustment factor	$\overline{WFDIST}_{fa}$	wage distortion factor for factor f in activity a
$\overline{IADJ}$	investment adjustment factor		

ENDOGENOUS VARIABLES

$DMPS$	change in domestic institution savings rates (= 0 for base; exogenous variable)	QF_{fa}	quantity demanded of factor f from activity a
DPI	producer price index for domestically marketed output	QG_c	government consumption demand for commodity
EG	government expenditures	QH_{ch}	quantity consumed of commodity c by household h
EH_h	consumption spending for household	QHA_{ach}	quantity of household home consumption of commodity c from activity a for household h
EXR	exchange rate (LCU per unit of FCU)	$QINTA_a$	quantity of aggregate intermediate input
$GOVSHR$	government consumption share in nominal absorption	$QINT_{ca}$	quantity of commodity c as intermediate input to activity a
$GSAV$	government savings	$QINV_c$	quantity of investment demand for commodity
$INVSHR$	investment share in nominal absorption	QM_c	quantity of imports of commodity
MPS_i	marginal propensity to save for domestic non-government institution (exogenous variable)	QQ_c	quantity of goods supplied to domestic market (composite supply)
PA_a	activity price (unit gross revenue)	QT_c	quantity of commodity demanded as trade input
PDD_c	demand price for commodity produced and sold domestically	QVA_a	quantity of (aggregate) value-added
PDS_c	supply price for commodity produced and sold domestically	QX_c	aggregated quantity of domestic output of commodity
PE_c	export price (domestic currency)	$QXAC_{ac}$	quantity of output of commodity c from activity a
$PINTA_a$	aggregate intermediate input price for activity a	$TABS$	total nominal absorption
PM_c	import price (domestic currency)	$TINS_i$	rate of direct tax on domestic institutions i
PQ_c	composite commodity price	$TRII_{ii'}$	transfers from institution i' to i (both in the set INSDNG)
PVA_a	value-added price (factor income per unit of activity)	$TTINS_i$	direct tax rate for institution i (i ∈ INSDNG)
PX_c	aggregate producer price for commodity	WF_f	average price of factor
$PXAC_{ac}$	producer price of commodity c for activity a	YF_f	income of factor f
QA_a	quantity (level) of activity	YG	government revenue
QD_c	quantity sold domestically of domestic output	YI_i	income of domestic non-government institution
QE_c	quantity of exports	YIF_{if}	income to domestic institution i from factor f

EQUATIONS

#	Equation	Domain	Description
	Price Block		
1	$PM_c = pwm_c \cdot (1+tm_c) \cdot EXR + \sum_{c' \in CT} PQ_{c'} \cdot icm_{c'c}$ $\begin{bmatrix} \text{import} \\ \text{price} \\ (LCU) \end{bmatrix} = \begin{bmatrix} \text{import} \\ \text{price} \\ (FCU) \end{bmatrix} \cdot \begin{bmatrix} \text{tariff} \\ \text{adjust-} \\ \text{ment} \end{bmatrix} \cdot \begin{bmatrix} \text{exchange rate} \\ (LCU\ \text{per} \\ FCU) \end{bmatrix} + \begin{bmatrix} \text{cost of trade} \\ \text{inputs per} \\ \text{import unit} \end{bmatrix}$	$c \in CM$	Import Price

2	$PE_c = pwe_c \cdot (1 - te_c) \cdot EXR - \sum_{c' \in CT} PQ_c \cdot ice_{c'c}$ $\begin{bmatrix}\text{export}\\ \text{price}\\ (LCU)\end{bmatrix} = \begin{bmatrix}\text{export}\\ \text{price}\\ (FCU)\end{bmatrix} \cdot \begin{bmatrix}\textit{tariff}\\ \textit{adjust -}\\ \textit{ment}\end{bmatrix} \cdot \begin{bmatrix}\textit{exchange rate}\\ (\textit{LCU per}\\ \textit{FCU})\end{bmatrix} - \begin{bmatrix}\text{cost of trade}\\ \text{inputs per}\\ \text{export unit}\end{bmatrix}$	$c \in CE$	Export Price
3	$PDD_c = PDS_c + \sum_{c' \in CT} PQ_{c'} \cdot icd_{c'c}$ $\begin{bmatrix}\textit{domestic}\\ \textit{demand}\\ \textit{price}\end{bmatrix} = \begin{bmatrix}\text{domestic}\\ \text{supply}\\ \text{price}\end{bmatrix} + \begin{bmatrix}\text{cost of trade}\\ \text{inputs per}\\ \text{unit of}\\ \text{domestic sales}\end{bmatrix}$	$c \in CD$	Demand price of domestic non-traded goods
4	$PQ_c \cdot (1 - tq_c) \cdot QQ_c = PDD_c \cdot QD_c + PM_c \cdot QM_c$ $\begin{bmatrix}\textit{absorption}\\ (\textit{at demand}\\ \textit{prices net of}\\ \textit{sales tax})\end{bmatrix} = \begin{bmatrix}\textit{domestic demand price}\\ \textit{times}\\ \textit{domestic sales quantity}\end{bmatrix} + \begin{bmatrix}\textit{import price}\\ \textit{times}\\ \textit{import quantity}\end{bmatrix}$	$c \in (CD \cup CM)$	Absorption
5	$PX_c \cdot QX_c = PDS_c \cdot QD_c + PE_c \cdot QE_c$ $\begin{bmatrix}\textit{producer price}\\ \textit{times marketed}\\ \textit{output quantity}\end{bmatrix} = \begin{bmatrix}\textit{domestic supply price}\\ \textit{times}\\ \textit{domestic sales quantity}\end{bmatrix} + \begin{bmatrix}\textit{export price}\\ \textit{times}\\ \textit{export quantity}\end{bmatrix}$	$c \in CX$	Marketed Output Value
6	$PA_a = \sum_{c \in C} PXAC_{ac} \cdot \theta_{ac}$ $\begin{bmatrix}\text{activity}\\ \text{price}\end{bmatrix} = \begin{bmatrix}\text{producer prices}\\ \text{times yields}\end{bmatrix}$	$a \in A$	Activity Price
7	$PINTA_a = \sum_{c \in C} PQ_c \cdot ica_{ca}$ $\begin{bmatrix}\text{aggregate}\\ \text{intermediate}\\ \text{input price}\end{bmatrix} = \begin{bmatrix}\text{intermediate input cost}\\ \text{per unit of aggregate}\\ \text{intermediate input}\end{bmatrix}$	$a \in A$	Aggregate intermediate input price
8	$PA_a \cdot (1 - ta_a) \cdot QA_a = PVA_a \cdot QVA_a + PINTA_a \cdot QINTA_a$ $\begin{bmatrix}\textit{activity price}\\ (\textit{net of taxes})\\ \textit{times activity level}\end{bmatrix} = \begin{bmatrix}\textit{value-added}\\ \textit{price times}\\ \textit{quantity}\end{bmatrix} + \begin{bmatrix}\textit{aggregate}\\ \textit{intermediate}\\ \textit{input price times}\\ \textit{quantity}\end{bmatrix}$	$a \in A$	Activity revenue and costs
9	$\overline{CPI} = \sum_{c \in C} PQ_c \cdot cwts_c$ $\begin{bmatrix}\text{CPI}\end{bmatrix} = \begin{bmatrix}\text{prices times}\\ \text{weights}\end{bmatrix}$		Consumer price index
10	$DPI = \sum_{c \in C} PDS_c \cdot dwts_c$ $\begin{bmatrix}\text{Producer price index}\\ \text{for non-traded outputs}\end{bmatrix} = \begin{bmatrix}\text{prices times}\\ \text{weights}\end{bmatrix}$		Producer price index for non-traded market output

Production and commodity block

11	$QA_a = \alpha_a^a \cdot \left(\delta_a^a \cdot QVA_a^{-\rho_a^a} + (1 - \delta_a^a) \cdot QINTA_a^{-\rho_a^a} \right)^{-\frac{1}{\rho_a^a}}$ $\begin{bmatrix}\textit{activity}\\ \textit{level}\end{bmatrix} = CES \begin{bmatrix}\textit{quantity of aggregate value-added},\\ \textit{quantity aggregate intermediate input}\end{bmatrix}$	$a \in ACES$	CES technology: activity production function
12	$\frac{QVA_a}{QINTA_a} = \left(\frac{PINTA_a}{PVA_a} \cdot \frac{\delta_a^a}{1 - \delta_a^a} \right)^{\frac{1}{1+\rho_a^a}}$ $\begin{bmatrix}\textit{value-added -}\\ \textit{intermediate-}\\ \textit{input quantity}\\ \textit{ratio}\end{bmatrix} = f \begin{bmatrix}\textit{intermediate-input}\\ \textit{- value-added}\\ \textit{price ratio}\end{bmatrix}$	$a \in ACES$	CES technology: Value—Added—Intermediate—Input ratio
13	$QVA_a = iva_a \cdot QA_a$ $\begin{bmatrix}\text{demand for}\\ \text{value-added}\end{bmatrix} = \mathrm{f} \begin{bmatrix}\text{activity}\\ \text{level}\end{bmatrix}$	$a \in ALEO$	Leontief technology: Demand for aggregate value-added
14	$QINTA_a = inta_a \cdot QA_a$ $\begin{bmatrix}\text{demand for aggregate}\\ \text{intermediate input}\end{bmatrix} = \mathrm{f} \begin{bmatrix}\text{activity}\\ \text{level}\end{bmatrix}$	$a \in ALEO$	Leontief technology: Demand for aggregate intermediate input
15	$QVA_a = \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot QF_{fa}^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}}$ $\begin{bmatrix}\textit{quantity of}\\ \textit{aggregate}\\ \textit{value-added}\end{bmatrix} = CES \begin{bmatrix}\textit{factor}\\ \textit{inputs}\end{bmatrix}$	$a \in A$	Value-added and factor demands

16	$W_f \cdot \overline{WFDIST}_{fa} = PVA_a \cdot \left(1 - tva_a\right) \cdot \alpha_a^{va} \cdot \left(\sum_{f \in F} \delta_{fa}^{va} \cdot QF_{fa}^{-\rho_a^{va}} \right)^{-\frac{1}{\rho_a^{va}}-1} \cdot \delta_{fa}^{va} \cdot QF_{fa}^{-\rho_a^{va}}$ $\left[\text{marginal cost of factor f in activity a}\right] = \left[\text{marginal revenue product of factor f in activity a}\right]$	$a \in A$ $f \in F$	Factor demand
17	$QINT_{ca} = ica_{ca} \cdot QINTA_a$ $\left[\text{intermediate demand for commodity c from activity a}\right] = \text{f}\left[\text{aggregate intermediate input quantity for activity a}\right]$	$a \in A$ $c \in C$	Disaggregated intermediate input demand
18	$QXAC_{ac} + \sum_{h \in H} QHA_{ach} = \theta_{ac} \cdot QA_a$ $\left[\textit{marketed quantity of commodity c from activity a}\right] + \left[\textit{household home consumption of commodity c from activity a}\right] = \left[\textit{production of commodity c from activity a}\right]$	$a \in A$ $c \in CX$	Commodity production and allocation
19	$QX_c = \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}}-1}$ $\left[\text{aggregate marketed production of commodity c}\right] = \text{CES}\left[\text{activity-specific marketed production of commodity c}\right]$	$c \in CX$	Output Aggregation Function
20	$PXAC_{ac} = PX_c \cdot \alpha_c^{ac} \cdot \left(\sum_{a \in A} \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}} \right)^{-\frac{1}{\rho_c^{ac}}-1} \cdot \delta_{ac}^{ac} \cdot QXAC_{ac}^{-\rho_c^{ac}-1}$ $\left[\text{marginal cost of commodity c from activity a}\right] = \left[\text{marginal revenue product of commodity c from activity a}\right]$	$a \in A$ $c \in CX$	First-Order Condition for Output Aggregation Function
21	$QX_c = \alpha_c^t \cdot \left(\delta_c^t \cdot QE_c^{\rho_c^t} + (1 - \delta_c^t) \cdot QD_c^{\rho_c^t} \right)^{\frac{1}{\rho_c^t}}$ $\left[\text{aggregate marketed domestic output}\right] = CET\left[\text{export quantity, domestic sales of domestic output}\right]$	$c \in$ $(CE \cap CD)$	Output Transformatio n (CET) Function
22	$\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PDS_c} \cdot \frac{1 - \delta_c^t}{\delta_c^t} \right)^{\frac{1}{\rho_c^t - 1}}$ $\left[\text{export-domestic supply ratio}\right] = \text{f}\left[\text{export-domestic price ratio}\right]$	$c \in$ $(CE \cap CD)$	Export-Domestic Supply Ratio
23	$QX_c = QD_c + QE_c$ $\left[\textit{aggregate marketed domestic output}\right] = \left[\textit{domestic market sales of domestic output [for } c \in (\text{CD} \cap \text{CEN})]\right] + \left[\text{exports [}\textit{for } c \in (\text{CE} \cap \text{CDN})]\right]$	$c \in$ $(CD \cap CEN)$ $\cup$ $(CE \cup CDN)$	Output Transformatio n for Non-Exported Commodities
24	$QQ_c = \alpha_c^q \cdot \left(\delta_c^q \cdot QM_c^{-\rho_c^q} + (1 - \delta_c^q) \cdot QD_c^{-\rho_c^q} \right)^{-\frac{1}{\rho_c^q}}$ $\left[\text{composite supply}\right] = \text{f}\left[\text{import quantity, domestic use of domestic output}\right]$	$c \in$ $(CM \cap CD)$	Composite Supply (Armington) Function
25	$\frac{QM_c}{QD_c} = \left(\frac{PDD_c}{PM_c} \cdot \frac{\delta_c^q}{1 - \delta_c^q} \right)^{\frac{1}{1 + \rho_c^q}}$ $\left[\textit{import - domestic demand ratio}\right] = f\left[\textit{domestic - import price ratio}\right]$	$c \in$ $(CM \cap CD)$	Import-Domestic Demand Ratio
26	$QQ_c = QD_c + QM_c$ $\left[\textit{composite } \text{supply}\right] = \left[\textit{domestic use of marketed } \text{domestic } \textit{output [for } c \in (CD \cap \text{CMN})]\right] + \left[\textit{imports [for } c \in (CM \cap \text{CDN})]\right]$	$c \in$ $(CD \cap CMN)$ $\cup$ $(CM \cap CDN)$	Composite Supply for Non-Imported Outputs and Non-Produced Imports
27	$QT_c = \sum_{c' \in C'} \left(icm_{cc'} \cdot QM_{c'} + ice_{cc'} \cdot QE_{c'} + icd_{cc'} \cdot QD_{c'} \right)$ $\left[\text{demand for transactions services}\right] = \left[\text{sum of demands for imports, exports, and domestic sales}\right]$	$c \in CT$	Demand for Transactions Services

Institution block			
28	$YF_f = \sum_{a \in A} WF_f \cdot \overline{WFDIST}_{f\,a} \cdot QF_{f\,a}$ $\left[\begin{array}{c}\text{income of}\\ \text{factor f}\end{array}\right] = \left[\begin{array}{c}\text{sum of activity payments}\\ \text{(activity-specific wages}\\ \text{times employment levels)}\end{array}\right]$	$f \in F$	Factor Income
29	$YIF_{i\,f} = shif_{i\,f} \cdot \left(\left(1 - tf_f\right) \cdot YF_f - trnsfr_{row\,f} \cdot EXR\right)$ $\left[\begin{array}{c}\text{income of}\\ \text{institution i}\\ \text{from factor f}\end{array}\right] = \left[\begin{array}{c}\text{share of income}\\ \text{of factor f to}\\ \text{institution i}\end{array}\right] \cdot \left[\begin{array}{c}\text{income of factor f}\\ \text{(net of tax and}\\ \text{transfer to RoW)}\end{array}\right]$	$i \in INSD$ $f \in F$	Institutional factor incomes
30	$YI_i = \sum_{f \in F} YIF_{i\,f} + \sum_{i' \in INSDNG'} TRII_{i\,i'} + trnsfr_{i\,gov} \cdot \overline{CPI} + trnsfr_{i\,row} \cdot EXR$ $\left[\begin{array}{c}\text{income of}\\ \text{institution i}\end{array}\right] = \left[\begin{array}{c}\text{factor}\\ \text{income}\end{array}\right] + \left[\begin{array}{c}\text{transfers}\\ \text{from other domestic}\\ \text{non-government}\\ \text{institutions}\end{array}\right] + \left[\begin{array}{c}\text{transfers}\\ \text{from}\\ \text{government}\end{array}\right] + \left[\begin{array}{c}\text{transfers}\\ \text{from}\\ \text{RoW}\end{array}\right]$	$i \in INSDNG$	Income of domestic, non-government institutions
31	$TRII_{i\,i'} = shii_{i\,i'} \cdot (1 - MPS_{i'}) \cdot (1 - TINS_{i'}) \cdot YI_{i'}$ $\left[\begin{array}{c}\text{transfer from}\\ \text{institution i' to i}\end{array}\right] = \left[\begin{array}{c}\text{share of \textit{net} income}\\ \text{of institution i'}\\ \text{transfered to i}\end{array}\right] \cdot \left[\begin{array}{c}\text{income of institution}\\ \text{i', net of savings and}\\ \text{direct taxes}\end{array}\right]$	$i \in INSDNG$ $i' \in INSDNG'$	Intra-Institutional Transfers
32	$EH_h = \left(1 - \sum_{i \in INSDNG} shii_{i\,h}\right) \cdot \left(1 - MPS_h\right) \cdot (1 - TINS_h) \cdot YI_h$ $\left[\begin{array}{c}\text{household income}\\ \text{disposable for}\\ \text{consumption}\end{array}\right] = \left[\begin{array}{c}\text{household income, net of direct}\\ \text{taxes, savings, and transfers to}\\ \text{other non-government institutions}\end{array}\right]$	$h \in H$	Household Consumption Expenditure
33	$QH_{c\,h} = \gamma_{c\,h} + \frac{\beta^m_{ch} \cdot \left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h} - \sum_{a \in A}\sum_{c' \in C} PXAC_{ac'} \cdot \gamma^h_{ac'h}\right)}{PQ_c}$ $\left[\begin{array}{c}\text{quantity of}\\ \text{household demand}\\ \text{for commodity c}\end{array}\right] = f\left[\begin{array}{c}\text{household}\\ \text{consumption}\\ \text{spending,}\\ \text{market price}\end{array}\right]$	$c \in C$ $h \in H$	Household Consumption Demand for Market commodities
34	$QHA_{ach} = \gamma^h_{ach} + \frac{\beta^h_{ach}\left(EH_h - \sum_{c' \in C} PQ_{c'} \cdot \gamma^m_{c'h} - \sum_{a \in A}\sum_{c' \in C} PXAC_{ac'} \cdot \gamma^h_{ac'h}\right)}{PXAC_{ac}}$ $\left[\begin{array}{c}\text{quantity of}\\ \text{household demand}\\ \text{for home commodity c}\\ \text{from activity a}\end{array}\right] = f\left[\begin{array}{c}\text{household}\\ \text{disposable}\\ \text{income,}\\ \text{producer price}\end{array}\right]$	$a \in A$ $c \in C$ $h \in H$	Household Consumption Demand for Home Commodities
35	$QINV_c = \overline{IADJ} \cdot \overline{qinv}_c$ $\left[\begin{array}{c}\text{fixed investment}\\ \text{demand for}\\ \text{commodity c}\end{array}\right] = \left[\begin{array}{c}\text{adjustment factor}\\ \text{times}\\ \text{base-year \textit{fixed}}\\ \text{investment}\end{array}\right]$	$c \in CINV$	Investment Demand
36	$QG_c = \overline{GADJ} \cdot \overline{qg}_c$ $\left[\begin{array}{c}\text{government}\\ \text{consumption}\\ \text{demand for}\\ \text{commodity c}\end{array}\right] = \left[\begin{array}{c}\text{adjustment factor}\\ \text{times}\\ \text{base-year \textit{government}}\\ \text{\textit{consumption}}\end{array}\right]$	$c \in C$	Government Consumption Demand
37	$EG = \sum_{c \in C} PQ_c \cdot QG_c + \sum_{i \in INSDNG} trnsfr_{i\,gov} \cdot \overline{CPI}$ $\left[\begin{array}{c}\text{government}\\ \text{spending}\end{array}\right] = \left[\begin{array}{c}\text{government}\\ \text{consumption}\end{array}\right] + \left[\begin{array}{c}\text{transfers to domestic}\\ \text{non-government}\\ \text{institutions}\end{array}\right]$		Government Expenditures
38	$YG = \sum_{i \in INSDNG} TINS_i \cdot YI_i + \sum_{f \in F} tf_f \cdot YF_f + \sum_{a \in A} tva_a \cdot PVA_a \cdot QVA_a$ $+ \sum_{a \in A} ta_a \cdot PA_a \cdot QA_a + \sum_{c \in CM} tm_c \cdot pwm_c \cdot QM_c \cdot EXR$ $+ \sum_{c \in CE} te_c \cdot pwe_c \cdot QE_c \cdot EXR + \sum_{c \in C} tq_c \cdot PQ_c \cdot QQ_c$ $+ \sum_{f \in F} YF_{f\,gov} + trnsfr_{gov\,row} \cdot EXR$ $\left[\begin{array}{c}\text{government}\\ \text{revenue}\end{array}\right] = \left[\begin{array}{c}\text{direct taxes}\\ \text{from}\\ \text{institutions}\end{array}\right] + \left[\begin{array}{c}\text{direct taxes}\\ \text{from}\\ \text{factors}\end{array}\right] + \left[\begin{array}{c}\text{value-}\\ \text{added}\\ \text{tax}\end{array}\right] + \left[\begin{array}{c}\text{activity}\\ \text{tax}\end{array}\right]$ $+ \left[\begin{array}{c}\text{import}\\ \text{tariffs}\end{array}\right] + \left[\begin{array}{c}\text{export}\\ \text{taxes}\end{array}\right] + \left[\begin{array}{c}\text{sales}\\ \text{tax}\end{array}\right] + \left[\begin{array}{c}\text{factor}\\ \text{income}\end{array}\right] + \left[\begin{array}{c}\text{transfers}\\ \text{from}\\ \text{RoW}\end{array}\right]$		Government Revenue

System Constraint Block			
39	$\sum_{a \in A} QF_{f\,a} = \overline{QFS}_f$ $\left[\begin{array}{c}\textit{demand for}\\ \textit{factor } f\end{array}\right] = \left[\begin{array}{c}\text{supply } \textit{of}\\ \textit{factor } f\end{array}\right]$	$f \in F$	Factor market
40	$QQ_c = \sum_{a \in A} QINT_{c\,a} + \sum_{h \in H} QH_{c\,h} + QG_c$ $+ QINV_c + qdst_c + QT_c$ $\left[\begin{array}{c}\textit{composite}\\ \text{supply}\end{array}\right] = \left[\begin{array}{c}\text{intermediate}\\ \text{use}\end{array}\right] + \left[\begin{array}{c}\text{household}\\ \text{consumption}\end{array}\right] + \left[\begin{array}{c}\text{government}\\ \text{consumption}\end{array}\right]$ $+ \left[\begin{array}{c}\text{fixed}\\ \text{investment}\end{array}\right] + \left[\begin{array}{c}\text{stock}\\ \text{change}\end{array}\right] + \left[\begin{array}{c}\text{trade}\\ \text{input use}\end{array}\right]$	$c \in C$	Composite Commodity Markets
41	$\sum_{c \in CM} pwm_c \cdot QM_c + \sum_{f \in F} trnsfr_{row\,f} = \sum_{c \in CE} pwe_c \cdot QE_c$ $+ \sum_{i \in INSD} trnsfr_{i\,row} + \overline{FSAV}$ $\left[\begin{array}{c}\text{import}\\ \text{spending}\end{array}\right] + \left[\begin{array}{c}\text{factor}\\ \text{transfers}\\ \text{to RoW}\end{array}\right] = \left[\begin{array}{c}\text{export}\\ \text{revenue}\end{array}\right] + \left[\begin{array}{c}\text{institutional}\\ \text{transfers}\\ \text{from RoW}\end{array}\right] + \left[\begin{array}{c}\text{foreign}\\ \text{savings}\end{array}\right]$		Current Account Balance for RoW (in Foreign Currency)
42	$YG = EG + GSAV$ $\left[\begin{array}{c}\textit{government}\\ \textit{revenue}\end{array}\right] = \left[\begin{array}{c}\textit{government}\\ \text{expenditures}\end{array}\right] + \left[\begin{array}{c}\textit{government}\\ \textit{savings}\end{array}\right]$		Government Balance
43	$TINS_i = \overline{tins}_i \cdot \left(1 + \overline{TINSADJ} \cdot tins01_i\right) + \overline{DTINS} \cdot tins01_i$ $\left[\begin{array}{c}\textit{direct} \text{ tax}\\ \text{rate } \textit{for}\\ \text{institution i}\end{array}\right] = \left[\begin{array}{c}\text{base rate adjusted}\\ \text{for scaling for}\\ \text{selected institutions}\end{array}\right] + \left[\begin{array}{c}\text{point change}\\ \text{for selected}\\ \text{institutions}\end{array}\right]$	$i \in INSDNG$	Direct institutional tax rates
44	$MPS_i = \overline{mps}_i \cdot \left(1 + \overline{MPSADJ} \cdot mps01_i\right) + DMPS \cdot mps01_i$ $\left[\begin{array}{c}\textit{savings}\\ \text{rate } \textit{for}\\ \text{institution i}\end{array}\right] = \left[\begin{array}{c}\text{base rate adjusted}\\ \text{for scaling for}\\ \text{selected institutions}\end{array}\right] + \left[\begin{array}{c}\text{point change}\\ \text{for selected}\\ \text{institutions}\end{array}\right]$	$i \in INSDNG$	Institutional savings rates
45	$\sum_{i \in INSDNG} MPS_i \cdot \left(1 - TINS_i\right) \cdot YI_i + GSAV + EXR \cdot \overline{FSAV} =$ $\sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$ $\left[\begin{array}{c}\text{non-govern-}\\ \text{ment savings}\end{array}\right] + \left[\begin{array}{c}\text{government}\\ \text{savings}\end{array}\right] + \left[\begin{array}{c}\text{foreign}\\ \text{savings}\end{array}\right] =$ $\left[\begin{array}{c}\text{fixed}\\ \text{investment}\end{array}\right] + \left[\begin{array}{c}\text{stock}\\ \text{change}\end{array}\right]$		Savings-Investment Balance
46	$TABS = \sum_{h \in H} \sum_{c \in C} PQ_c \cdot QH_{c\,h} + \sum_{a \in A} \sum_{c \in C} \sum_{h \in H} PXAC_{ac} \cdot QHA_{ach}$ $+ \sum_{c \in C} PQ_c \cdot QG_c + \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$ $\left[\begin{array}{c}\text{total}\\ \text{absorption}\end{array}\right] = \left[\begin{array}{c}\text{household}\\ \text{market}\\ \text{consumption}\end{array}\right] + \left[\begin{array}{c}\text{household}\\ \text{home}\\ \text{consumption}\end{array}\right]$ $+ \left[\begin{array}{c}\text{government}\\ \text{consumption}\end{array}\right] + \left[\begin{array}{c}\text{fixed}\\ \text{investment}\end{array}\right] + \left[\begin{array}{c}\text{stock}\\ \text{change}\end{array}\right]$		Total Absorption
47	$INVSHR \cdot TABS = \sum_{c \in C} PQ_c \cdot QINV_c + \sum_{c \in C} PQ_c \cdot qdst_c$ $\left[\begin{array}{c}\text{investment-}\\ \text{absorption}\\ \text{ratio}\end{array}\right] \cdot \left[\begin{array}{c}\text{total}\\ \text{absorption}\end{array}\right] = \left[\begin{array}{c}\text{fixed}\\ \text{investment}\end{array}\right] + \left[\begin{array}{c}\text{stock}\\ \text{change}\end{array}\right]$		Ratio of Investment to Absorption
48	$GOVSHR \cdot TABS = \sum_{c \in C} PQ_c \cdot QG_c$ $\left[\begin{array}{c}\text{government}\\ \text{consumption-}\\ \text{absorption}\\ \text{ratio}\end{array}\right] \cdot \left[\begin{array}{c}\text{total}\\ \text{absorption}\end{array}\right] = \left[\begin{array}{c}\text{government}\\ \text{consumption}\end{array}\right]$		Ratio of Government Consumption to Absorption

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