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ABSTRACT

The biofuel policy of India stipulates a blending target of 20% for both bioethanol and biodiesel. In the case of biodiesel, this target is to be achieved using wastelands and fallow lands to cultivate nonedible oil seed plants without affecting food security. This paper examines economy-wide impacts of expansion of biodiesel production to meet the blending target using a computable general equilibrium model. The paper assesses the impacts of biodiesel expansion on household welfare, other sectors of the economy, carbon emissions, rural development, and employment generation. Results indicate that expanding biodiesel production to meet the national target is a welfare-improving strategy. The sector can generate 0.70%–1.0% one-time incremental growth with significant employment and income generation in rural areas. Thus, biodiesel provides an opportunity for better energy security and inclusive growth, without adverse effects on the other sectors of the economy. The biodiesel sector, however, faces many challenges and removal of existing constraints is necessary to realize its potential.

ABBREVIATIONS

CES	-	constant elasticity of substitution
CGE	-	Computable General Equilibrium
SAM	-	Social Accounting Matrix
SVO	-	straight vegetable oil
TPD	-	tons per day

I. INTRODUCTION

1. India is an energy-deficient nation by global standards. According to the Integrated Energy Policy of the Indian Government's Planning Commission, India's per capita energy consumption was 439 kilogram of oil equivalent (KGOE) in 2003, which was much lower than not only the average of the developed countries but also the global average of 1,688 KGOE. The energy deficit is especially pronounced in the liquid transport fuels sector, which faces two basic challenges—rising energy demand in the face of limited reserves and higher dependence on increasingly costlier imported crude oil. With more than 95% of India's surface transport dependent on petroleum products, demand from transport fuels is also accelerating with India's economic growth. The country's proven oil reserves were estimated in 2009 to be 775 million tons, while consumption is about 160 million tons per annum. Thus, the indigenous sources of oil do not have the ability to cover the country's growing demand even in the short term, and so the country is increasingly becoming dependent on imported crude oil.

2. With global demand and global energy prices likely to increase in the medium to long term, the macroeconomic impacts, especially in terms of balance of payments, could adversely affect the country's future development. This grim energy prospect for India has forced her policy makers to intensify their efforts to search for alternative fuel options. In this context, biofuels may offer options for meeting part of India's energy needs.

3. India initiated biofuel production around the turn of the century to reduce its dependence on foreign oil and improve energy security. The country began a 5% bioethanol blending (E5) pilot program in 2001 and formulated the National Mission on Biodiesel in 2003. The mission was not implemented, and similar to many other countries around the world, India's biofuel program has experienced missed deadlines and supply shortages attributed to various factors. A major reason for the failure of the biodiesel program is the absence of appropriate pricing policy for the feedstock, by-products, and biodiesel. Sharp fluctuations in the price of oil and global concerns over food security also contribute to skepticism regarding the role of biofuels. After some exploratory work and a prolonged debate, India adopted the National Policy on Biofuels in December 2009. The program proposes a non-mandatory 20% blending target for both biodiesel and bioethanol by 2017.

4. Gunatilake and Abeygunawardean (Forthcoming) show, using a cost–benefit analysis, that sugarcane bioethanol has limited scope in India because of inability of the sector to generate adequate social benefits, and because of food security concerns. Gunatilake et al. (2011) also show that bioethanol has limited or no ability to cushion India's economy against the adverse impacts of oil price shocks. They recommend that first-generation bioethanol in India should be produced only from molasses—a by-product of sugar manufacturing. However this study discourages the diversion of molasses bioethanol for use as a transport fuel from its current uses in industry and as a potable alcohol. In contrast to bioethanol, biodiesel generates adequate social benefits and if confined to wastelands, with limited irrigation, biodiesel crops would not compete with agricultural resources in India (Gunatilake 2011). Given the limitations identified with bioethanol, this paper focuses only on the economy-wide impacts of biodiesel.

5. ADB (2011) estimates that 32 million hectares (ha) of wastelands should be allocated to biodiesel crops, together with some yield improvements, to meet the 20% blending target stipulated in Indian biofuel policy. In a partial equilibrium setting, the most prominent two biodiesel crops—*Jatropha curcas* and *Pongamia pinnata*—showed adequate economic returns to justify their cultivation (Gunatilake 2011). This type of analysis, however, does not capture the economy-wide impacts—such as economic growth, income generation, employment generation, fiscal effects, and cross-sectoral effects of allocating vast lands for a new economic venture

such as biodiesel. These macro impacts better describe the economics of the biofuels industry and allow formulation of evidence-based policies for enhancing energy security. This paper quantifies and analyzes the economy-wide impacts of expansion of biodiesel crops to meet the national target in India.

II. BIODIESEL SECTOR IN INDIA

6. About 400 wild species found in India produce nonedible oils that can be converted to biodiesel. India's biofuel policy pertaining to biodiesel has identified *Jatropha curcas* and *Pongamia pinnata* as the main feedstocks for biodiesel. As shown in *Cross-Sectoral Implications of Biofuel Production and Use in India* (ADB 2011), the issues related to the two feedstocks are very similar and hence the analysis here considers only jatropha. In 2011, the growth of jatropha is being promoted in different parts of India through various incentives, such as community development programs, minimum support pricing for jatropha seed, aforestation programs, etc. A salient feature of India's biofuel program is to only utilize wastelands, degraded forest, and non-forest lands for cultivation of oil seed plants. Of about 55 million ha of wastelands in India, about 32 million ha are suitable for biodiesel production. Other non-croplands—up to 8 million ha—are also available for biodiesel production. If all these lands can be allocated for biodiesel production, together with some yield improvements, India can meet its 20% blending target. If only wastelands and fallow lands are used with limited irrigation, biodiesel may not compete for resources with food crops.

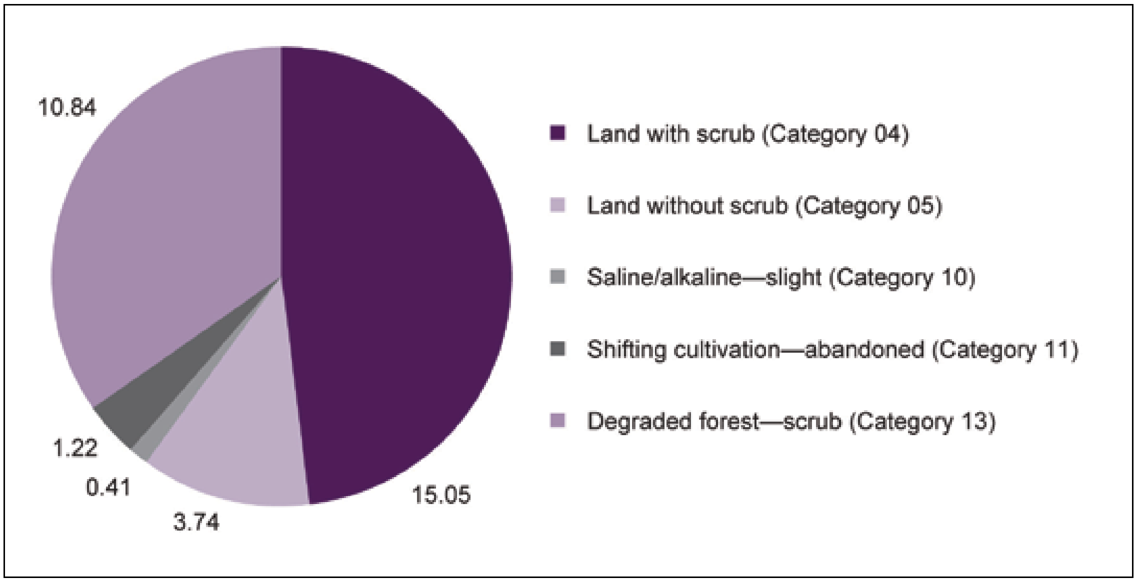
7. The *Wasteland Atlas of India* (Ministry of Rural Development 2005) has estimated that of the total land area of India (297.32 million square kilometers [km^2]), 55.37 million ha of lands are wastelands. The information from the atlas is used as the basis for assessing the land requirement for biodiesel production. The atlas classifies wasteland under 13 categories. The Department of Land Resources under the Ministry of Rural Development has suggested setting out criteria (Box 1) for the selection of suitable land for oil seed plantations. Based on these criteria, six categories of wastelands were recommended for oil seed plantations. According to this assessment, the total potential area available was estimated to be 32.3 million ha, and their distribution is shown in Figure 1. Availability here refers only to physical availability; access to land for biofuel plantations depends on a number of factors including climatic and soil conditions, access to infrastructure such as roads and electricity, as well as the ownership of the land. The available information about wasteland suitability for oil seed plantations is incomplete, and a proper wasteland mapping exercise should precede any major biodiesel development program in India.

Box 1: Wasteland Selection Criteria for Oil Seed Plantations

- Annual rainfall should exceed 600 millimeters.
- The pH of the soil should be less than 9.
- The temperatures should not fall below 0°C and frost conditions should not prevail.
- The slope of land should not exceed 30°.
- The land should not be waterlogged.
- The land should not be barren, rocky, or stony.

Source: Ministry of Rural Development (2005).

Figure 1: Various Types of Wasteland Potentially Suitable for Oil Seed Plantations
(million hectares)



Source: Ministry of Rural Development (2005).

8. Though India started its biofuel mission back in 2003, it approved the National Biofuel Policy only in December 2009. For lack of clarity in the intervening period, India has achieved only limited progress in this sector. India's biodiesel processing capacity is estimated at 1 million tons per year. However, it is only producing an estimated 70,000 tons at present (Business Line 2010). The shortage of feedstock is considered a major bottleneck of the growth of the industry. Most jatropha seeds are now being used for plantations and nurseries, limiting their use for production of biodiesel and pushing up the selling price of jatropha seed.

9. Biodiesel production is undertaken in three steps: (i) plantation—production of oil seeds, (ii) oil extraction—production of straight vegetable oil (SVO), and (iii) transesterification—production of biodiesel. Unlike bioethanol, the higher gestation period—time between planting and first yield—of biodiesel crops (4–5 years for jatropha and 6–7 years for pongamia) results in a longer payback period and creates additional problems for smallholders. In general, the normal payback period for a jatropha plantation is approximately 9–10 years while the pongamia plantation has a payback period of 14–15 years.

10. The extraction of seed is performed to produce SVO, which is transesterified and turned into biodiesel as a core product, with oil cake as a by-product. Oil cake is generally used as an organic manure or fuel for power generation. As a common practice, the oil extraction units are set up in a distributed manner to avoid excess transport costs in bringing oil cake back to the farms. It is financially more feasible to set up small, decentralized extraction units of 5–10 tons per day (TPD) rather than larger units.

11. A wide variation in transesterification capacity has been seen across India, ranging between 30 and 300 TPD. Across the globe, SVO transesterification technology is commercially proven and established. Comparative analysis between 30 TPD, 100 TPD, and 300 TPD shows relatively lower costs in larger capacities than smaller ones due to economies of scale. In 2011, there is a shortage of oil seed availability in the market and therefore larger-capacity plants could suffer from an underutilization of capacity. Smaller-capacity plants can function at full capacity and may register better profitability.

12. Besides the sale of biodiesel as a core product, glycerin is a by-product of the transesterification process and also has commercial value. At the prevailing market price of glycerin, it can contribute approximately 12% of total revenue of biodiesel. The long-term pricing of glycerin remains a debatable issue. As of 2011, glycerin is in relatively limited supply and it fetches a fairly attractive market price of Rs27.0/liter. Considering biodiesel production targets in the medium to long term, glycerin supply may exceed the demand, which in turn may drastically diminish the market price.

13. Life cycle cost assessment of biodiesel suggests that 78% of the total cost for biofuel production is made up of feedstock cost. The Government of India, along with a few state governments, has announced the administered price for biodiesel at Rs26.5/l, at which the financial return is to be inadequate to provide incentives to the producer (ADB 2011). The inadequate administered price of biodiesel is one key hindrance for the development of the biodiesel market in India. Given the market price of SVO at Rs28.0/kg, biodiesel production can only be financially feasible if glycerin attracts a market price of Rs27.0/l. Since transesterification is an established and proven technology, operating cost would likely not undergo any major change in the future. Hence, the availability and cost of feedstock are two key variables that can affect the biodiesel ex-factory price.

14. Once the pricing constraint is removed under the new biofuel policy implementation, biodiesel sector is expected to grow. However, pricing is only one issue that currently constrains the sector's growth. Uncertainty regarding agronomy, pests and diseases, and high-yielding varieties of these two wild plants are also major barriers to the expansion of the sector. Moreover, the physical availability of lands does not mean they can readily be used as oil seed plantations. Complex property right issues and various other issues like provision of supplementary infrastructure (roads, electricity, etc.) have to be resolved to ensure growth in the biodiesel sector. Understanding the economy-wide impacts would provide additional impetus for policy makers to address these issues.

III. THE COMPUTABLE GENERAL EQUILIBRIUM MODELING FRAMEWORK

A. Relevance of Computable General Equilibrium Modeling

15. The impact of the growth of the biofuel sector and the role of various policy instruments to facilitate its growth is analyzed using a computable general equilibrium (CGE) model of India. The CGE modeling technique has a number of features that make it suitable for economy-wide impact analysis of biodiesel expansion to meet the national target, such as:

(i) It simulates the functioning of different markets in the economy, including markets for labor, capital, and commodities, and provides a useful perspective on how changes in economic conditions will likely be mediated through prices and markets.

(ii) Its structure permits a consideration of an expansion of the economy in a new venture such as biofuel.

(iii) It assures that all economy-wide constraints are respected. In the Indian context, biofuel production and use are expected to reduce demand for imported fuel partially, provide a better use for degraded land, and raise demand for labor in the rural areas.

(iv) As the model can be fairly disaggregated (compared to the econometric models), it can provide an economic simulation laboratory to examine how different factors and impacts will affect the performance and structure of the economy, including how they will interact and, most importantly, how to quantify interactive effects of welfare indicators such as gross domestic product (GDP) growth and income increase (Arndt et al. 2009).

B. Overview of India's Computable General Equilibrium Model

16. India's CGE model is a multisector CGE model with four factors of production; namely, capital, land, unskilled labor, and skilled labor. The model includes 30 sectors—9 agricultural, 7 service, and 14 manufacturing. Within the existing structure of the economy and subject to budget constraints, producers (enterprises) in the model maximize profits under constant returns to scale, with the choice between the above-described production factors governed by the constant elasticity of substitution (CES) function. Factors are then combined with fixed-share intermediates using a Leontief specification. Under profit maximization, factors receive income where marginal revenue equals marginal cost based on endogenous relative prices. For households, the initial factor endowments are fixed. Therefore, supply factors at the household level are inelastic. Their commodity-wise demands are expressed for given income and market prices, through the constant elasticity demand function in the tradition of the Global Trade Analysis Project model (Hertel 1997). Also, households save and pay taxes to the government. The government receives income from imposing indirect taxes, direct taxes, and export and/or import tariffs on economic activities and then makes transfers to households, enterprises (in the form of subsidies), and the rest of the world. The government also purchases commodities in the form of government consumption expenditures, and the remaining income of government is saved. All savings from households, enterprises, government, and the rest of the world (foreign savings) are collected in a savings pool from which investment is financed.

17. The rest of the world supplies goods, which are imperfect substitutes for domestic output, provides transfer payments, and demands exports. The standard small-country assumption is made, implying that India is a price taker in import markets and can import as much as it wants. Because imported goods are differentiated from domestically produced goods, the two are aggregated using the Armington-type CES function. As a result, the imports of a given good depend on the relationship between the prices of the imported and the domestically produced varieties of that good. By contrast, India faces a perfectly elastic world demand curve at a fixed world price under the small-country assumption. On the supply side, constant elasticity of transformation function is used to define the output of a given sector as revenue-maximizing aggregates of goods for the domestic market and for foreign markets. This implies that the response of the domestic supply of goods in favor or against exports depends upon the price of those goods in foreign markets vis-à-vis their prices in domestic markets, given the elasticity of transformation between goods for the two types of markets.

18. The flow of conventional commodities, factors, taxes, tariffs, and transfers in our CGE model is shown in the appendix, Figure A.1. The substitution and transformation possibilities at the industry level included in the CGE model are shown in the appendix, Figure A.2. These diagrams are meant to complement the above description of the model.

19. The model is Walrasian. Markets for commodities clear through adjustments in prices. In our model, we assume all factors are mobile except land, which is assumed to be a sluggish factor in tune with the CGE model (Hertel 1997). We further assume that the economy faces a fixed supply of production factors—land, unskilled labor, skilled labor, and capital. Thus, equilibrium is attained in capital and skilled labor through adjustment in factor prices.

So movement of factors between sectors occurs; aggregate demand and supply of factors attain equilibrium, and the economy realizes a single rate of return for factors like capital and skilled labor across sectors. Since land is a sluggish factor, rate of return for land differs across sectors. Though unskilled labor is mobile between sectors, we apply a different equilibrating mechanism in our model. In a country such as India, we can assume that there is a perfectly elastic supply of unskilled labor at a fixed real price of labor. We have assumed a savings-driven closure in which foreign savings is exogenously fixed and investment is endogenous.

20. The CGE model is calibrated to the 2006–2007 Social Accounting Matrix (SAM) of India shown in the appendix table. This table is constructed from national accounts statistics of India, the latest input–output table of India, and from the SAM constructed by Ojha et al. (2009). We have chosen 2006–2007 as the base year of the model, since detailed national accounts data for subsequent years are not available. Since neither jatropha plantation nor biodiesel processing sectors are included in national accounts statistics, our accounting of these sectors is based on a primary survey in the selected states contributing most to the growth of these sectors. To that extent, our results should be taken with caution. The model is calibrated so that the initial equilibrium reproduces the base-year values from the SAM.

21. Our model requires estimates of various types of elasticity measures: demand elasticities of exports and imports; elasticity of substitution between factors of production; and elasticity of substitution between varieties of goods. Most of our estimates are based on the published literature and are drawn primarily from Ojha et al. (2009) and Chadha et al. (1998).

22. We assume economic decision making to be the outcome of decentralized optimizing by producers and consumers within a coherent economy-wide framework. A variety of substitution mechanisms are specified, including substitution among labor types, between capital and labor, between imports and domestic goods, and between exports and domestic sales, all occurring in response to variations in relative prices. The details of sector classification are shown in Table 1.

Table 1: Sector Classification of the Indian Computable General Equilibrium Model

No.	Description	No.	Description
1	Paddy	16	Biodiesel
2	Wheat	17	Refined petroleum products
3	Other cereals	18	Chemicals
4	Cash crops	19	Paper and paper products
5	Jatropha	20	Fertilizer
6	Animal husbandry	21	Other manufacturing
7	Forestry	22	Machinery
8	Fishing	23	Electricity
9	Coal	24	Biomass
10	Crude oil	25	Water distribution
11	Gas	26	Construction
12	Food and beverages	27	Land transport
13	Textiles and leather products	28	Air transport
14	Wood	29	Sea transport
15	Minerals	30	All other services

Source: Social Accounting Matrix of India.

23. As shown in Table 1, feedstock cultivation and processing sectors of biodiesel are modeled as separate entities. The processing sector of biodiesel consists of two parts: oil extraction and transesterification. But in the model, both are included in the biodiesel sector. Sector 17 includes various petroleum products apart from transport fuel, such as diesel, petrol, kerosene, etc. Out of total domestic consumption in this sector, the share of diesel and petrol

comes to about 45% of which diesel corresponds to about 40%.[1] While further breakdown of this sector would enrich the analysis, data constraints did not permit it. Basic structural features for the major sectors at this level of disaggregation of India's economy are presented in Table 2. In 2011, shares of the jatropha and biodiesel sectors are near zero, and so are not shown separately in Table 2.

Table 2: Structure of India's Economy in 2006–2007

	Share of Total (%)			
	GDP	**Exports**	**Imports**	**Domestic Consumption**
Total GDP	100.0	100.0	100.0	100.0
Agriculture	**18.2**	**3.4**	**1.8**	**17.2**
Food crops	9.8	2.1	0.7	9.1
Cash crops	2.5	0.4	0.4	2.4
Mining	**2.8**	**0.4**	**15.5**	**6.6**
Manufacturing	**16.3**	**61.4**	**74.8**	**21.5**
Other petroleum products	1.3	3.0	3.3	1.4
Machinery	2.2	6.9	11.1	3.5
Services	**62.7**	**34.8**	**7.7**	**54.7**
Transport services	6.4	5.2	0.4	5.1

GDP = gross domestic product.
Source: Social Accounting Matrix of India.

24. The analysis is based on a static CGE model with 2006–2007 chosen as the base year. As mentioned earlier, we assumed perfectly elastic supply of labor in our base case model. However, unlimited supply of unskilled labor in rural India could be a questionable assumption. Agricultural operations have been affected due to shortage of unskilled labor in many parts of India and there is seasonal variation in agricultural wages. Biofuel plantations could result in seasonal shortage of unskilled labor for other agricultural operations. To better understand the labor constraint, we have also undertaken a simulation with the assumption that the supply of unskilled labor is fixed. In this case, real wages of unskilled labor would rise due to competitive pressure. This scenario can provide useful insights regarding the impact of expansion of jatropha production vis-à-vis other agriculture sectors and the economy.

C. Biodiesel Scenarios

25. The main objective of this analysis is to assess the potential economic impacts of growth of the biodiesel sector in India. Since India has announced a national biofuel policy, it makes sense to assess the impact of policy prescriptions on India's economy. We have considered three policy scenarios for our assessment:

- ***Scenario 1*:** The area under jatropha cultivation is increased from base year value to the amount that is required to meet the 20% biofuel policy blending target. This means that land under jatropha cultivation is increased to 32 million ha. We assume that the increased land comes from the pool of fallow land, wasteland, or degraded forests.

- ***Scenario 2*:** Scenario 1 plus the assumption that overall land productivity in the agriculture sectors has been enhanced because of technology improvement, such as improved varieties, better access to fertilizer, and better agricultural practices. The extent of the productivity increase is assumed to be 20% in the biodiesel sector, including both the feedstock and the processing sectors.

[1] India generally imports crude oil, hence, the share of diesel and other petroleum products in Table 2 is small.

- ***Scenario 3*: ** Scenario 2 with the assumption that the supply of unskilled labor in the economy is fixed. In this case, the real wage of unskilled workers increases or declines to attain equilibrium.

26. In the three simulations, we have assumed market-driven price regimes in all sectors except in the biodiesel and the feedstock (jatropha) sectors. The biodiesel sector price is aligned to diesel price in calorific terms. If the market-driven price differs from the diesel price in calorific terms, the government intervenes with a tax or subsidy to maintain this price level. This type of policy intervention is envisaged in India's biofuel policy document. Moreover, in 2011, the biodiesel price is administered by the government. An infinitely elastic demand in the biodiesel and feedstock sectors is assumed, together with administratively determined prices. This is done to make the pricing mechanism more in tune with reality. This means any quantity of biodiesel can be supplied under the given price. The model restricts biodiesel production at the 20% blending level by limiting the land availability to the corresponding level of 32 million ha.

IV. SIMULATION RESULTS

27. The CGE model scenario results provide an indicative direction and should not be considered as a forecast. Furthermore, in a sector such as biodiesel, which is at an early stage of development and very little information is available, the results should be interpreted with caution. The results are presented in the order of welfare impacts, fiscal impacts, climate change impacts, employment generation, intersectoral impacts, and rural development.

A. Welfare Impacts

28. An increase in the allocation of land for jatropha implies that one of the sluggish factors of production in the economy, i.e., land, is increased. The extent to which jatropha production would increase depends on the market-driven price, cost function, and the prices of other factors of production. Since this additional land is not coming from land allocated to other agriculture sectors, the production of agriculture sectors would not fall unless other primary factors such as prices (viz. labor, capital) rise significantly due to increased demand for jatropha. Apart from land, the principal primary input required for jatropha cultivation is unskilled labor, which is assumed to be infinitely elastic. Thus, increased cultivation should not have a significant effect on other agriculture sectors. Table 3 summarizes the results.

Table 3: Economy-Wide Impacts of Jatropha Cultivation to Meet 20% Blending by 2017

Economic Indicator	Scenario 1 (%)	Scenario 2 (%)	Scenario 3 (%)
Equivalent variation (Rs billion)	360.88	374.84	278.09
GDP	0.956	0.997	0.737
Change in value of GDP (Rs million)	376,842	393,004	290,397
Real return to factor			
Land	1.72	1.74	1.41
Unskilled labor	**	**	0.48
Skilled labor	0.81	0.84	0.44
Capital	0.64	0.71	0.48
Fiscal deficit	0.27	0.28	0.26
Reduction in greenhouse gas emissions (tons, million)	12.12	13.21	11.11
Employment generation (million)	30.11	33.21	**

GDP = gross domestic product.
** Not applicable. The price is fixed.
Source: Authors' estimates.

29. Given that our model is a static model, the results should be interpreted as one-time changes from the baseline. Results are expressed in percentage terms unless otherwise stated in the first column of Table 3. As shown in Table 3, overall GDP increases by 0.96% or by Rs377.0 billion in scenario 1. Moreover, India's income rises by Rs360.8 billion in terms of equivalent variation that can be interpreted as change in household income at constant prices. The factors of production gain from the transformation to jatropha. When the productivity of jatropha increases, the economic gains are magnified (scenario 2 in Table 3). Real GDP now increases by about 1%. In absolute terms, it amounts to Rs393.0 billion. This explains the increase in growth. As Table 3 shows, real returns in the overall economy increase only marginally. Returns to land increase at a higher rate because unproductive wastelands are converted to productive uses.

30. If we drop the assumption of infinitely elastic supply of labor as in scenario 3, the picture becomes less rosy. Now, increased jatropha production pushes up the real wage of unskilled workers, which in turn affects other agriculture sectors. As a result, GDP increases by 0.74% in contrast to 0.96% in scenario 1. The smaller increase in GDP occurs due to the decline in the output of other agriculture sectors.

B. Fiscal Deficit

31. Scenario 1 increases the fiscal deficit by 0.27%, whereas in scenario 2 it rises by 0.28%. Here fiscal deficit is not computed as percentage of GDP but as absolute percentage change, which implies that change in fiscal deficit is not high. In the base year, the agriculture sectors received a variety of subsidies including a fertilizer subsidy. When outputs of agriculture sectors expand, subsidies also expand due to the effect within the sector and also due to an increased subsidy going to the fertilizer sector. Moreover, to maintain the biodiesel sector will require some subsidies at initial stages with low diesel prices. If increase in government revenue (due to overall growth) is relatively less than that of the subsidy, the fiscal deficit would increase. In scenario 2 we find a small increase in the fiscal deficit. In scenario 3 the fiscal deficit is lower. This happens mainly due to the lower growth of the economy. Overall, the results show that biodiesel expansion to meet the national target will not result in significantly higher fiscal deficits.

C. Carbon Emission Reduction

32. In comparison to fossil fuel, biodiesel emits less greenhouse gas (GHG). Therefore, the increased land allocation for jatropha with increased tree cover and consumption of biodiesel will result in reduction in GHG emission. Table 3 indicates that the reduction in GHG emissions is to the tune of 12.12 million tons in scenario 1 and 13.21 million tons in scenario 2. The computation of GHG emission needs explanation. When there is positive growth in the economy, GHG emission will also increase. The numbers corresponding to reduction in GHG emission in the table represent the fall due to substitution of diesel use by biodiesel. In addition, the growth of jatropha in marginal land leads to reduction in GHG emission. The numbers in the table include both these effects minus the growth effect on emissions.

D. Employment Generation

33. Increased production in the feedstock (jatropha) and biodiesel processing sectors have employment effects. As the overall economy registers small positive growth, there are indirect, induced employment expansions as well, albeit marginal, in other sectors. In our model we have assumed that the total supply of skilled labor is fixed, whereas there is an infinitely elastic supply of unskilled labor in the economy. Thus, it is possible to estimate the amount of new unskilled jobs that would be created under scenarios 1 and 2. According to our model estimates, about

30.1 million additional jobs for unskilled workers would be created in scenario 1 if the 20% blending target is implemented. If the productivity effect is enforced in scenario 1, the number of new jobs created would be increased, since the economy now registers additional growth. According to the model, about 33.2 million additional jobs for unskilled workers would be created in scenario 2.

34. We have not reported any employment generation for unskilled workers in scenario 3. This is because we have assumed that the supply of unskilled workers in the economy is fixed. Here, unskilled workers move between sectors so that demand of unskilled workers equals the available supply. The equilibrating mechanism in this case is the wage rate, which rises and falls to attain full equilibrium. Given that the farming systems are not fully developed and the data on labor requirements along the supply chain of biodiesel production are incomplete, these estimates of employment generation should be treated with caution.

E. Effects on Other Sectors

35. On the domestic output effect, the result of scenario 1 shows that the output of the jatropha sector rises by 3,010.0% (Table 4), whereas the output of the biodiesel sector increases by 770.3%. This is not surprising because current production of oil seed and biodiesel is very low compared to the required quantities to meet the target. The results also show that there is no decreasing output of other major agriculture sectors, since the augmentation of area under jatropha cultivation is done by making use of unused lands. When overall agriculture productivity increases as in scenario 2, the results show additional significant increases in output of jatropha and biodiesel on top of the large increase in scenario 1.

Table 4: Impacts of Biodiesel Expansion on Other Sectors

	Scenario 1, % change		Scenario 2, % change		Scenario 3, % change	
Sector	**Output**	**Price**	**Output**	**Price**	**Output**	**Price**
Jatropha	3,010.01	**	3,220.11	**	2,760.10	**
Biodiesel	770.29	**	777.53	**	650.01	**
Paddy	0.29	1.29	0.31	1.30	0.18	0.88
Wheat	0.33	0.87	0.35	0.91	0.22	0.59
Cereals	0.30	1.17	0.31	1.18	0.21	0.82
Cash crops	0.09	1.10	0.11	1.14	0.05	0.77
Diesel, petroleum products	0.84	–0.08	0.87	–0.10	0.62	–0.03

** Not applicable.
Source: Authors' estimates.

36. The prices of paddy, wheat, cereals, and other cash crops increase respectively by 1.29%, 0.87%, 1.17%, and 1.10% in scenario 1. These marginal price increases may be due to increases in input demands due to jatropha intervention in the economy. The results clearly show that increasing biofuel production significantly improves social welfare without having any significant negative effects on the agriculture sectors. The minute decrease of petroleum prices indicates that even 20% blending of biodiesel has very limited impact on the overall energy economy in India.

37. A fixed supply of unskilled workers in the economy implies that an expansion in the jatropha plantation would have a cost-push effect on other sectors that demand unskilled workers. With limited supply, the increased demand for unskilled workers would push up the real wage of unskilled workers. This would, in turn, affect the growth of other agriculture sectors. The data in Table 3 indicate all agriculture sectors growing at a slower pace in scenario 3. However, the good news is that all the agriculture sectors register positive growth.

F. Rural Development

38. Compared to the wage income increase in both agro and non-agro sectors, the nonwage income increase is much higher. In the agriculture sector that includes jatropha, the wage income increase of unskilled workers is about Rs24.4 billion (Table 5). Unskilled workers thus receive about 45% of the wage increase and if the available amount of labor is fixed (scenario 3) unskilled workers receive 53% of the wage increase. This significant income for unskilled workers is an important element in inclusive rural development—a priority of the Government of India. The wage increase in non-agro sectors is about Rs11.0 billion. The income increases for skilled workers in both agro and non-agro sectors are not high. This is because nonedible oil seed production and its processing do not require much skilled labor. However, they register a Rs3.3 billion increase in income due to their employment in the biodiesel sector, which has received a boost.

Table 5: Distribution of Unskilled Wage Income and Non-wage Income

	Agro Sectors, Wage Income, Rs billion		
Sector	**Scenario 1**	**Scenario 2**	**Scenario 3**
Jatropha	24.41 (45%)	24.51 (42%)	22.38 (53%)
Paddy	2.53 (5%)	2.87 (5%)	1.65 (4%)
Wheat	2.63 (5%)	2.99 (5%)	1.72 (4%)
Cereals	9.57 (17%)	10.89 (18%)	6.24 (15%)
Cash crops	7.39 (13%)	8.41 (14%)	4.82 (11%)
Others	8.12 (15%)	9.24 (16%)	5.30 (13%
Total	54.65 (100%)	58.91 (100%)	42.11 (100%)
	Nonwage Income, Rs billion		
Jatropha	72.85 (45%)	72.92 (41%)	66.80 (53%)
Paddy	7.62 (5%)	8.95 (5%)	5.00 (4%)
Wheat	7.94 (5%)	9.33 (5%)	5.19 (4%)
Cereals	29.20 (18%)	34.30 (20%)	19.07 (15%)
Cash crops	22.32 (14%)	26.20 (15%)	14.57 (12%)
Others	23.14 (14%)	24.10 (14%)	15.05 (12%)
Total	163.07 (100%)	175.79 (100%)	125.68 (100%)

Source: Authors' estimates.

39. Gains accrued as nonwage income in the agro (Rs125.7–Rs163.1 billion) and non-agro sectors (Rs144.7–Rs144.4 billion) are larger compared to wage income increases (Appendix Table A1). While agro sectors gain higher nonwage income increases compared to nonagriculture sectors, nonwage income in the nonagriculture sectors also gains significantly due to the growth of the biodiesel sector and to the overall growth of the economy. The major portions of nonwage income are profits accruing along the various segments of the supply chain. Therefore, the biodiesel sector will provide adequate income incentives to entrepreneurs to engage in this sector, making it a feasible venture for rural development in India. Both wage and nonwage increases occur mainly in the rural economy, providing a boost to rural India.

40. A larger proportion of both wage and nonwage income increases accrue in the jatropha sector. For example, about 45% of both wage and nonwage income goes to the jatropha sector under scenario 1. Most of these income increases occur in the rural sectors because jatropha will be grown and processed in rural areas. Together with employment generation, biodiesel provides a significant rural development opportunity.

41. One key assumption used in the above analyses is that biodiesel crops will be grown in wastelands or fallow lands and there is no displacement of food crops. This approach has merit in a stable market environment, but if the prices of food, land, or both were to escalate significantly, marginal or wastelands may be reclaimed to produce food. In such situations

biodiesel crops will compete with food crops. Incentives and a stable, conducive business environment for biodiesel also may induce conversion of food lands for biodiesel crops, undermining food security. Today's food cropland could be expanded if the relative price of food is high enough to justify investments in land reclamation, forest conversion, or other expansion of farming. To a growing extent, these dynamics may be driven by forces external to India as an emerging middle class triggers greater food import dependence. Therefore, any program to support biodiesel should factor this in and incorporate policy measures to ensure that biodiesel expansion does not affect food security.

42. There are suitable policy measures, such as land certification for biodiesel incentives, taxes on biodiesel (under high oil price scenarios), and additional incentives to the agriculture sector, to prevent adverse impacts of biodiesel expansion on the food sector. On the other hand, biodiesel expansion, in the very long run, can benefit the agriculture sector. Converting wastelands into oil seed croplands is similar to a land reclamation program that prevents natural decay of lands. Limited irrigation and incorporation of organic wastes of oil seed crops into soils will improve soil fertility over time. After one cycle of biodiesel crops, these lands can be used for horticultural or other crops if prevailing economic conditions permit such a change. In that sense, adding about 32 million ha to agricultural lands in India will enhance the agricultural resource base significantly.

V. CONCLUSIONS AND POLICY IMPLICATIONS

43. The key results suggest that biodiesel can provide India with an opportunity to enhance economic growth and improve economic conditions of rural wage earners. Since rural workers are the worst off in Indian society, biodiesel production can provide an avenue for poverty reduction within a more inclusive growth policy framework. The negative externality, i.e., a higher fiscal deficit, does not seem to dampen the growth effect. Therefore, the policy of using degraded land for biofuel production is a welfare-improving strategy. It also promotes energy security, without any major negative macroeconomic impacts on the other sectors of the economy. The biodiesel sector, however, faces many challenges including allocation of vast amounts of lands for oil seed plantations, resolving property right issues of the wastelands, developing high-yielding varieties and suitable agronomic practices, and correcting information and coordination failure issues that prevent development of markets. Realizing the potential of biodiesel, as described in this paper, depends on the soundness of public policy and effectiveness of its implementation in addressing the challenges.

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APPENDIX

Table A1: Distribution of the Gains

	Scenario 1		Scenario 2		Scenario 3	
	Agro Sectors	Non-Agro Sectors	Agro Sectors	Non-Agro Sectors	Agro Sectors	Non-Agro Sectors
Distribution of Gains (Rs million)						
Unskilled Wage Income	54,656.00	11,380.00	58,912.00	11,321.00	42,111.00	8,770.00
Jatropha	24,412.23		24,512.00		22,385.37	
Paddy	2,526.26		2,873.16		1,647.53	
Wheat	2,631.96		2,993.50		1,716.53	
Cereals	9,572.32		10,886.86		6,242.74	
Cash crops	7,394.90		8,408.62		4,821.67	
Others	8,118.33	6,011.27	9,237.86	5,485.72	5,297.17	4,972.27
Diesel, petroleum products		4,294.99		4,705.87		2,813.14
Biodiesel		1,073.75		1,129.41		984.60
Skilled Wage Income	1.00	3,317.00	1.00	3,293.00	1.00	2,556.00
Jatropha	0.33		0.39		0.00	
Paddy	0.00		0.00		0.00	
Wheat	0.00		0.00		0.00	
Cereals	0.20		0.20		0.20	
Cash crops	0.40		0.40		0.40	
Others	0.40	1,457.45	0.40	1,153.07	0.40	950.49
Diesel, petroleum products		1,377.14		1,550.68		1,163.16
Biodiesel		482.41		589.26		442.36
Nonwage Income	16,3067.00	144,432.00	175,794.00	143,684.00	125,660.00	111,300.00
Jatropha	72,847.45		72,918.00		66,799.19	
Paddy	7,620.57		8,949.24		4,977.09	
Wheat	7,940.94		9,326.04		5,186.64	
Cereals	29,203.65		34,296.25		19,073.74	
Cash crops	22,318.04		26,201.63		14,571.95	
Others	23,136.36	66,886.22	24,102.84	64,139.63	15,051.38	48,004.44
Diesel, petroleum products		59,650.00		60,720.89		46,885.60
Biodiesel		17,895.78		18,823.48		16,409.96

Note: All data are in percentage form unless specified.
Source: Authors' estimates.

Figure A.1: Flow of Conventional Commodities, Factors, Payments, and Transfers in Economy

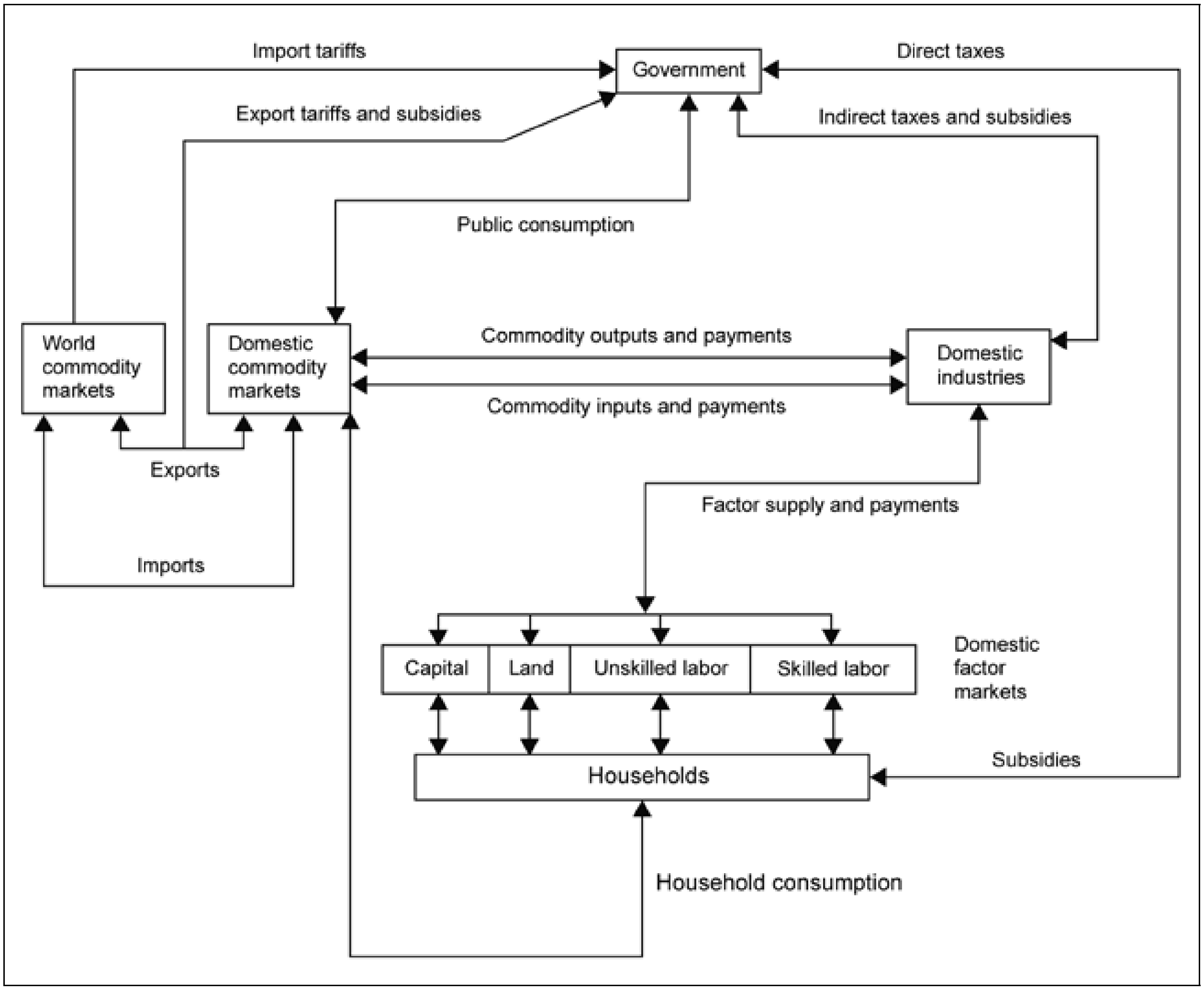
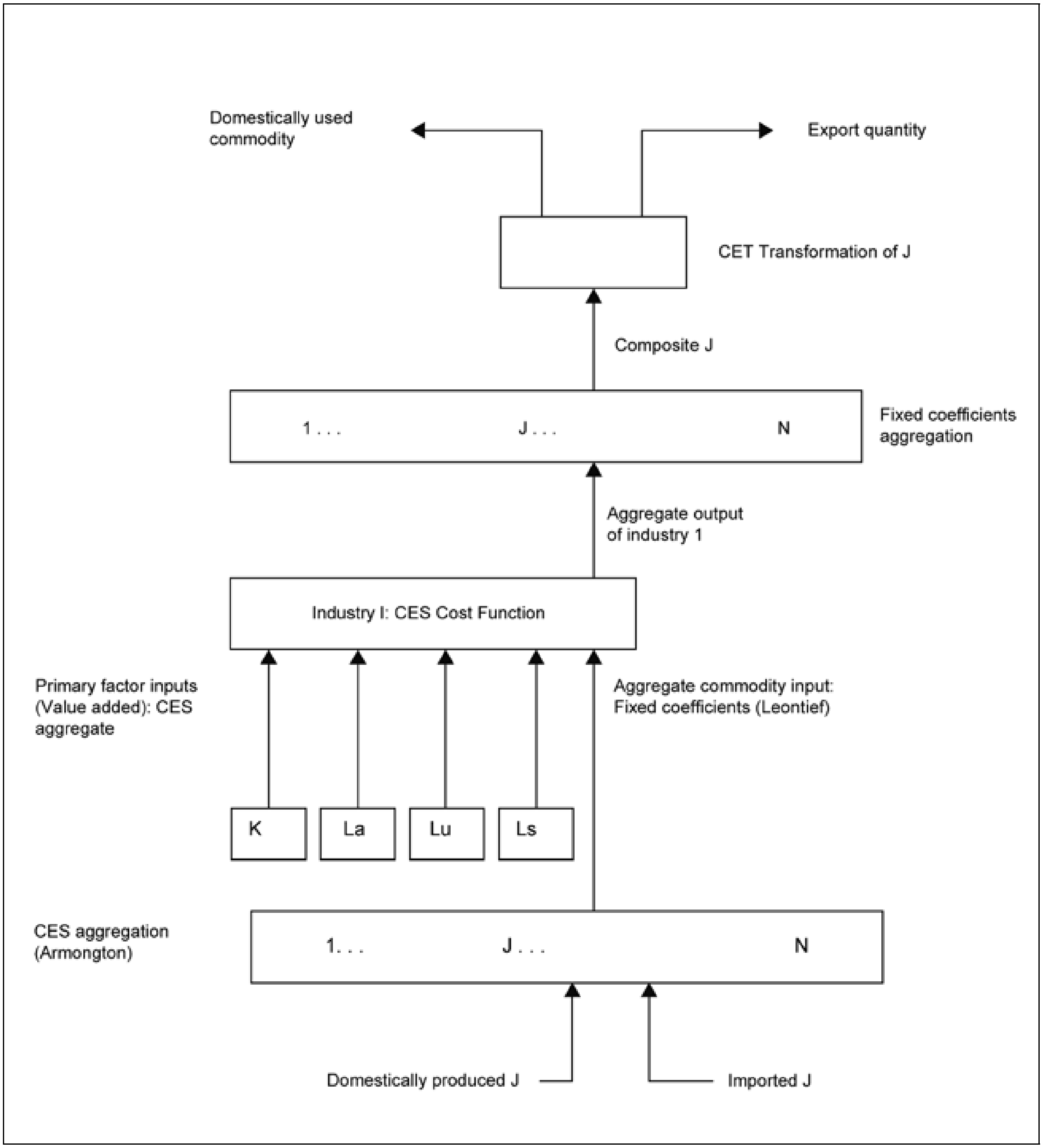


Figure A.2: Substitution and Transformation Possibilities at the Industry Level in the CGE Model



CES = constant elasticity of substitution, CET = constant elasticity of transformation, CGE = Computable General Equilibrium.
Notes: 1. K: Capital, La: Land, Lu: Unskilled workers, Ls: Skilled workers.
2. Sectors 1 ….. N.

Economy-Wide Impacts of Biodiesel Production and Use in India:
A Computable General Equilibrium Model Assessment

Biofuels are receiving the attention of policy makers of energy-deficient nations as a means to enhance energy security and reduce carbon emissions. Economy-wide impacts of allocating vast amounts of agricultural resources for energy crop production are not well understood. This paper assesses the economy-wide impacts of growing biodiesel crops to meet 20% blending target set in the biofuel policy of India. The results show that biodiesel can generate 0.7%–1.0% one-time incremental growth in India's economy with significant employment generation in rural areas, without adverse effects on the other sectors of the economy.

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