INDIAN ENERGY SECURITY AND BIOFUEL STRATEGY IN A GLOBAL CONTEXT

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ABSTRACT

The emergence of biofuel energy offers the prospect of significant climate change mitigation, as well as greater energy independence for many countries. At the same time, biofuel represents an unusual precedent in economics, the possibility of substitution between two essential but very different commodities, energy and food. The first characteristic has dramatically heightened interest in biofuel production around the world. Intensified concerns about greenhouse gas stabilization and rapid innovation portend a booming new agribusiness energy industry, with pervasive induced effects on transportation and related sectors.

For lower income countries like India, fossil fuels pose two risks – global warming pollution and price inflation. Alternative energy development can address the former, but only some sources represent appropriate magnitudes to affect the latter. Because India imports over two thirds of its conventional energy fuels, it will remain a price taker in oil markets. Strategies for alternative transport fuel development, such as biodiesel from oil crops, need to be seen in this light. Biofuels have at best uncertain net effects on GHG emissions, and because they recruit (even marginal) agricultural resources, they can offer significant relief against rising conventional energy prices only if the combined direct cost of production and indirect cost of diverted agrofood resources.

In this report, we examine the evidence on emerging global energy price trends and assess alternative approaches India might take to the prospect of rising oil prices. In the context of biodiesel, even projects that could displace at 20 percent of domestic diesel supply, and therefore will have limited impact on energy price inflation. To offset this kind of adversity, especially for the poor, we examine two main alternative strategies, promoting energy efficiency and agricultural productivity. The former takes a demand-side management approach to energy scarcity (as well as GHG emissions), and is shown to promote both growth and rising domestic real incomes. The latter strategy aims to offset cost of living risks where the poor are most vulnerable, in agrofood commodities. Here we find that even modest improvements in agrofood productivity can offset adverse livelihoods effects of much higher energy prices, even promoting growth and higher real employment and wages in the process. The main conclusion of this analysis is that the best response to energy price risk, as well as fossil fuel emissions, may be more indirect than domestic fuel substitution. While there single policy can meet all needs for sustainable growth, efficiency and productivity oriented approaches to both energy and food scarcity should be seriously considered.

1 INTRODUCTION

1. New sources and uses of biofuel energy offer the prospect of climate change mitigation and less reliance on fossil fuels. At the same time, biofuel represents an unusual precedent in economics, the possibility of substitution between two essential but very different commodities, food and energy. The first characteristic has dramatically heightened interest in biofuel production around the world, but particularly in high income economies, whose expenditure patterns are most energy-intensive. Rising concerns about the need for climate stabilization and rapid innovation to reduce greenhouse gas (GHG) emission have stimulated visions of a booming new agribusiness energy industry, with pervasive induced effects on transportation and related sectors. At the same time, diversion of agricultural resources to energy production has implications for food markets that are only beginning to be fully understood, but are of special concern to poor countries whose expenditure patterns are most food-intensive. Both commodities are essential to human well-being, and their prices are important determinants of real living standards.

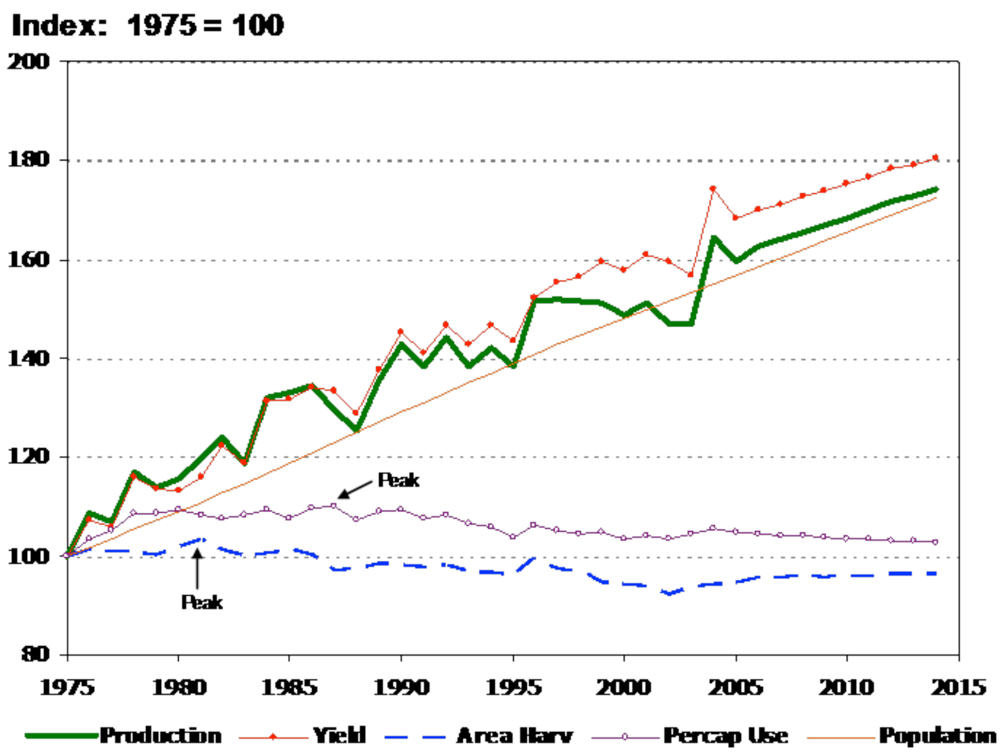
2. As part of this rising awareness, the Government of India is very actively exploring its biofuel potential. Because it imports more than 70 per cent of its oil and gas, it hopes to increase energy security by launching one of the world's biggest jatropha biodiesel projects. The country's Ministry of Rural Development has proposed spending $375m over five years to plant 1.2m acres of jatropha and studying the crop's viability as a biofuel feedstock. If this experiment is successful, the government would aim for 30m acres of jatropha plantations and promote commercial cultivation. Because it remains a low income country with intermittent food security challenges, India has clearly enunciated a policy not to promote comestible feedstocks or diversion of conventional farmland to biodiesel production. Therefore, a basic component of the jatropha strategy is marginal land use, estimated at 60m hectares nationwide. If 10% of this were recruited to jatropha cultivation, it could produce 4m-5m tonnes of biodiesel a year, or about 10 per cent of today's domestic diesel fuel demand.

3. The non-comestible, marginal land approach has merit in a stable market environment, but if the prices of food, land, or both were to escalate significantly it could become difficult to sustain. Economists generally believe that no resources are truly marginal, but will eventually be utilized when their opportunity cost rises enough. Likewise, today's food cropland could be expanded if the relative price of food rose enough to justify investments in land reclamation, forest conversion, or other exensification of farming. To a growing extent, this dynamic may be driven by forces external to India as an emerging middle class triggers greater food import dependence.

4. Food and energy are closely intertwined, first by the energy dependence of food production, second by linkage between agriculture and biofuel production. Both commodities are essential, one for survival and the other for prosperity. In modern times,

food prices have been kept low by productivity gains and policy intervention. While energy prices have risen gradually in high income countries, they were often buffered in low income countries by subsidies. The result of these trends (apart from individual crises) has been relatively stable food and energy living standards within and between economies both North and South. However, sustained recent escalation of global fuel prices threatens to disrupt this status quo, and biofuels might compound this problem. Direct energy price effects will reduce real incomes and divert expenditure from other necessities, while indirect stimulus to biofuel development will increase pressure on food prices, eroding living standards from a different direction.

Figure 1: Global Trends in Cereal Production

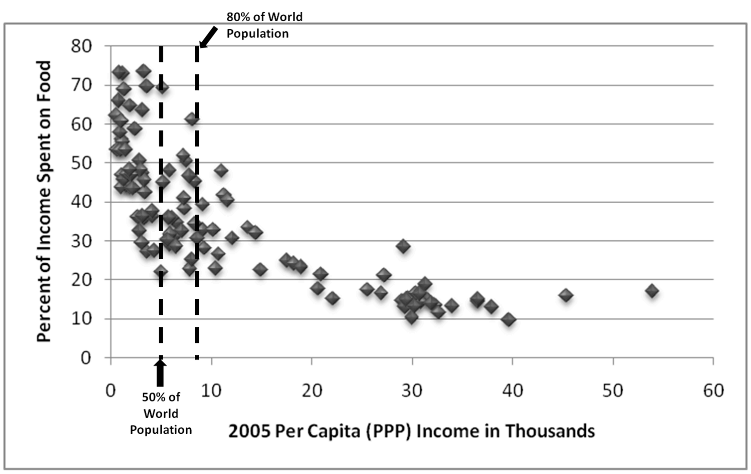


Source: Author estimates from World Bank and USDA data.

5. Of course, economic sustainability depends on different rules today than it did in previous centuries. Resources are not infinite, and their costs will continue to rise with increasing and prolonged exploitation. Higher prices for resources will have two economic impacts, incentives for innovation and rationing. Scarcity of food can be expected to trigger agricultural productivity growth, like the Green Revolution, which dramatically increased agricultural yields and food security in developing countries.

Figure 1 clearly illustrates this process in the case of global cereals, which still provide half the protein for the world's poor majority, 58% of humanity who live on $2.50 or less per day.[1] For its part, fuel scarcity can trigger efficiency, renewable energy innovation, recycling – all rational and technologically progressive responses to rising energy prices. This basic innovation process has not only helped us overcome scarcity in the past, but triggered new waves of prosperity in knowledge-intensive industries.

Figure 2: Food and Poverty



Source: Author estimates from World Bank and USDA data.

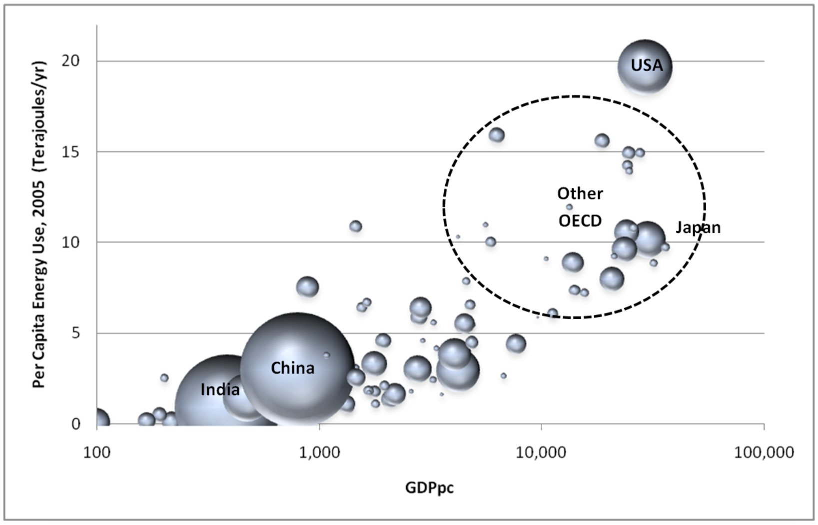
6. Rationing is the second, more ominous impact of scarcity. As something becomes more expensive, those without the right combination of willingness and purchasing power will be driven out of the market. During 2007-2008, a number of factors contributed to rapid escalation of prices for basic cereals, including rice, wheat, and corn. Figure 2 indicates how profound the social implications of these price increases can be. For a sample of 114 countries, we see expenditure on food as a share of total income (vertical), plotted against GDPPC.

7. Now contrast this with Figure 3, which shows patterns of national energy dependence by income and population. Clearly, expenditure patterns in higher income countries are much more energy intensive on a per capita basis. These two figures reveal a basic fundamental dichotomy in North-South energy-food dependence, with important implications for biofuel policy. Food is of course essential to everyone, but while Northern countries will be relatively more sensitive to energy scarcity, Southern countries will be relatively much more sensitive to food scarcity. In terms of vulnerability to the price effects of such scarcity, however, there is an important asymmetry in the

[1] Chen and Ravallion (2008).

North-South food-energy dichotomy – ability to pay. Whichever way scarcity might drive a global food-fuel auction, the poor would be at a severe disadvantage.

Figure 3: Energy and Prosperity



Source: Author estimates from International Energy Agency and World Bank data. Bubble diameter is proportional to population

8. For these reasons, food scarcity and price effects require special policy consideration in contexts like biofuel, where food-fuel tradeoffs may emerge. This is so regardless of whether biofuels enter markets in response to spontaneous economic forces or policy interventions. In the first case, one might argue that entry confers a lower priced alternative on global energy consumers, yet this corresponds to an indeterminate externality for food consumers. When policy makers influence the economics of biofuels, they may be responding to interests of some stakeholders with incomplete information regarding spillover effects that will play out in the marketplace.

9. In this report, we use a global economic forecasting model to more fully assess the complex domestic and international welfare effects of the modern biofuel economy. In particular, we examine how international food and fuel trends may influence the domestic policy options open to economies like India. Because it has a large low income population, even marginal land may have an opportunity cost if food prices rise substantially in response to external or domestic market forces.

10. Some observers are concerned that significant biofuel expansion has the potential to undermine a long held consensus between North and South: a strong de facto policy preference for cheap food. OECD economies have long subsidized their own agricultural activities with the combined intent of supporting food security, rural populations, improving profitability across the spectrum of agrofood industry and services, and raising

real household purchasing power. In the South, many economic development policies have been built on bedrock of food security, especially for politically sensitive urban poor populations. Cheap food has many other features that make it attractive for development strategy, including implicit wage subsidy for urban industrialization, export competitiveness, and impetus for structural change in agriculture. Whether cheap food is an explicit or implicit tenet of domestic policy around the world, two generations of monotone declines in food prices have been rationalized politically within both North and South.

11. This trend has been internalized in relations between these two spheres of the global economy. Apart from isolated crises, cheap food has enabled development assistance to devote most of its resources to post-subsistence needs, including economic and social infrastructure. This advances societies beyond basic needs and promotes more the articulated networks of political and economic linkage that constitute open multilateralism. Thus within and between North and South relations, a de facto consensus prevails. Interestingly, the agricultural reform agenda of the Doha round of trade negotiations is an exception that, in light of its current difficulties, proves this rule.

12. Were the cheap food consensus to unravel, it could have implications as dramatic as other great multilateral realignments in modern history, including the Cold War and, more ominously, overt conflicts within and between countries that experience dramatic changes in food purchasing power. Although we have been spared this experience for many years, it is not difficult to envision the dynamics of a world with sustained increases in food prices. This would be a world where economic convergence, an welcome historic trend of poorer countries growing faster, would be reversed. Given dramatic initial differences in per capita income, a multinational food auction would doubtless be won by higher income bidders, with dire consequences for food security in low income countries. The international implications of this could be ugly indeed, but domestic stability is likely to be the first casualty. History has definitive lessons for leaders whose populations enter food crises. Political consensus evaporates, leaving an ultimatum between regime change and marital law. Neither alternative, unfortunately, offers the needed remedy, and cycles of social instability often ensue.

2 INDIA'S BIOFUEL POLICY ARCHITECTURE

13. At present, India uses petroleum products to meet 95% of its transportation energy needs and is increasingly reliant on foreign imports to service this demand (GOI 2009). In 2007-08, India imported approximately 77% of its crude oil needs (GOI 2009); the majority of which came from the Middle East and Africa (IEA 2007). The International Energy Agency projected imports could rise to as much as 90% by 2030 if present consumption trends continue (IEA 2007).

14. India initiated biofuel production nearly a decade ago to reduce its dependence on foreign oil and thus improve energy security. The country began 5% ethanol blending (E5) pilot programs in 2001 and launched a National Mission on Biodiesel in 2003 to achieve 20% biodiesel blends by 2011-2012 (GOI 2002; GOI 2003). Similar to many countries around the world, India's biofuel programs have experienced set backs, primarily because of supply shortages and global concerns over food security.

15. To rectify these concerns and affirm its commitment to promoting sustainable biofuels, India implemented a National Policy on Biofuels in December 2009. The program proposes 20% indicative blending targets (ie. not mandatory) for both biodiesel and ethanol by 2017 (GOI 2009). The December 2009 policy document outlines a broad strategy for the biofuel program and briefly catalogs policy measures being considered to support the program. Although the policy contains limited specifics on how the program will be implemented, the country's intention to avoid conflicts with food security is firmly stated throughout the policy document. The policy specifically requires the use of non-food feedstocks grown on marginal lands unsuitable for agricultural production. However, no details on how this requirement will be enforced are contained in the policy.

16. This paper reviews the policy history of India's ethanol and biodiesel programs and summarizes the recent National Policy on Biofuels.

A. Ethanol Program: 2001-2008

17. In light of rising oil prices and increased dependence on oil imports, India established an ethanol pilot program in 2001. The program consisted of three E5 blending programs in Maharashtra and Uttar Pradesh and research and development (R&D) studies investigating the technical feasibility of ethanol use (Gopinathan and Sudhakaran 2009). The pilot projects were deemed successful and in September 2002, the Ministry of Petroleum and Natural Gas mandated E5 blending targets for nine states and four Union Territories, effective January 1, 2003 (GOI 2002). The nine states participating in the program were: Andhra Pradesh, Goa, Gujrat, Haryana, Karnataka, Maharashtra, Punjab, Tamil Nadu, Uttar Pradesh. The four Union Territories were: Chandigarh, Damman and Diu, Dadra and Nagar Haveli, Pondicherry.

18. The 5% blending target was established after consultations with key stakeholders at the state and central government levels, including the Society for Indian Automobile Manufacturers and major sugar manufacturers (Gopinathan and Sudhakaran 2009). The groups determined there were adequate surplus supplies of molasses and alcohol in the country to meet the initial 5% target as well as possible scale ups to 5% and 10% countrywide blending targets (Gopinathan and Sudhakaran 2009). Under the program, India's oil marketing companies (OMCs) were responsible for purchasing and blending ethanol.

19. In April 2003, India further solidified its ethanol program when the Planning Commission released its expert report on biofuels (GOI 2003). The expert committee analyzed various blending targets, price and feedstock availability scenarios and issued the following recommendations to advance India's ethanol program:

- The country must move toward the use of ethanol as a substitute for gasoline
- Production of molasses and distillery capacity can be expanded to meet 5-10% blends of ethanol
- Ethanol may be manufactured using molasses as the primary feedstock supplemented by sugarcane juice when there is an excess supply of sugarcane
- Restrictions on the movement of molasses and establishing ethanol manufacturing plants may be removed
- Imported ethanol should be subjected to suitable duties
- Buyback arrangements with oil marketing companies (OMCs) will be arranged
- Financial incentives should be provided to establish new state of the art distilleries
- R&D programs should be established to research alternative feedstocks including sugarbeet, corn, potatoes, grain, straw

(GOI 2003: vi-vii)

20. At the time the initial policy was established, India was endowed with surplus sugar supplies. However, severe droughts in 2003 and 2004 reduced sugar supplies by over 60% from historic averages and molasses supplies by over 53% (Gopinathan and Sudhakaran 2009). Further, ethanol was subject to various central and state alcohol taxes and levies, which created challenges for moving ethanol around the country (Gopinathan and Sudhakaran 2009). This further diminished ethanol supplies and as result, India had to import 447 million liters of ethanol from Brazil in 2004 to meet the E5 blending target (Gopinathan and Sudhakaran 2009). As result, in October 2004, India amended the E5 mandate requiring E5 blends only when adequate ethanol supplies were available and when the domestic price of ethanol was comparable to the import parity price of petrol (Gopinathan and Sudhakaran 2009, referencing Ministry of Petroleum and Natural Gas Basic Statistics, 2004).

21. India continued importing ethanol to meet its blending targets and became the largest importer of Brazilian ethanol in 2005 (GOI 2006). That year India imported 411 million liters from Brazil, which accounted for approximately 9% of global ethanol trade (GOI 2006). However, transporting ethanol across states remained difficult. As result, the majority of the imported ethanol was used for chemical manufacturing instead of for fuel blending purposes (GOI 2006).

22. Therefore, the government recommended a further scale back in the ethanol program when it issued its Integrated Energy Policy (IEP) in August 2006. The IEP contained the following recommendations for the ethanol program:

- Set the import tariff on ethanol independent of use and at a level no greater than the price of petroleum products
- Require, not mandate, OMCs to blend 5% ethanol
- Price ethanol at its economic cost in relation to petrol but not higher than its import parity price
- Allow for 5-7 year forward contract purchases at the parity price of petrol
- Consider waiving all or part of the excise and levies charged on blended petrol
- Incentivize research on cellulosic ethanol

(GOI 2006: 96)

23. Despite the recommendations in the IEP, the Ministry of Petroleum and Natural Gas strengthened and expanded the ethanol program when it unveiled its Ethanol Blending Program (EBP) in September 2006. The EBP mandated E5 blends, effective November 1, 2006, in 20 states and 4 Union Territories, subject to commercial viability (Ministry of Petroleum and Natural Gas 2007). India experienced a surplus in sugar production during the 2005-2006 season, which most likely facilitated the new policy decision. As result of the new policy, 10 states enacted the EBP by 2007.

24. The 11th Five Year Plan covering the period 2007-2012 recommended increasing ethanol blending mandates to 10% once E5 blends were put in place across the country (GOI 2007). The Planning Commission, the authors of the Plan, recommended this increase to occur in the middle of the 11th plan period. In September 2007, the Cabinet Committee on Economic Affairs (CCEA) implemented E5 blends across the country[2] and recommended E10 blends where feasible, effective October 2007. E10 blends became mandatory across the country in October 2008 (Cabinet Committee on Economic Affairs 2007).

25. The E10 blending mandate remains in effect and will be scaled up to 20% blends (E20) by 2017, as mandated by the country's recently enacted National Policy on Biofuels (GOI 2009). The National Policy on Biofuels will be further reviewed following a review of India's biodiesel policy history. As result of its continued efforts to support a domestic ethanol industry, India is currently the world's 9th leading ethanol producer, tied with Thailand and Colombia, having produced 300 million liters of ethanol in 2008 (REN21 2009).

[2] The policy excludes the areas of Jammu and Kashmir, the Northeastern States and Island Territories.

B. Biodiesel Program: 2003-2008

26. India established its biodiesel program in 2003 with the launch of the National Mission on Biodiesel (GOI 2003). The Mission called for mandating a 20% biodiesel blending target by 2011-2012 using Jatropha curcas as the primary feedstock. Jatropha is a small shrub capable of growing on degraded lands that produces non-edible oilseeds that can be used to manufacture biodiesel. Although approximately 400 non-edible oilseeds can be found in India, the Committee selected Jatropha for the biodiesel program because of its higher oil content (40% by weight) and lower gestation period (2-3 years) in comparison with other oilseeds (GOI 2003).

27. To meet a 20% blending target, the Committee recommended cultivating Jatropha on 17.4 million hectares of under utilized and degraded land (approximately 5% of India's total land area), according to the following land types detailed below in Table 1.

Table 1: National Mission on Biofuels Jatropha Cultivation Recommendation

Land Type	**Area**	**Percentage**
	million ha	**%**
JFM Forest lands	3	17%
Agricultural border fences	3	17%
Agroforestry schemes	2	11%
Culturable fallow lands	2.4	14%
Integraged Watershed Development wastelands	2	11%
Public lands along roads, railways, canals	1	6%
Government-designated wastelands	4	23%
TOTAL	**17.4**	**100%**
India total land area	**328.7**	**5%**

Sources: (GOI 2003; CIA 2009)

28. The Mission was to be implemented in two phases: a research and demonstration phase from 2003-2007 (Phase I) and an implementation phase from 2007-2012 (Phase II). The main goals of Phase I were to bring 400,000 ha of land under cultivation, to establish a research network of 42 public universities and to enact a 5% blending target (B5). The program would be expanded under Phase II to achieve a 20% blending target (B20) by 2011-2012.

29. To support the Mission, the Ministry of Petroleum and Natural Gas enacted a National Biodiesel Purchase Policy and set a price of Rs 25 per liter ($0.56/liter), subject to periodic review, effective November 1, 2006 (GOI 2005). The Ministry designated 20 OMCs in 12 states as purchase centers. The buyback program remains in effect but the buyback price was raised to Rs 26.50 per liter ($0.58/liter) in October 2008 (Cabinet Committee on Economic Affairs 2007).

30. Although the biofuel blending targets were not codified, interest in Jatropha rapidly accelerated after the launch of the National Mission on Biodiesel. According to a global Jatropha market survey, India was the world's leading Jatropha cultivator in 2008, controlling approximately 45% (407,000 ha) of global cultivation (approximately 900,000 ha) (GEXSI 2008). Further, the GEXSI study anticipated India would remain a leading cultivator and projected nearly 2 million hectares would be under cultivation by 2015.

31. Despite India's initial progress in promoting Jatropha, the industry has experienced set backs because of declining international oil prices and because of continued variability in the agronomic performance of the crop. To date, there remains considerable uncertainty surrounding the seed yields, input and maintenance requirements for the crop (Achten, Verchot et al. 2008), all of which have inhibited market development. Additional concerns surrounding the land tenure implications and rural livelihood benefits have further stymied the industry (FOE 2009). As result, India's Integrated Energy Policy, released in 2006, recommended significant increases in research funding for Jatropha and Pongamia, another tree born oilseed (GOI 2006). Further, the 11th Five Year Plan, which began in 2007, recommended a blending target of 5% biodiesel blends by the end of the 11th Plan in 2012, a significant reduction from the 20% target proposed under the National Mission on Biodiesel (GOI 2007). In August 2008, a Group of Ministers decided to discontinue the National Mission on Biodiesel (Dey and Jayaswa 2008).

32. However, in September 2008, the Ministry of New and Renewable Energy (MNRE) resumed discussions on biodiesel and issued a draft National Biofuels Policy (GOI 2008). The draft policy seemingly backed off the country's exclusive promotion of Jatropha and instead called for using any non-edible oilseeds grown on marginal, degraded or wastelands. The draft policy also recommended establishing 20% blending targets by 2017 for both ethanol and biodiesel.

C. National Policy on Biofuels

33. On December 24, 2009, the government implemented the National Policy on Biofuels (GOI 2009). The policy establishes indicative 20% blending targets by 2017 for both ethanol and biodiesel. Both targets will be phased in over time and until a phase in schedule is finalized, the current E10 mandatory blending target will remain in effect. There is no mandatory nationwide blending target for biodiesel at present. Blending targets will be periodically reviewed and adjusted as needed. The Policy proposes establishing a National Registry of feedstock availability to help monitor production potential and set blending targets.

34. The Ministry of New and Renewable Energy (MNRE) is tasked with coordinating the Policy. Two new committees, the National Biofuel Coordination Committee (NBCC) and the Biofuel Steering Committee headed by the Prime Minister and Cabinet Secretary,

respectively, will be established to coordinate and implement the Policy. As with previous biofuel policies, OMCs will be responsible for purchasing, storing, distributing and marketing biofuels.

2.1.1 Feedstocks

35. The new policy is not feedstock specific, as was the case with previous biodiesel policies. Instead, the policy calls for using non-food feedstocks grown on degraded lands or wastelands in order to avoid conflicts with food security. According the government, this provision will distinguish India's program from other international biofuel programs. This stipulation is aimed more towards biodiesel feedstocks because the policy goes on to state the government will promote the use of non-edible oilseeds cultivated on degraded lands for biodiesel. The policy does not mention Jatropha but instead states the government will assess the potential of over 400 tree born non-edible oilseeds currently growing in India. The policy does not list preferred ethanol feedstocks but mentions molasses has historically been the primary feedstock used in India.

2.1.2 Mode of production

36. In order to avoid conflicts with food production, the policy promotes establishing plantations on government/community owned wastelands and on degraded or fallow lands. Both forest and non-forest lands will be considered. Contract farming schemes will also be devised in order to raise feedstocks on privately owned wastelands. Seed buyback programs will be implemented to encourage contract farming. The policy specifically states plantations on agricultural lands will be discouraged. However, the policy does not provide any guidance as to how these provisions will be enforced.

2.1.3 Policy mechanisms

37. The Policy identifies several policy mechanisms that will be considered to promote biofuel production. The Policy document contains little detail on the specifics of each policy mechanism because presumably, these items are still under development. Many of the proposed mechanisms resemble those recommended in the 2003 Planning Commission expert report on biofuels (GOI 2003). The Policy outlines mechanisms in the following areas: subsidies, preferential financing, fiscal incentives, RD&D, demonstration projects and international collaboration.

2.1.4 Subsidies

38. The primary government subsidies under consideration are price supports, land concessions and labor subsidies. In terms of price supports, the policy proposes establishing minimum support prices (MSP) for oilseed procurement, which will be paid by the OMCs. Additionally, the government will evaluate developing a statutory minimum price (SMP) program for oilseed procurement at biodiesel processing centers. The Policy recommends modeling an oilseed SMP program after the existing SMP program for sugarcane procurement. If implemented, this could greatly expand the number of buyback locations operating in the country. Restricting buybacks to the 20 designated OMC locations has frequently been criticized (GOI 2006). Additionally, the government may also establish a minimum purchase price (MPP) for biodiesel. The OMCs would administer this program as well.

39. Qualifying oilseed plantations will also be eligible to receive a subsidy for labor costs under the government's Mahatma Gandhi National Rural Employment Guarantee Act (Ministry of Rural Development 2010). The law guarantees 100 days of labor per year for Rs. 60/day ($1.33) for adult members of rural households living below the poverty line. The law typically applies to unskilled labor on publicly funded projects, such as construction.

40. Additionally, the National Policy on Biofuels proposes the establishment of oilseed plantations on government/community owned wastelands. States will be in charge of governing all land use decisions related to such plantations. In certain states with existing biofuels policies, including Uttarakhand, Chhattisgarh, Andhra Pradesh and Karnataka, the government leased wasteland areas to companies for free (Altenburg, Dietz et al. 2009). Further, the policy stipulates that local panchayat institutions shall be consulted in all land use decisions concerning establishing plantations on government/community owned lands.

2.1.5 Preferential Financing

41. Recognizing the need to create the necessary infrastructure to facilitate biofuel production, the Plan calls for national finance institutions to devise preferential financing schemes for biofuel projects. The National Bank of Agriculture and Rural Development (NABARD) will provide loans to farmers to help with plantation costs. Additionally, the Indian Renewable Energy Development Agency (IREDA), the Small Industries Development Bank of India (SIDBI) and various commercial banks will be encouraged to provide financing for all activities to develop biofuel value chains.

42. Further, the government of India will seek financing from mulilateral and bilateral lending institutions as well as carbon financing opportunities. Finally, the government will also permit 100% foreign direct investment (FDI) in biofuel projects in order to facilitate international investment and joint ventures. However, FDI will not be allowed for

plantation projects or for projects seeking to export biofuels. Therefore, FDI will likely be sought for processing and refining technologies.

2.1.6 Fiscal Incentives

43. Additional subsidies and grants may also be considered to promote new and second-generation biofuel production. The Policy does not state the specific feedstocks being considered under this categorization. If necessary, the government will create a National Biofuel Fund to provide financing for these efforts. The plan also calls for incorporating biofuels into other pre-existing central and state government financing schemes for promoting renewable energy. However, the plan does not reference specific policy schemes where biofuels should be integrated.

44. The government will also reduce or eliminate taxes and duties on biofuels. The policy will maintain the current concessional excise duties on bioethanol and biodiesel. Presently, the excise duty for ethanol is 16% while biodiesel is exempt from this tax. No further central government taxes or duties will be implemented for ethanol and biodiesel. The government will also reduce customs and excise duties for plant and engine technologies but the precise reduction rates are not detailed in the Policy.

2.1.7 Research, Development and Demonstration (RD&D)

45. The government will also undertake research, development and demonstration efforts to establish competitive domestic biofuels industries. Research and development efforts will primarily focus on establishing plantations, biofuel processing and production technologies, improving the efficiency of end-use applications and by-product utilization. Demonstration projects will be set up for both ethanol and biodiesel projects. These projects will focus on production and conversion technologies. The government will engage in public private partnerships (PPP) to support these initiatives.

46. The government will fund research initiatives at academic, government, non-profit and corporate research institutions to support the RD&D programs. Multi-institutional research programs will clearly defined objectives and timelines will be established to facilitate these efforts. Further, the government will establish an R&D Subcommittee under the Biofuel Steering Committee to oversee these efforts. The sub-committee will be led by the Department of Bio-Technology and will include members from the Ministry of Agriculture, Ministry of New and Renewable Energy and the Ministry of Rural Development. The Ministry of New and Renewable Energy will coordinate the sub-committee as this Ministry is responsible for implementing the overall biofuel policy.

2.1.8 International Cooperation

47. India will also pursue strategic international partnerships to carry out the biofuel policy and cultivate its domestic biofuels industries. Priority areas for such collaborations

will include technology transfer, joint research and technology development, field studies, pilot scale plants and demonstration projects.

48. In November 2009, one month before the official announcement of its biofuel policy, India entered into an MOU with the US Department of Energy to promote biofuel cooperation (GOI 2009). The goal of the MOU is to support the production, conversion, utilization, distribution and marketing of biofuels in a sustainable and environmentally friendly manner in accordance with each country's respective strategies and goals. The MOU outlines cooperation in 8 specific areas, subject to revision and expansion. The 8 areas are:

1. feedstock production, primarily non-edible oilseeds for biodiesel and sugarcane, sweet sorghum, sugar beet and cassava for ethanol
2. advanced conversion technologies
3. technologies for end use applications in transportation and electricity generation
4. biodiesel by-product reuse
5. development of test measures, standards and procedures for biofuels
6. development of joint policy studies and business models for biofuel research
7. technology transfer
8. establishing a continuing dialog to support biofuels in both countries

49. Additionally, in March 2010, the US Department of Energy, General Motors (GM) and the Central Salt & Marine Chemicals Research Institute (CSMCRI) entered into a five-year agronomic research project on Jatropha (PR Newswire 2010). The project will consist of two demonstration farms in Gujarat, one 33-hectare plot in Bhavnagar, Gujarat and a 20-hectare plot in Kalol, Gujarat. The goal of the projects is to identify high yielding Jatropha varieties and to evaluate the environmental impacts of Jatropha through life cycle assessment.

50. The policy mechanisms outlined in the National Biofuels Policy are summarized below in Table 2.

Table 2: Summary of the National Biofuel Policy Policy Mechanisms

Mechanism	Initiatives	Description
Subsidies	Price supports	Development of Minimum Support Prices (MSP), Statutory Minimum Prices (SMP) and Minimum Purchase Prices (MPP) to facilitate feedstock cultivation and biofuel production. Oil Marketing Companies (OMCs) and biofuel processors will administer payments.
	Labor subsidy	Qualifying projects will be eligible to participate in the government-sponsored Mahatma Gandhi National Rural Employment Guarantee Act which provides 100 days of work per year at Rs. 60 per day for adult members of rural households living below the poverty line.
	Land grants	The government will facilitate establishing oilseed plantations on government/community owned degraded lands and wastelands. States are required to govern all decisions related to land use and government land allocation. Consultations with local Panchayat institutions are required for all land use decisions on government/community owned lands.
Preferential Financing	Domestic financing	The following agencies will provide project financing to assist with industry development: • National Bank on Agriculture and Rural Development (NABARD), • Indian Renewable Energy Development Agency (IREDA) • Small Industries Development Bank of India (SIDBI) Commercial banks
	International financing	• Multilateral, bilateral and carbon financing opportunities will be pursued • 100% foreign direct investment (FDI) permitted for biofuel technologies
Fiscal incentives	National Biofuels Fund	May be developed to promote investment in new and second generation biofuel technologies
	Tax and duty relief	• Ethanol excise duty to remain at 16%, biodiesel to remain exempt from excise duty • No other Central taxes or duties for biofuels will be implemented
	Renewable Energy Sector	Biofuel projects will be incorporated and deemed eligible for existing fiscal incentives related to

	fiscal incentives	renewable energy promotion
RD&D	R&D	R&D will focus on the following initiatives: • feedstock production • advanced conversion technologies • end use application technologies • by-product utilization
	Demonstration projects	Public Private Partnerships (PPP) will be pursued to establish ethanol and biodiesel demonstration projects
	R&D Subcommittee	An R&D Subcommittee under the Biofuel Steering Committee will be established to coordinate RD&D efforts. The Department of Bio-Technology will lead the Subcommittee.
International Collaboration	Bilateral and multilateral partnerships	Appropriate partnerships will be sought out to promote technology transfer, joint scientific and technical cooperation, field studies, pilot scale plants and demonstration projects.

Source: (GOI 2009)

D. Imports/Exports

51. The new Policy prioritizes domestic production and consumption over importing and exporting biofuels. The government proposes setting duty and tax rates so that imports are at parity cost with domestic sources. Imports will only be considered when necessary. Imports of Free Fatty Acid (FFA) oils, which can be used as biodiesel feedstocks, are prohibited. Exports will only be considered after domestic demand is met. The National Biofuel Coordination Committee will govern decisions related to exports and imports.

E. Role of States

52. The policy requires each state to designate a nodal agency to coordinate biofuel activity within its boundaries. Relevant state agencies, such as panchayati raj institutions, forestry departments, universities and research institutions, should be invited to actively participate in biofuel governance activities. Most importantly, state governments are required to decide on all land use activities for establishing plantations on government wasteland and degraded lands. The states will also facilitate infrastructure development.

F. Awareness and Capacity Building

53. Finally, the government will initiate efforts to raise awareness on the significance of biofuels and the importance of establishing a domestic energy sector. A key initiative will be to develop the requisite human resource capacity to support this industry. The government will encourage universities and training institutes to implement suitable curricula to support these efforts.

54. To summarize, a timeline of India's biofuel policy development for both ethanol and biodiesel is presented below in Table 3.

Table 3: Biofuel Policy Timeline

Year	Month	Ethanol	Biodiesel
2001		E5 demonstration projects Maharashtra and Uttar Pradesh R&D Trials	
2003	January	E5 mandatory blends in 9 States and 4 Union Territories	
	April	***Planning Commission Expert Report on Biofuels***	
		recommended expanding E5 blends and pursue E10 blends	established National Mission on Biodiesel
		E20 by 2011-2012	B20 using Jatropha by 2011-2012
2006	August	***Integrated Energy Policy***	
		recommended relax E5 mandates and research second generation technologies	recommended significant research on Jatropha and Pongamia to reduce uncertainty
	November	Ethanol Blending Program (EBP) announced E5 mandatory in 20 States and 4 Union Territories	
2007	January	***11th Five Year Plan***	
		recommended nationwide E5 scale up and E10 blends	B5 blends nationwide by 2012

		by 2010	
2008	August		Group of Ministers stop National Mission on Biodiesel
	September	***Draft National Biofuels Policy***	
		E20 by 2017	B20 by 2017 using non-edible oilseeds
	October	E10 mandated in 20 States and 4 Union Territories	
2009	November	***US/India Biofuel MOU***	
		support research in advanced feedstock techologies identified 8 priority areas: 1. feedstock production, primarily non-edible oilseeds for biodiesel and sugarcane, sweet sorghum, sugar beet and cassava for ethanol 2. advanced conversion technologies 3. technologies for end use applications in transportation and electricity generation 4. biodiesel by-product reuse 5. development of test measures, standards and procedures for biofuels 6. development of joint policy studies and business models for biofuel research 7. technology transfer 8. establishing a continuing dialog to support biofuels in both countries	
	December	***National Biofuels Policy***	
		E20 by 2017	B20 by 2017 using non-edible oilseeds

3 TRENDS IN ENERGY MARKETS AND TECHNOLOGY

55. Over the last generation, global energy and food price have followed opposing trends, with energy prices rising and food prices falling nearly monotonically. Now that biofuel substitution offers significant linkage between the two markets, we can expect this divergence to be reversed or at least attenuated. For energy prices, this is a welcome shift from the perspective of the world's majority (energy consumers). A large share of world population, however, will have the opposite reaction to rising food prices.

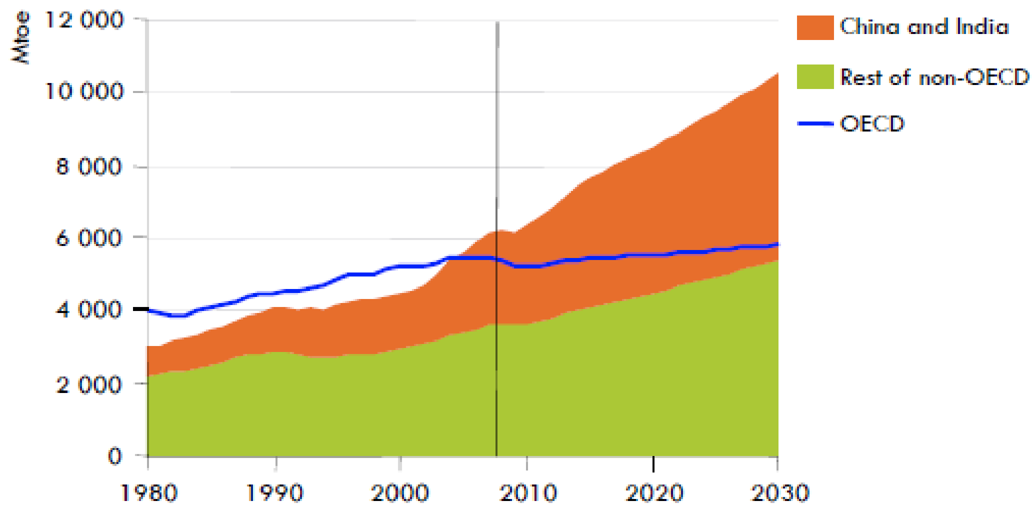
56. On a global scale, the energy-food trade-off can be thought of in terms of a single production possibility frontier, shifting resources to balance price extremes between the two products. For an individual country, however, the decision framework is very different, depending on the relative sizes of domestic and foreign markets. Because India imports over two thirds of its conventional energy and produces most of its own food to meet basic needs of a poor majority, it has limited control over conventional fuel prices and little flexibility to substitute with agricultural capacity. While India can develop significantly greater hydro, solar, and some other renewable energy alternatives, it is constrained primarily to land classified as marginal for biofuel production. Thus the best the country can hope for in jatropha production is about 10% domestic diesel fuel displacement, an amount unlikely to significantly impact externally driven transport fuel prices.

57. Biodiesel may have a GHG advantage, although this has to be discounted by process and distribution emissions, but even on marginal land it has an agrofood opportunity cost. Most economists would agree that no land hospitable to a tree crop can be truly marginal, but on so with respect to existing prices and technologies. If new incentives emerge to increase national agrofood output, any eligible land resources will be reconsidered, and both intensive and extensive agrofood investments can be expected to alter land use patterns.

58. Apart from a surge in 2007, modern agrofood relative prices have been relatively stable, but there is an important indirect threat to affordable food from energy price trends. If energy prices escalate significantly in the long run, the livelihoods impact of this on the poor could be adverse overall and particularly with respect to food. Both energy and food are essential commodities, and price inflation in the former will undermine purchasing power for the latter. India may not be able to influence energy prices with its biofuel agenda, but it may be more effective to offset this by promoting agricultural productivity growth, both in terms of the same marginal land use and across the agrofood economy generally. This approach will have two additional benefits, supporting food security and higher incomes from traditional resource use patterns, while at the same time accommodating the demand side management benefits of higher energy prices. Put more simply, this policy response would increase the agrofood content of GDP while lower its energy content, perhaps a more appropriate path for a low income economy to achieve sustainable development.

59. To better understand the implications of such an approach, we review global energy market conditions going forward, comparing official estimates with our own projections of long terms adjustments. The figure below shows IEA projections of demand. In their reference scenario, they estimate that 93% of the growth of energy demand will come from non_OECD countries, primarily China and India.

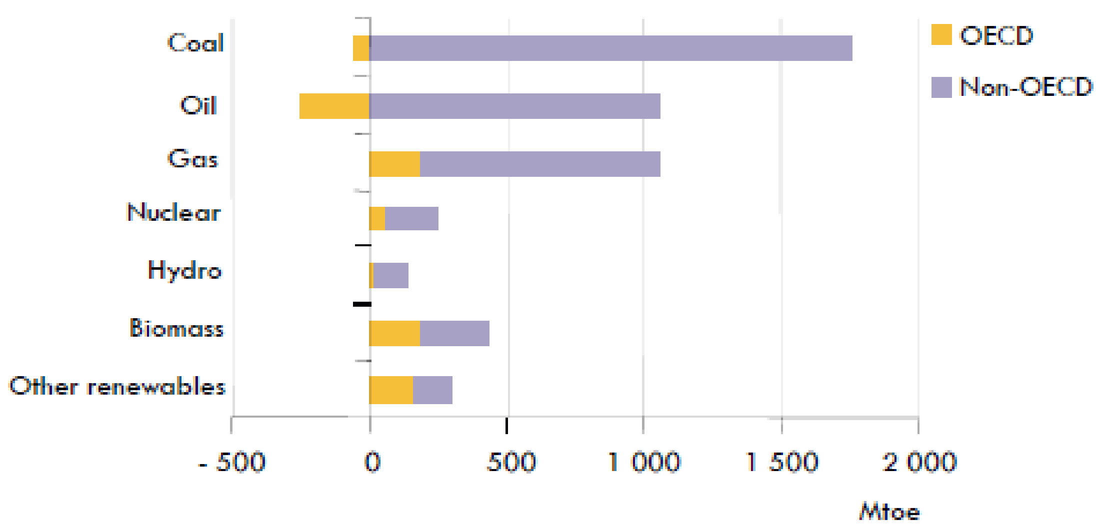
Figure 4: World Primary Energy Demand



Source: IEA.

Of this total demand, 77% will be with conventional fossil fuels (Figure), goods for which India has only limited market power.

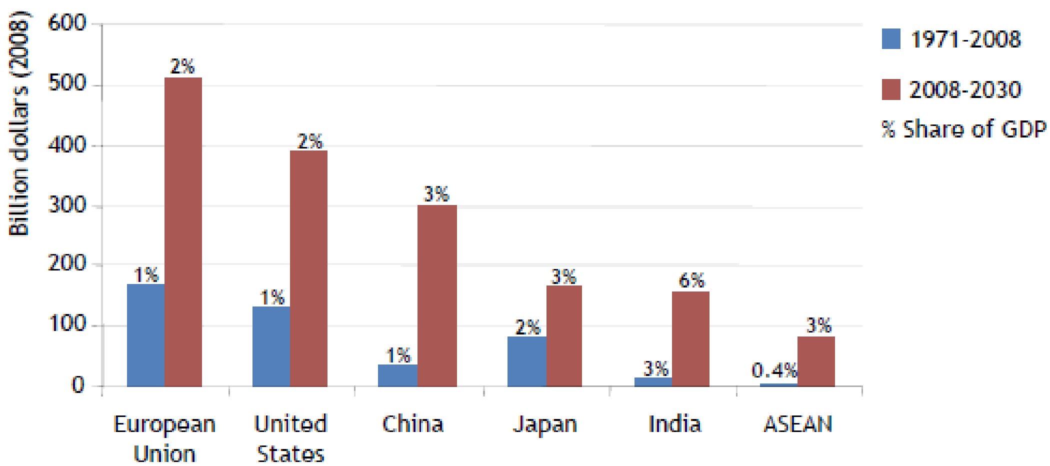
Figure 5: Fuel Composition of New Energy Demand (2030)



Source: IEA.

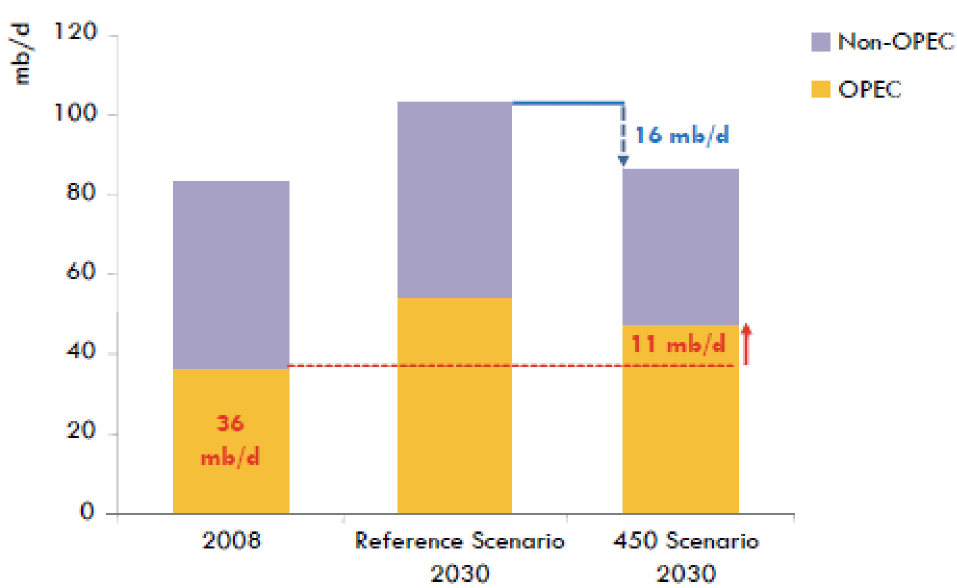
Meanwhile, global energy scarcity will lead to intensified competition from net importers.

Figure 6: Average Annual Net Imports of Oil and Gas



On the global supply side, the market share of OPEC is expected to rise substantially.

Figure 7: Oil Production by Source



60. Taken together, these trends imply that global conventional prices will experience unprecedented pressures from a combination of demand growth and market concentration. Assuming significant price increases result, the appropriate response for

each country will depend on a variety of conditions. In the case of India, energy price increases have the adverse effect of lowering real incomes but the benefit of promoting energy efficiency. Rather than fighting the real income effect directly, it is reasonable to ask if biodiesel development or agrofood promotion would more effectively address the real income effect, without eliminating the efficiency incentive. In the next section, we use a global forecasting model to assess these impacts and alternative policy responses.

4 DOMESTIC POLICY RESPONSES TO EXTERNAL MARKET FORCES

61. An economy the size of India cannot ignore global market conditions, but neither does it need to accept them as given. In the case of conventional fuel energy, India's long term position may be that of a price taker, but in agrofood domestic capacity is such that India can significantly buffer itself against external shocks. This is true, in fact, both for direct (agrofood price) and indirect (other essential commodity) price shocks, as we shall see below. Many scenarios that examine biofuels from a climate perspective do not consider the price risks in conventional energy markets, but the trends we examined in the previous section suggest these may be very serious.

62. To assess India's policy options with respect to global energy price trends, we apply a global dynamic forecasting model, calibrated to a custom version of the GTAP 7 database. The model is described schematically in an annex below and fully documented elsewhere. The dataset begins with the standard GTAP 7 system, but disaggregates three biofuels (cane and starch ethanol, biodiesel) and byproducts by country, and then adds more data on emissions, demographics, etc. obtained from independent sources.

63. To better understand the influence of global energy price uncertainty on the Indian economy and options available to policymakers, we consider a set of five basic scenarios. The first of these is a business-as-usual reference case, calibrated to independent consensus growth rates around the world and assuming no change in the real prices of primary commodities. In the next two scenarios, we assume that global oil and gas prices both rise 50% by 2030, reflecting upper bounds that have been widely publicized in independent media and discussed by official agencies like IEA and the U.S. Department of Energy. In response to this scenario, we consider three types of domestic policy, biofuel deployment, energy efficiency standards, and agrofood productivity growth. In the first cases, we assume that government policies target 20% biodiesel and ethanol transport fuel substitution for diesel and gasoline, stepwise, with biodiesel deployment first and then ethanol deployment added to this. Next, we assume a combination of policy and private technology diffusion lead to annual gains in overall conventional fuel use efficiency of 1 percent per annum over 2012-2030, a demand side management target that has been achieved or exceeded in many economies. For comparison, we assume in the fifth scenario that a combination of agricultural policies leads to 1 percent annual growth of agricultural productivity. The results of all these for the Indian economy are then assessed by a variety of macroeconomic indicators.

S1: Global oil and gas prices rise 50% over the period 2010-2030.

S2: Scenario 1 with biodiesel standard.

S3: Scenario 1 with biodiesel and ethanol standards.

S4: Scenario 3 with 1 percent annual energy efficiency gains.

S5: Scenario 4 with 1 percent agrofood productivity growth.

Table 1: Policy Scenarios

Table 2: Macroeconomic Results
(S1 percent change Baseline level in 2030, S2-5 change from S1)

	S1	S2	S3	S4	S5
Real GDP	-4.8%	1.1%	1.3%	0.9%	2.9%
Real Cons	-6.6%	2.1%	2.4%	3.4%	6.2%
Exports	-4.1%	-0.9%	-1.0%	2.4%	1.3%
Imports	-9.3%	0.0%	-0.1%	2.7%	3.2%
Agfood Imports	-8.3%	2.3%	3.0%	9.5%	-29.5%
Energy Imports	-27.6%	-10.6%	-12.5%	-19.0%	-13.0%
GDPPC_PPP	-4.1%	-0.9%	-0.9%	1.3%	5.1%
CPI	3.0%	0.7%	0.8%	4.6%	1.7%
Food CPI	-2.6%	0.4%	0.6%	1.9%	-11.9%
Energy CPI	48.6%	5.4%	5.8%	-9.0%	0.4%
Real HH Income	-4.7%	0.9%	1.1%	2.3%	4.2%
Real Wages	-5.9%	0.4%	0.7%	3.7%	7.9%
GHG Emissions	-13.2%	-6.7%	-7.5%	-18.1%	-15.6%

64. Table 2 summarizes the macroeconomic impacts of the four counterfactual policy scenarios. The most arresting feature of these results is the moderate real GDP impact of the energy policies considered. In particular, India's intended 20% transport biofuel commitment would have a minimal impact on aggregate growth, as would energy efficiency measures. In all three cases (Scenarios 2-4), we see about half a percentage point lower growth in 2030, meaning that two decades later these policies would delay growth by only about one month behind a baseline rate of 6%. If these policies can be justified on other grounds, macroeconomic growth risk apparently does not support an objection to them.

65. Biofuels do, however, impose an aggregate efficiency cost in terms of real living standards and competitiveness, with lower real consumption, GDPPC at purchasing power parity, exports, and imports. This is inevitable as long as fossil fuels remain

cheaper in BTU terms, and subsidy schemes to make biofuels competitive impose other costs on society. Without such measures, imposing the blending standard raises the energy CPI for households by about 6%. It is noteworthy that most of the aggregate impact arises from the biodiesel policy, but this is to be expected since it represents about 80% of the total biofuel deployment.

66. The biofuel standard does improve India's energy self-sufficiency, as imports fall about 13%, less than the 20% biofuel standard because the latter only covers transport fuels. It is worth noting that energy efficiency measures increase these import savings by more than half, highlighting the value of complementary demand side measures when addressing energy security.

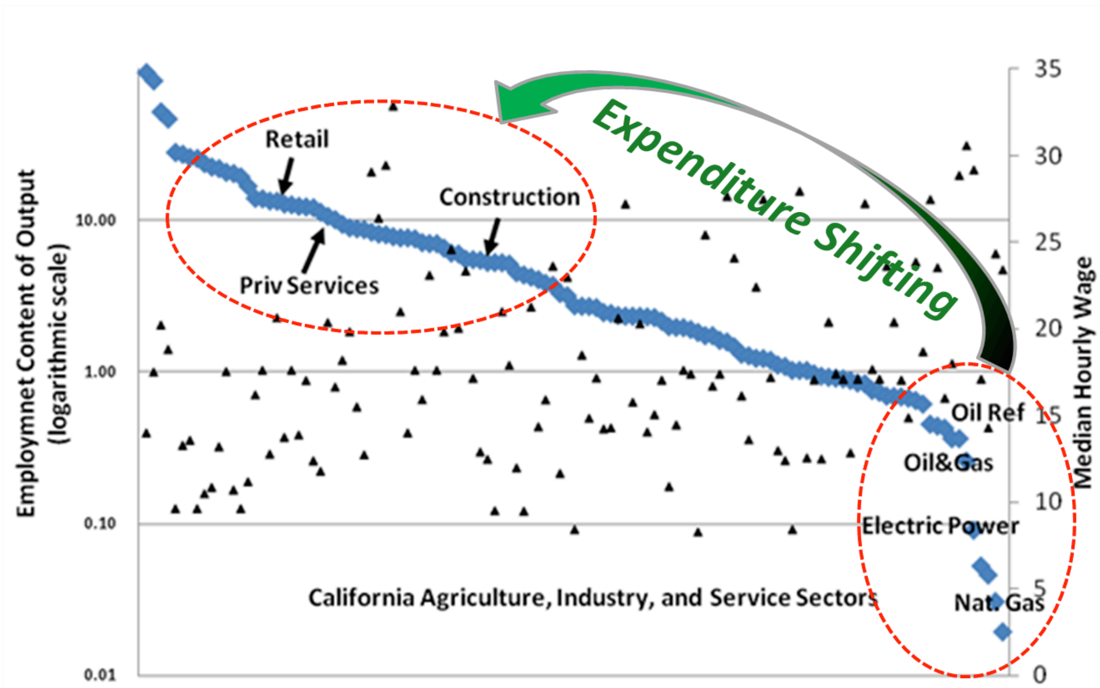
67. Within India, because these fuels divert agricultural resources, they undermine food security. This can be seen in a significant (3%) agrofood import increase and a modest (0.6%) agrofood CPI increase. Scenario 5 addresses this challenge constructively, since only moderate productivity growth would reverse this impact substantially. It must be recalled, however, that we are assuming the vast majority of biofuel, jatropha based diesel, is produced on marginal land that does not compete directly with agrofood. If this were not the case, the fuel-food impact would be much more adverse.

68. Anticipating escalating energy prices, what would then be an appropriate policy response? Many believe energy security should be achieved from the supply side, and for some renewables with significant growth potential and perhaps nuclear power this can make sense. Too much emphasis on supply side solutions, however, particularly those that recruit agricultural resources, has two disadvantages. First, eligibility of agricultural resources is constrained in a country like India because it's food capacity remains close to basic needs levels. Second, supply elasticities are further limited by such policy constraints when they confine production to marginal land. Taken together, these circumstances severely limit the efficacy of agricultural solutions to the problem of energy substitution.

69. A second approach to energy security is to recognize the rationing signal embodied in escalating energy prices and promote demand side solutions like energy efficiency. Development and diffusion of more efficient technologies may entail costs, but the benefits are far reaching and lasting. Even with modest improvements, like 1 percent annually, energy efficiency can be a potent remedy for energy price shocks. The reason is illustrated in the figure below, using data from California. The conventional energy supply chain (in any country) is dramatically less employment intensive that most other consumption categories. Thus if you can save a household one rupee on energy, this money will then be diverted to customary expenditure categories (largely food and services), which can be an order of magnitude more job intensive. Moreover, efficiency moderates energy price inflation and adverse real income effects while it is creating jobs elsewhere in the economy. Thus the CPI falls and real wage and income effects are even more positive than the growth stimulus. This is a multifaceted approach to energy

security, with much greater upside potential than exploiting limited agricultural resources in a food-scarce low income economy.

Figure 8: Energy Efficiency and Employment

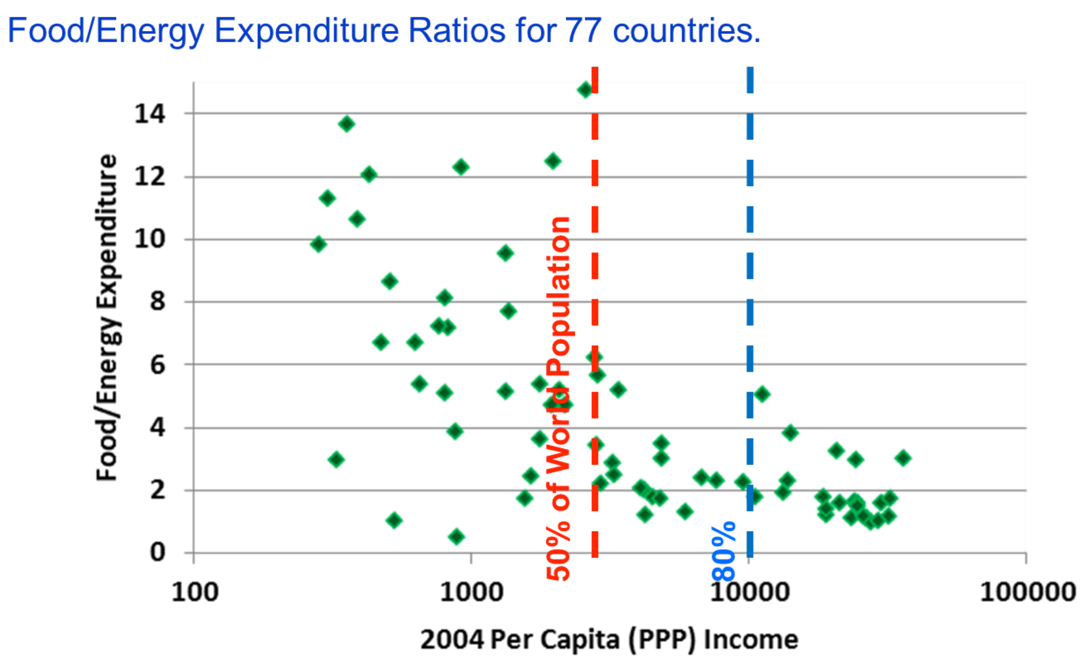


70. The demand side approach is illustrated in Scenario 3, where we assume 1% annual energy efficiency gains across the economy. While the cost/price distortion from biofuels remains in place, real incomes, consumption, and employment all rise as households and firms save money on energy. Overall trade increases in both directions, but energy imports fall even more. Food security appears to be undermined as agrofood imports increase with domestic purchasing power, but again we have assumed agrofood productivity is static. One very important gain is an 18.1% reduction in economywide GHG emissions, three times the benefit adducible to the biofuel standard. Again, with the right combination of demand and supply side policies, just one month's delay in growth over twenty years enables the economy to achieve significant climate mitigation.

71. A third line of attack, addressing both energy and food security, is captured in the last scenario, where public resources are targeted at both energy demand and agrofood supply. If energy and food security are both important policy goals, this can be partially offset by moderating price trends in other essential commodities, particularly one category with very large expenditure shares in a low income country. Figure 9 shows, for 77 countries, the ratio of agrofood to energy expenditure shares by households.

Obviously, agrofood prices are much more important to most households than energy prices. By returning to basic agrofood promotion, India can offset energy price inflation impacts on real incomes, without undermining incentives to conserve energy and thereby reduce emissions. The putative green advantage of biofuels, it should be recalled, is blunted by the downward pressure this substitute good exerts on conventional fuel prices, an unintended effect that reduces the efficiency cost of biofuel substitution but increases its environmental cost.

Figure 9: Food is More Important than Energy



Source: Author estimates, from national data sources.

72. In the last scenario, assuming just 1 percent annual agrofood productivity gains achieves dramatic overall growth. Relal GDP, consumption, employment, and all other living standard related macro aggregates rise substantially At the same time, imported agrofood dependence falls about 30%, food prices are substantially lower, and we can expect that national health indicators would improve accordingly. Energy imports still fall relative to the baseline, but somewhat less do because of economic expansion. Overall, however, we have a virtuous cycle of greater national self-sufficiency in food and energy, higher incomes and employment, lower GHG emissions, and full economic accommodation of the biofuel agenda.

73. How feasible is the last scenario? Data on other country experience with energy efficiency suggest that there is plenty of low hanging fruit for India to harvest such

improvements. For agricultural productivity, history also suggests that the right policy initiatives can do as well or better than we have assumed. As Table 3 of historical values suggests, this improvement is well within historical potential in the region. The growth effects are dramatic not only because of expansion in the primary sector of the world's second most populous economy, but because they again reverse the net effects of substantial energy price inflation. Because they are combined with energy efficiency policies, the real output gains from productivity growth lead to falling resource costs, greater international competitiveness, and even higher real incomes across India's vast low income rural sector.

74. In a very real sense then, combined policies of this kind lead to sustainable energy, environmental, and food security. Demand side solutions are promoted on the energy fuel side, where India has relatively limited market power as a supplier. This attenuates and even reverses energy price escalation, averting resource pulls to this activity that would simply promote greater energy use. At the same time, promoting productivity growth across the country's still dominant agrofood economy increases output, employment, and lowers relative prices of this essential category to substantially offset price increases in energy commodities.

Table 3: Average Annual Growth of Agricultural Output

	1970–1979	1980–1989	1990–1999	2000–2006
Sub-Saharan Africa	1.31	2.6	3.1	2.2
LatinAmerica and Caribbean	3.07	2.37	2.87	3.13
Brazil	3.83	3.73	3.29	4.41
Middle East and North Africa	2.94	3.37	2.73	2.34
NE Asia, High	2.15	1.03	-0.01	-0.01
NE Asia, Low	3.11	4.55	5.06	3.85
PRC	3.09	4.6	5.17	3.87
SE Asia	3.68	3.59	3.13	3.54
South Asia	2.56	3.39	3	2.19
India	2.69	3.52	2.94	2
North America	2.17	0.73	2.03	1.1
Oceania	1.79	1.25	2.93	-0.04
Western Europe	1.54	0.94	0.46	-0.35
Eastern Europe	1.8	0.25	-2.18	-0.19
Russian Federation	1.32	0.98	-4.62	2.7
Developing countries	2.82	3.46	3.64	3.09
Developed countries	1.88	0.86	1.21	0.39
Russian Federation and Eastern Europe	1.47	0.77	-3.88	1.81
World	2.23	2.13	2.04	2.22

Source: Jha, Roland-Holst, and Sriboonchitta (2009).

Conclusions

75. Energy is closely linked with historical prosperity, but energy dependence also confers important risks. Primary among these are global warming pollution from conventional energy use and risks to real incomes from escalating energy prices. In this report, we evaluate these issues for India from the perspective of global market forces and domestic policy responses. Generally speaking, we find convincing evidence that conventional energy prices may establish substantially higher trends over the next two decades. At the same time, however, we find that India has flexibility in addressing this challenge.

76. In particular, our analysis supports the wisdom of policy packages that combine supply side energy solutions, like biofuel development, demand side management, and inflation hedging in other essential commodities. In the former case, we show that promoting energy use efficiency can save households and enterprises money, create more jobs elsewhere in the Indian economy, and stem erosion of real incomes from more expensive imported energy or less efficient domestic substitutes, while at the same time reducing long term environmental risks.

77. A second, more indirect response to energy price inflation is to promote agrofood productivity growth. This has the primary benefit of reinforcing food security and traditional livelihoods across the country, but indirect it also disciplines prices of another essential commodity group, agrofood, which deflation can substantially or more than offset energy price inflation in the budgets of poor households. Even modest assumptions about energy efficiency and agrofood productivity gains can reverse negative shocks to per capita (PPP) incomes for the majority of India's population.

78. Most market observers agree that energy prices are on a trend of sustained increases, supported by burgeoning new demand from China and other rapidly emerging economies. On the supply side, India has little market power to stem these trends, particularly in biodiesel, where using marginal land it can at best meet 10 percent of its domestic need. Given the uncertainties associated with the strategy of developing these fuel supplies on so-called marginal demand, perhaps the government should at least in parallel consider more determined approaches to demand side management and agrofood promotion.

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APPENDIX 1 - MODEL SUMMARY

This paper uses a version of the World Bank's LINKAGE Model, a global, multiregion, multisector, dynamic applied general equilibrium model. The base data set—GTAP Version 7.0—is defined across 118 country and/or region groupings, and 57 economic sectors. For this paper, the model has been defined for an aggregation of 13 country and/or regions and 10 sectors, including sectors of importance to the poorer developing countries—grains, textiles, and apparel. The regional and sectoral concordances can be found in **Error! Reference source not found.** in the main text. The remainder of this section outlines briefly the main characteristics of supply, demand, and the policy instruments of the model.

Production

All sectors are assumed to operate under constant returns to scale and perfect competition. Production in each sector is modeled by a series of nested CES production functions that are intended to represent the different substitution and complementarity relations across the various inputs in each sector. There are material inputs that generate the input/output table, as well as factor inputs representing value added.

Three different production archetypes are defined in the model—crops, livestock, and all other goods and services. The CES nests of the three archetypes are graphically depicted in Figures A-1 through A-3. Within each production archetype, sectors will be differentiated by different input combinations (share parameters) and different substitution elasticities. Share structures are largely determined by base year data, and the elasticities are given values by the modeler.

The key feature of the crop production structure is the substitution between intensive cropping versus extensive cropping, i.e., between fertilizer and land (Figure A-1). Livestock production captures the important role played by feed versus land, i.e., between ranch- versus range-fed production (Figure A-2). Production in the other sectors more closely matches the traditional role of capital/labor substitution, with energy introduced as an additional factor of production (Figure A-3).

In each period, the supply of **primary** factors—capital, labor, and land—is usually predetermined. However, the supply of land is assumed to be sensitive to the contemporaneous price of land. Land is assumed to be partially mobile across agricultural sectors. Given the comparative static nature of the simulations that assume a longer-term horizon, both labor and capital are assumed to be perfectly mobile across sectors (though not internationally).

Model current specification has an innovation in the treatment of labor resources. The GTAP data set identifies two types of labor skills—skilled and unskilled. Under the standard specification, both types of labor are combined together in a CES bundle to form aggregate sectoral labor demand, i.e., the two types of labor skills are directly substitutable. In the new specification, a new factor of production has been inserted, which we call *human* capital. It is combined with capital to form a physical *cum* human capital bundle, with an assumption that they are complements. On input, the user can specify the percentage of the skilled labor factor to allocate to the human capital factor.

Once the optimal combination of inputs is determined, sectoral output prices are calculated assuming competitive supply (zero-profit) conditions in all markets.

Consumption and Closure Rules

All income generated by economic activity is assumed to be distributed to a single representative household. The single consumer allocates optimally his or her disposable income among the consumer goods and saving. The consumption/saving decision is completely static: saving is treated as a “good” and its amount is determined simultaneously with the demands for the other goods, the price of saving being set arbitrarily equal to the average price of consumer goods.

Government collects income taxes, indirect taxes on intermediate and final consumption, taxes on production, tariffs, and export taxes and/or subsidies. Aggregate government expenditures are linked to changes in real GDP. The real government deficit is exogenous. Closure therefore implies that some fiscal instrument is endogenous in order to achieve a given government deficit. The standard fiscal closure rule is that the marginal income tax rate adjusts to maintain a given government fiscal stance. For example, a reduction or elimination of tariff rates is compensated by an increase in household direct taxation, ceteris paribus.

Each region runs a current-account surplus (deficit) that is fixed (in terms of the model numéraire). The counterpart of these imbalances is a net outflow (inflow) of capital, subtracted from (added to) the domestic flow of saving. In each period, the model equates gross investment to net saving (equal to the sum of saving by households, the net budget position of the government, and foreign capital inflows). This particular closure rule implies that investment is driven by saving. The fixed-trade balance implies an endogenous real exchange rate. For example, removal of tariffs, which induces increased demand for imports, is compensated by increasing exports—which is achieved through a real depreciation.

Foreign Trade

The world trade block is based on a set of regional bilateral flows. The basic assumption in LINKAGE is that imports originating in different regions are imperfect substitutes (Figure A-4). Therefore in each region, total import demand for each good is allocated across trading partners according to the relationship between their export prices. This specification of imports—commonly referred to as the Armington specification—implies that each region faces a downward-sloping demand curve for its exports. The Armington specification is implemented using two CES nests. At the top nest, domestic agents choose the optimal combination of the domestic good and an aggregate import good consistent with the agent’s preference function. At the second nest, agents optimally allocate demand for the aggregate import good across the range of trading partners.

The bilateral supply of exports is specified in parallel fashion using a nesting of constant-elasticity-of-transformation (CET) functions. At the top level, domestic suppliers optimally allocate aggregate supply across the domestic market and the aggregate export market. At the second level, aggregate export supply is optimally allocated across each trading region as a function of relative prices.

Trade variables are fully bilateral and include both export and import taxes and/or subsidies. Trade and transport margins are also included; therefore world prices reflect the difference between FOB and CIF pricing.

Prices

The LINKAGE model is fully homogeneous in prices, i.e., only relative prices are identified in the equilibrium solution. The price of a single good, or of a basket of goods, is arbitrarily chosen as the anchor to the price system. The price (index) of the Organisation for Economic Co-operation and Development (OECD) manufacturing exports has been chosen as the numéraire, and is set to 1.

Elasticities

Production elasticities are relatively standard and are available from the authors. Aggregate labor and capital supplies are fixed, and within each economy they are perfectly mobile across sectors.

Equivalent Variation Aggregate National Income

Aggregate income gains and/or losses summarize the extent to which trade distortions are hindering growth prospects and the ability of economies to use the gains to help those whose income could potentially decline.

Real income is summarized by Hicksian equivalent variation (EV). This represents the income consumers would be willing to forego to achieve post-reform well-being (u^p) compared to baseline well-being (u^b) at baseline prices (p^b):

$$EV = E\left(p^b, u^p\right) - E\left(p^b, u^b\right)$$

where *E* represents the expenditure function to achieve utility level *u* given a vector of prices *p* (the *b* superscript represents baseline levels, and *p* the post-reform levels). The model uses the extended linear expenditure system (ELES), which incorporates savings in the consumer's utility function. The discounted real income uses the following formula:

$$CEV = \sum_{t=2005}^{2015} \beta^{(t-2004)} EV_t^a \;/\; \sum_{t=2005}^{2015} \beta^{(t-2004)} Y_t^d$$

where *CEV* is the cumulative measure of real income (as a percent of baseline income), b is the discount factor (equal to 1/(1+*r*) where *r* is the subjective discount rate), Y^d is real disposable income, and EV^a is adjusted equivalent variation. The adjustment to *EV* extracts the component measuring the contribution of household saving, since this represents future consumption. Without the adjustment, the *EV* measure would be double counting. The saving component is included in the *EV* evaluation for the terminal year. Similar to the OECD, a subjective discount rate of 1.5% is assumed in the cumulative expressions.

Specification of Endogenous Productivity Growth

Productivity in manufacturing and services is the sum of three components:

- a uniform factor used as an instrument to target gross domestic product growth in the baseline simulation

- a sector-specific fixed shifter which allows for relative differentials across sectors (for example, manufacturing productivity two percentage points higher than productivity in the services sectors)
- a component linked to sectoral openness as measured by the export-to-output ratio

The openness component takes the following functional form:

$$(1) \qquad \gamma_i^e = \chi_i^0 \left(\frac{E_i}{X_i} \right)^{\eta}$$

where g^e is the growth in sectoral productivity due to the change in openness, c^0 is a calibrated parameter, *E* and *X* represent respectively sectoral export and output, and h is the elasticity. The parameter c^0 has been calibrated so that (on average) openness determines roughly 40% of productivity growth in the baseline simulation, and the elasticity has been set to 1.

In agriculture, productivity is fixed in the baseline, set to 2.5% per annum in most developing countries. However, a share of the fixed productivity is attributed to openness, using equation (1).

In the baseline, GDP growth is given. Agricultural productivity is similarly given, and equation (1) is simply used to calibrate the shift parameter, c^0, so that a share of agricultural productivity is determined by sectoral openness. Average productivity in the manufacturing and services sectors is endogenous and is calibrated in the baseline to achieve the given GDP growth target. The economy-wide (excluding agriculture) productivity parameter is endogenous. Equation (1) is used to calibrate the same c^0 parameter, under the assumption that some share of sectoral productivity is determined by openness, for example 40%.

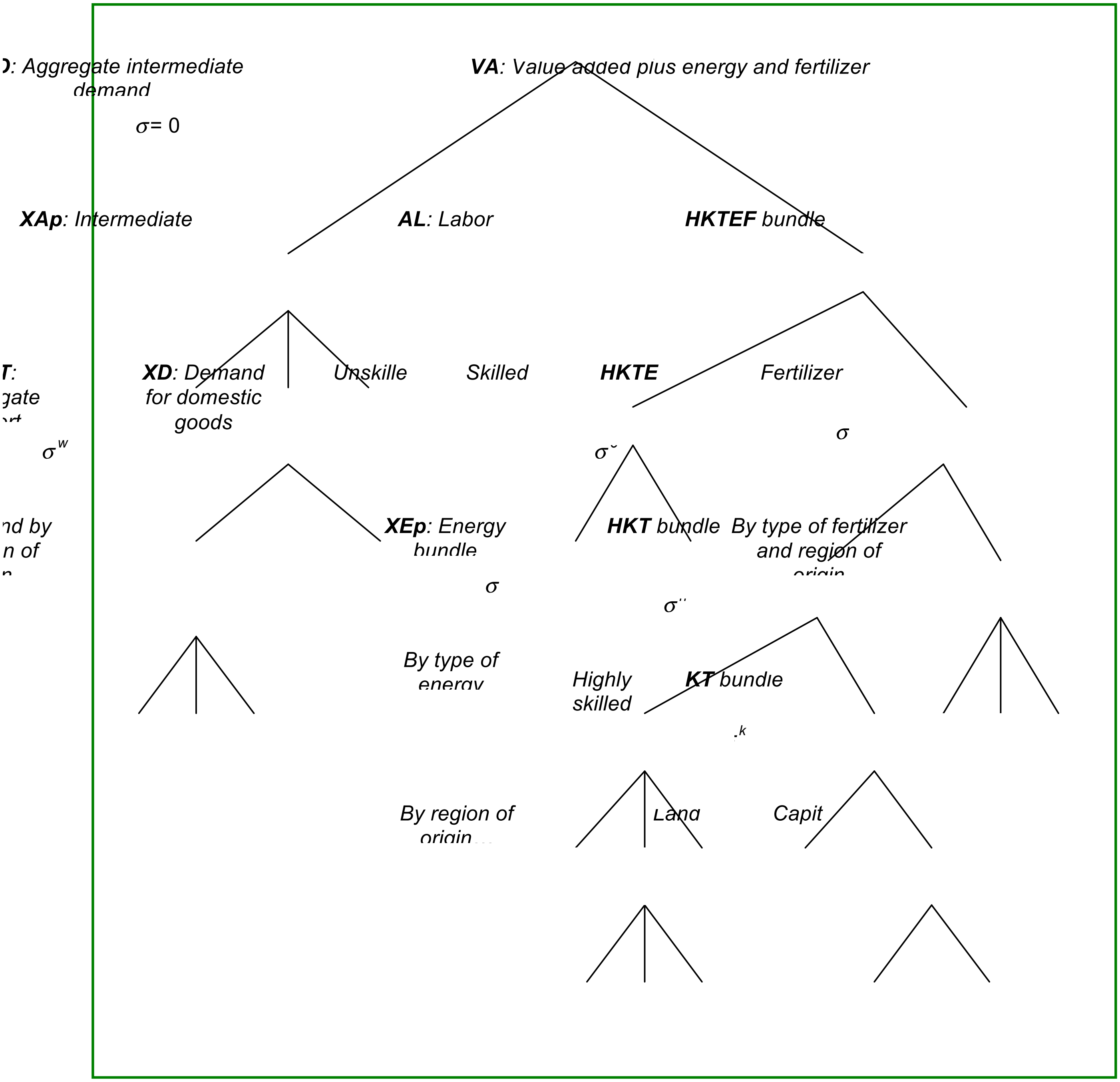
In policy simulations, the economy-wide productivity factor, along with other exogenous productivity factors (sector-specific shifters) are held fixed, but the openness-related part of productivity is endogenous and responds to changes in the sectoral export-to-output ratio. In the manufacturing and services sectors, the elasticity is set at 1. In the agricultural sectors it is set to 0.5.

Say sectoral productivity is 2.5%, and that 40% of it can be explained by openness, i.e., 1.0%, with the residual 1.5% explained by other factors. Assume sectoral openness increases by 10%. If the elasticity is 1, this implies that the openness-related productivity component will increase to 1.1% and total sectoral productivity will increase to 2.6% (implying that the total sectoral productivity increases by 4% with respect to the 10% increase in sectoral openness).

***XP**: Output*

σ^p

Figure A1.1: Production Function for Crops



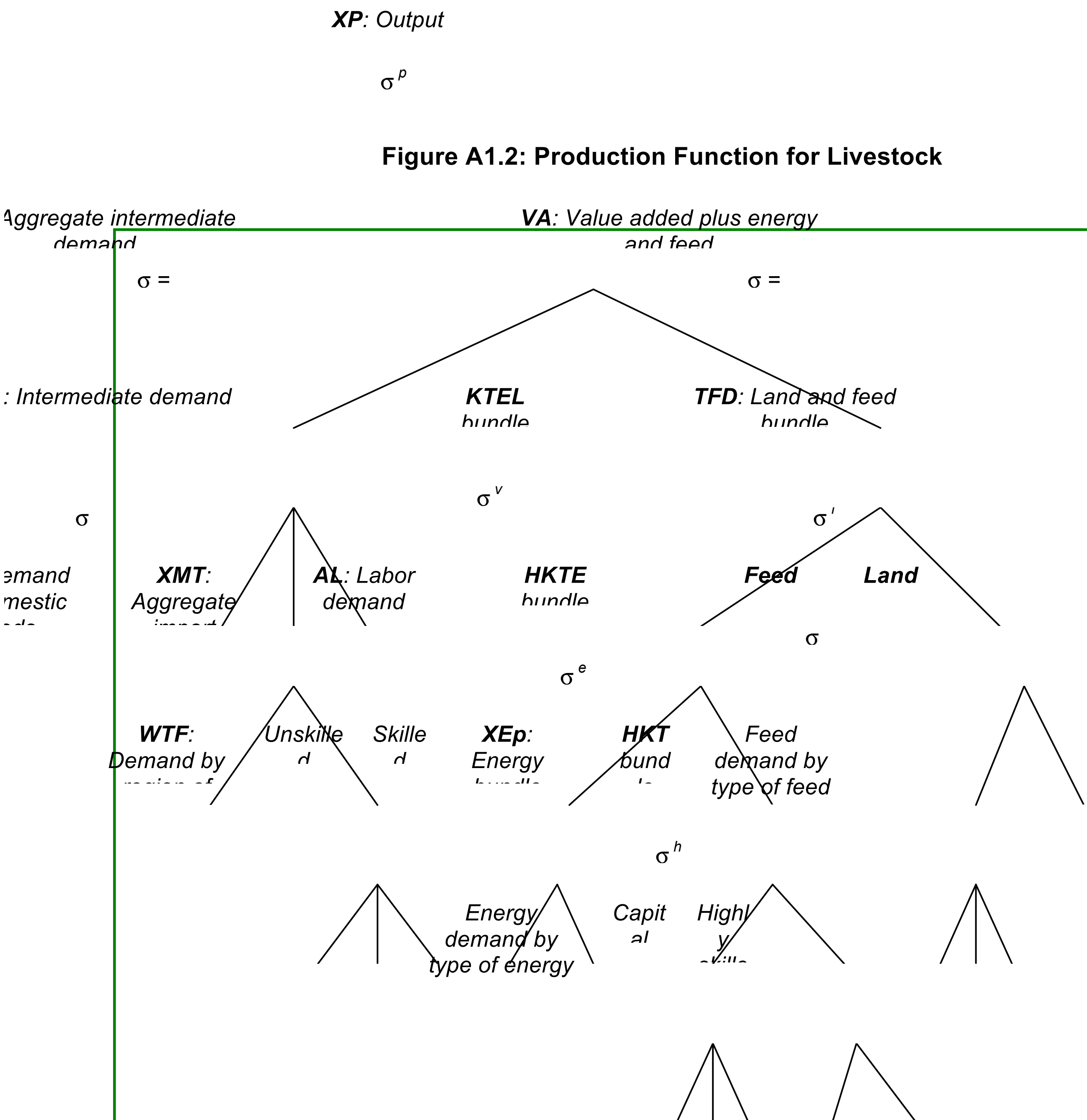


Figure A1.2: Production Function for Livestock

XP:

Figure A1.3: Production Function for Non-agriculture

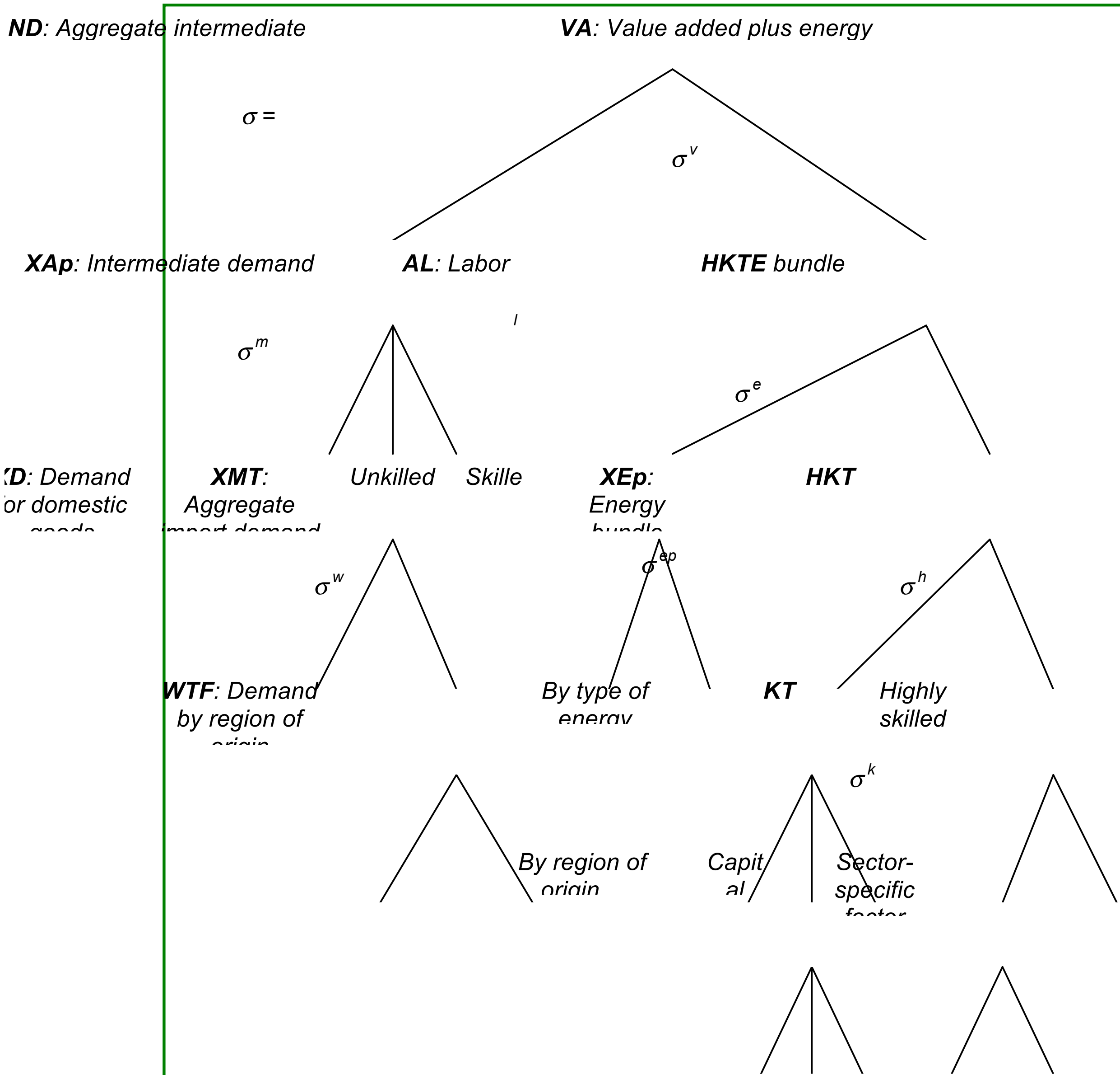


Figure A1.4: Trade Aggregation