Does the US Biofuel Mandate Increase Poverty in India?

by

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Abstract

In recent years, many countries have adopted aggressive policies that promote biofuels as a substitute for gasoline in transportation. For instance, 40% of US grain is now used in transportation. This share is expected to rise significantly under the current Renewable Fuels Mandate. In this paper, we focus on the effect of the US mandate on poverty in India. First, we use a model with endogenous land use to estimate the effect of the mandate on the world price of selected food commodities, namely rice, wheat, sugar and meat and dairy, which provide almost 70% of food calories in India, and fuel for transportation. We obtain world price increases of the order of 10% for most of these commodities. Next we estimate their price pass-through to the Indian domestic market. Finally, using household data on Indian food consumption, wages and income, we estimate the effect on welfare. We account for the positive effects of food price increases through wages and income. We show that the net impact on welfare is negative and regressive, i.e., the policy affects the poorest the most. The current mandate may create about 35 million new poor in India alone. With imperfect pass-through of world prices food markets, this number declines to 14 million. The main implication is that even if biofuel policies lead to only a modest increase in food prices, they may cause a significant increase in poverty in developing countries.

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1. Introduction

Many countries have actively promoted the use of biofuels in transportation. For example, more than 40% of US grain is now used for transportation. About 10% of US gasoline comes from ethanol produced from corn. This number is expected to rise several fold because of the Renewable Fuels Standard. The European Union, China, Brazil and other countries have similar policies that divert corn, sugarcane and other commodities from food to energy. Several studies have attributed recent food price increases to biofuel policy. However, there have been no systematic studies on their welfare impacts.

In this paper, we estimate the effect of the US biofuel mandate on poverty in India. We first use a calibration model of the world economy to predict the effect of US policy on the price of certain food crops that are critical to the Indian diet. We then use household food consumption data from India to estimate the welfare effects of these food price increases through the increase in cost of consumption and household income. Even with very modest price increases (10-12%) of crops such as rice and wheat, and accounting for the positive effects of food prices on agricultural wages and incomes, we show that the US policy will create about 35 million new poor in India alone, if world prices pass through perfectly to the domestic market. With significant government intervention and imperfect pass through, the number of new poor in India may be about 14 million.[2]

India is an important country to study because of its high incidence of poverty. According to a 2005 World Bank estimate, about 41% of the population was below the international poverty line of $1.25 a day, which amounts to nearly 437 million people. Eight Indian states have more poor people than the 26 poorest African states combined, according to the Oxford Poverty and Human Development Initiative. Most of the poor live in rural areas where 72% of the population resides. A fifth of the population suffers from malnutrition (FAO 2010). Because of its heavy dependence on imported oil, India has also embarked on an ambitious biofuel program.[3]

[2] This lower bound, of course, hides the welfare costs of intervening in the food market.
[3] Biofuel production in the country has increased rapidly, from 183 million gallons in 2005 to 285 million in 2009. Approximately 94% of the biofuel produced in India is ethanol (EIA 2011). Blending of biofuels is mandated in 10 states and its current share in transportation is 5% which is expected to rise in the near future. Concrete proposals for a target biofuel share of 26% of the transport fuel mix exist (Swarup, 2011).

Our study is unique in several respects. We use a model with endogenous supply-side adjustments to trace the effect of US energy policy on world food markets. The impacts we obtain are near the lower bound of most price estimates in the literature. We then estimate the pass-through of these prices from the world market to the Indian domestic market. Next, we compute the welfare effects on households by considering the cost of consuming these food commodities, as well as the direct impact on fuel prices. But unlike previous studies in the literature[4] we allow households to adjust their consumption basket in response to energy-induced price changes. Second, we estimate the effect of price changes on the incomes of workers. For this purpose, we use employment survey data to estimate wage-price elasticities in rural and urban India, and use the industry composition across the per capita expenditure distribution to assess the distribution of income effects across the per capita expenditure distribution. The net effects of these price increases on household expenditure are computed by simultaneously considering increase in household income and cost of consumption. Finally, we use the results of welfare analysis to estimate how US biofuel policy will affect the poverty rates in India.

We can obtain insights on who gets affected by these price changes. For instance, the impact on consumption is highly regressive, especially for rural households. The effect on wages is slightly progressive, suggesting that the poorest workers benefit from the increase in the price of these commodities since they work in the farming sector. However, households that are better off benefit relatively more through the agricultural profit effect mainly because it is the better off rural and urban households who own assets in the agricultural sector. Both the wage and income effects for rural households are an order of magnitude higher than those living in urban areas. The net effects on welfare are generally regressive with the highest level of welfare loss experienced by poorest households in both rural and urban areas. The urban and rural households that are at the high end of the expenditure distribution actually experience smaller welfare losses from this policy, mainly because they spend a small share of their budget on these commodities, but the value of their assets rises.

The model we use to predict the effect of biofuel policy on commodity prices allows for supply-side adjustments. Many other studies which focus more on the immediate impacts of diverting

[4] For example, Ferreira et al. (2011), Porto (2006) and Nicita (2009) and Ural Marchand (2012).

food to fuel predict larger price effects. We repeat the distributional analysis in order to estimate the effect of a 25% increase in the price of rice, wheat, sugar and meat and dairy products on poverty rates in India. We find that with perfect pass-through, about 85 million new poor may be created. The lower range for this number under imperfect pass-through, is 26 million. These estimates suggest that in the short-run the poverty impacts may be quite significant and are likely to decrease as adjustments take place in the economy.

In section 2, we outline the global calibration model and estimate the impacts of biofuel mandates in US and India on the price of selected food commodities. In section 3, the theoretical framework for distributional analysis is presented. Section 4 describes the estimation methodology, and presents the results on different components of welfare impacts for Indian households. Section 5 examines the impacts on poverty and section 6 concludes the paper. The details of the calibration model, as well as estimation of price pass-though and wage elasticities are presented in the Appendix .

2. A Ricardian Model

Under the Renewable Fuels Mandate, the share of biofuels in transportation in the US is expected to increase to nearly 30% share by the year 2022. Ethanol produced from corn, which is mainly used today, is mandated to increase steadily from the current annual level of 11 to 15 billion gallons by 2015. However, the bill also requires an increase in the consumption of newer cellulosic biofuels from near zero now to 21 billion gallons per year in 2022. Since we focus on the effect of the US biofuel mandate on India, we also impose the Indian mandate, which specifies a 15% share of transport fuels by 2022.[5]

In our dynamic partial equilibrium economy, three regions (US, India and Rest of the World, ROW) produce and trade five major food products (rice, wheat, sugar, other crops and meat and dairy). Rice and wheat are chosen because they are the most important cereal crops in terms of providing nutrition for the poor in India and because they consume a lot of acreage, hence most likely to be impacted from diversion of land to energy. Rice, wheat and sugar together supply

[5] However, because the US economy is several times larger than the Indian economy, the US mandate overwhelmingly dominates the results. The marginal increase in world prices because of the Indian mandate is approximately of the order of one percent (see below).

60% of all calories in India (FAOSTAT). Other crops we consider include all grains other than rice and wheat, starch crops and oil crops. Meat and dairy include all meat products and dairy such as milk and butter. These commodities compete for land that is already under farming as well as fallow land that is currently under grassland or forest cover.[6] Transport energy is supplied by a blend of gasoline and biofuels. We thus consider six final consumption goods in the model - namely the five food commodities and fuel for transportation.

Each region chooses land and energy (gasoline and biofuels) to supply transportation fuel and the five food commodities. Both the US and India impose mandates that require a certain amount of transportation fuels to be supplied by biofuels. This policy causes food grains to be diverted from food to energy and leads to the conversion of new land to farming not only in these two countries but in nations that have large endowments of arable land. World prices for the selected crops – rice, wheat, sugar and meat and dairy, increase. We only report the price increases for the year 2015. Details for the calibration model are presented in the Appendix.

US and Indian biofuel mandates

The US mandate (Energy Independence Security Act, 2007) sets the US target for biofuels at 9 billion gallons annually by 2008, increasing to 36 billion gallons by 2022. The bill specifies the use of first and second gen biofuels as shown in Figure 1. The government of India has been pursuing biofuel programs for some time in an effort to reduce its dependence on imported oil, which supplies two-thirds of consumption. The share of biofuels is expected to grow from the current share of 5% to 20% respectively in 2017 (Eisentraut 2010).

Two scenarios are defined. In the first one (benchmark scenario), no biofuel policy is implemented. This serves as the counterfactual. In the second, US and Indian biofuel mandates are introduced in the model. Under the biofuel mandates of the two countries, 20 million additional hectares of land are brought into cultivation globally. Global food production declines by about 2%. Table 1 shows the price increases in the model in year 2015 with the mandate relative to the counterfactual, expressed as a percentage. The numbers show that the effect on world food prices is modest and in any case, lower than that predicted by other studies, possibly

[6] We distinguish cereal crops from meat because these two goods have different income elasticities and producing meat is more land intensive than cereals. On average, one hectare of land produces either one ton of meat or three tons of cereals and other crops (Bouwman 1997).

because of supply-side adjustments built in our model.[7] The highest growth rate in prices is observed for wheat.[8]

Table 1: Increase in Commodity Prices due to Biofuel Policy (year 2015)

	Percentage change
Rice	7.83
Wheat	12.08
Sugar	0.84
Meat and Dairy	11.79
Other Crops	11.89
Transport Fuel	38.19

Notes: The table reports the rise in commodity prices under the regulated scenario compared to the benchmark (without biofuel policy). Both U.S. and Indian biofuel mandates are implemented.

Acreage under biofuel production in the US increases by 21 million hectares relative to no mandate in the year 2015. This represents about 12% of US cropland. Since most of this additional land is released from other crops, US production of food crops falls by about 7%. The production of ethanol in India increases by about 2 billion gallons compared to the benchmark case. This causes a modest diversion of land from food to energy production. Only one percent of cultivated land in India is allocated to energy production. Food production decreases by less than 2%. Since ethanol is produced from sugar in India, it causes a modest rise in sugar price. The main impact of the Indian mandate is felt in the gasoline market with a 38% increase in the price of fuel. However, it reduces gasoline consumption by only 6% because fuel consumption is highly inelastic.(Table 1A) The rise in the price of transport fuel price (which is a blend of gasoline and ethanol) is mainly due to a rise in the world price of ethanol because of an increase in the cost of supply.

3. Framework for Estimating Distributional Impacts

Measuring distributional impacts of biofuel policy requires comparison of the net expenditures of households before and after the price increase. In other words, it requires the estimation of

[7] These include expansion of agricultural acreage, and modest assumptions with respect to technological change in the form of yield increases in agriculture and efficiency gains in the transport sector (e.g., increased fuel efficiency in automobiles).

[8] These price increase estimates are in the lower range of most studies (REF). We also repeat the distributional analysis to estimate the effect of a larger increase (25%) in food prices.

percentage gain or loss in household welfare with respect to their net expenditure under the baseline scenario. In this paper, we estimate the negative compensating variation for each household as a percentage of their initial expenditure, and obtain a nonparametric distribution of these impacts across the per-capita expenditure spectrum. We allow households to respond to price changes by adjusting their expenditure patterns.[9] This micro-level approach adopted in this paper allows us to differentiate households in terms of their expenditure patterns, factor endowments, location, cultural attributes and the household structure. Because the biofuel policy affects the prices of certain commodities more than others, and because there are significant differences across households in terms of their consumption basket and income-generating activities, it is imperative to exploit these different levels of heterogeneity provided in the household survey. The method followed in this paper allows us to assess distributional effects by identifying which households are most affected, and by analyzing the channels through which they are affected, without losing information by aggregating the data. This is a nontrivial advantage of using a micro-level technique which has not been previously applied to assess the impact of biofuel policy, even though it is a highly debated question in the literature.

The theoretical model in this paper follows Deaton (1989), Porto (2006, 2010), Ravallion (1990), Nicita (2009) and Ural Marchand (2012). Consider the following net expenditure function:

$$B(p,u) = E(p,u) - w(p) - \pi(p) \tag{6}$$

where p is the vector of prices, $E(p,u)$ is expenditure required to reach utility level u, $w(p)$ denotes the wage income of the household and $\pi(p)$ is the profit obtained by selling agricultural products. In order to capture second order consumption effects, consider a Taylor series expansion of $B(p,u)$ around an initial price level p^0 and u^0:

$$B(p,u) = B(p^0,u^0) + \sum_i \left(\frac{\partial e}{\partial p_i} - \frac{\partial w_i}{\partial p_i} - \frac{\partial \pi}{\partial p_i}\right) dp_i + \frac{1}{2}\sum_i \sum_j \left(\frac{\partial^2 e}{\partial p_i \partial p_j}\right) dp_i dp_j. \tag{7}$$

Using the envelope theorem, $\partial e/\partial p_i$ is equivalent to the Hicksian demand at the initial price level $h_i(p_i,u) = x_i$. The compensated price elasticity of good i with respect to good j is then

[9] Other studies have adopted a more restrictive approach that compares households given a fixed consumption basket used by Ferreira et al. (2011), Porto (2006), Nicita (2009) and Ural Marchand (2012).

given by $\varepsilon_{ij} = \frac{\partial^2 e}{\partial p_i \partial p_j}\frac{p_j}{x_i}$. The term $dB(p,u) = B(p,u) - B(p^0,u^0)$ denotes the compensation the household needs in order to achieve the initial utility level u^0. When this term is positive, it is a net transfer, hence a welfare loss; on the other hand, a negative number indicates that the household is better off, thus experiencing a welfare gain. The negative compensating variation can be written as a fraction of initial expenditure as follows. Multiplying the right hand side by p_i/p_i and both sides with $1/e$ yields:

$$dlnW = -\frac{dB(p,u)}{e} = -\frac{1}{e}\sum_i \left(x_i p_i - \varepsilon_{w_i} w_i - \varepsilon_{\pi_i}\pi_i\right)\frac{dp_i}{p_i} - \frac{1}{2e}\sum_i \sum_j \varepsilon_{ij} x_i p_i \frac{dp_i}{p_i}\frac{dp_j}{p_j} \quad (8)$$

where $dlnW$ is defined as the welfare effect for the household as a fraction of their initial net expenditure, ε_{w_i} is the elasticity of wage income and ε_{π_i} is the elasticity of profits with respect to the price of good.

Each member of the household contributes to household income, which may be affected by the change in the commodity price vector. Therefore, we can express the household wage income as $w_i = \sum_h w_i^h$ and $\pi_i = \sum_h \pi_i^h$ where $h = 1, \dots, H$ represents members of the household. Equation (8) can then be simplified to:

$$\begin{aligned} dlnW = &-\sum_i \theta_i dlnp_i - \frac{1}{2}\sum_i \sum_j \theta_i \varepsilon_{ij} dlnp_i dlnp_j \\ &+ \sum_h \sum_i \theta_{w_i}^h \varepsilon_{w_i} dlnp_i + \sum_h \sum_i \theta_{\pi_i}^h \varepsilon_{\pi_i} dlnp_i \end{aligned} \quad (9)$$

where $\theta_i = x_i p_i / e$ is the expenditure share of good i, $\theta_{w_i}^h$ is the share of wage income and $\theta_{w_i}^h$ is the share of profits in the household budget contributed by member h.

It is useful to provide an interpretation of (9) at this stage. The first term on the right hand side of (9) gives the direct consumption impact from the change in the price vector, $dlnp_i$ which is induced by the introduction of biofuel policy. Households that are consumers of the basket of goods $i = 1, \dots, n$ will experience a negative impact on their budget due to the increase in their cost of consumption. This impact will be proportional to the importance of these goods in their budget, *i.e.* the budget shares θ_i. This share is computed for each household from household survey data. The second term in (9) estimates the response of households to the price increases by allowing them to adjust their consumption basket. This second order effects tend to mitigate the effect of the first-order (direct) impact on the household budget. The increase in the price of good i induces increases in the consumption of substitute goods and a reduction in the consumption of complement goods. These second order relationships between consumption goods are given by the six by six elasticity matrix ε_{ij}.[10]

The last two terms in equation (9) measure the effect of the change in commodity prices on household incomes. They enter as positive terms in the household net expenditure. All of these income changes are measured at the individual level for each member h of the household, and then aggregated up to the household level. Individuals who are affiliated with an industry i experience an increase in their wages by $\varepsilon_{w_i} dlnp_i$ where ε_{w_i} is the wage-price elasticity.[11] We estimate these elasticities by using two rounds of the Indian NSS employment survey, detailed below. The impact on household net expenditure is then proportional to the contribution of member h to the household budget, the corresponding weight given by $\theta_{w_i}^{h}$ and again computed from the surveys. A similar interpretation applies to the last term in (9) which measures the effect of price changes on the profit of household farms, although the estimation is less straightforward due to data limitations, again explained later in the paper. It is important to note that equation (9) does not include all possible sources of incomes for households and focuses only on the types of income which are likely to be affected by the price changes. For example, detailed household-level data for other sources of income, such as remittances, rents and transfers is not available and thus not incorporated in equation (9).

4. Estimation

The Consumption Response

The products that are studied in this paper, especially rice, constitute an important part of the budget for a typical Indian household. Table 2 presents the expenditure shares of commodities considered in this paper. In general, food expenditure is relatively more important, and fuel

[10] For each good there are 36 second-order terms that summarizes the behavioral response of the household. The set of elasticities used are given in Table 1A. The cross-price elasticities for fuel are set to zero as this commodity is assumed to be separable.

[11] Here, the terms *good* and *industry* are used interchangeably. We clarify the definitions in the next section.

expenditure is relatively less important for rural households. Rice has the highest share as an individual food item, followed by meat and dairy. Although the prices of wheat and sugar are impacted from the policy, they do not constitute a large share of Indian household budget. The expenditure shares of food items decreases significantly as we move from poorer to relatively better off households because the budget share of other non-food items, or relatively more expensive food items increases.

Table 2: Average Expenditure Shares of Commodities

	Rice	Wheat	Sugar	Meat and Dairy	Other Food	Fuel
Rural	0.134	0.059	0.025	0.108	0.280	0.030
Urban	0.066	0.048	0.018	0.115	0.224	0.061

Notes: Average monthly expenditure shares as a fraction of total expenditures (including non-food) are obtained from the 61st round of NSS Expenditure Survey. Sampling weights are used in estimation of the mean expenditure shares. Only purchased items are included. The "other food" category includes starchy foods, other cereal, fruits and vegetables, oil, spices and beverages.

The immediate consumption response describes the first-order, short-run impacts of the increase in food prices. In the medium to long run, there will be adjustments in the structure of the budget at the household level. Households will substitute away from food commodities that are relatively more expensive and move towards cheaper substitutes, thus mitigating the impact of the increase in prices. Some of the recent studies that analyze the effect of price changes on household welfare uses first order approximations – they do not incorporate household responses to price changes (Porto, 2006; Nicita, 2009; Ural Marchand, 2012). However, this would be a significant restriction for the purposes of this paper. Moreover, the global calibration model described earlier in the paper considers medium-run adjustments such as land-use changes, so we must allow adjustments at the household level in order to maintain temporal consistency. Table 1A in the appendix lists the own-price and cross-price elasticities used in this section.[12]

This matrix of price elasticities is then substituted for ε_{ij} into equation (9) to obtain the consumption impact for each household. Therefore, each household is affected by a price change

[12] We initially tried to estimate a quadratic demand system in order to obtain the elasticities. However, that turned out to be problematic as some categories are narrowly defined (e.g., sugar), while others are much more aggregated (e.g., other food).

in good i proportional to the budget share of good i, as well as a price change for good j that depends on the extent of substitution between goods i and j. The household consumption effect CE can be written as:

$$CE = -\sum_{i} \theta_i dlnp_i - \frac{1}{2}\sum_{i}\sum_{j} \theta_i \varepsilon_{ij} dlnp_i dlnp_{j.} \tag{10}$$

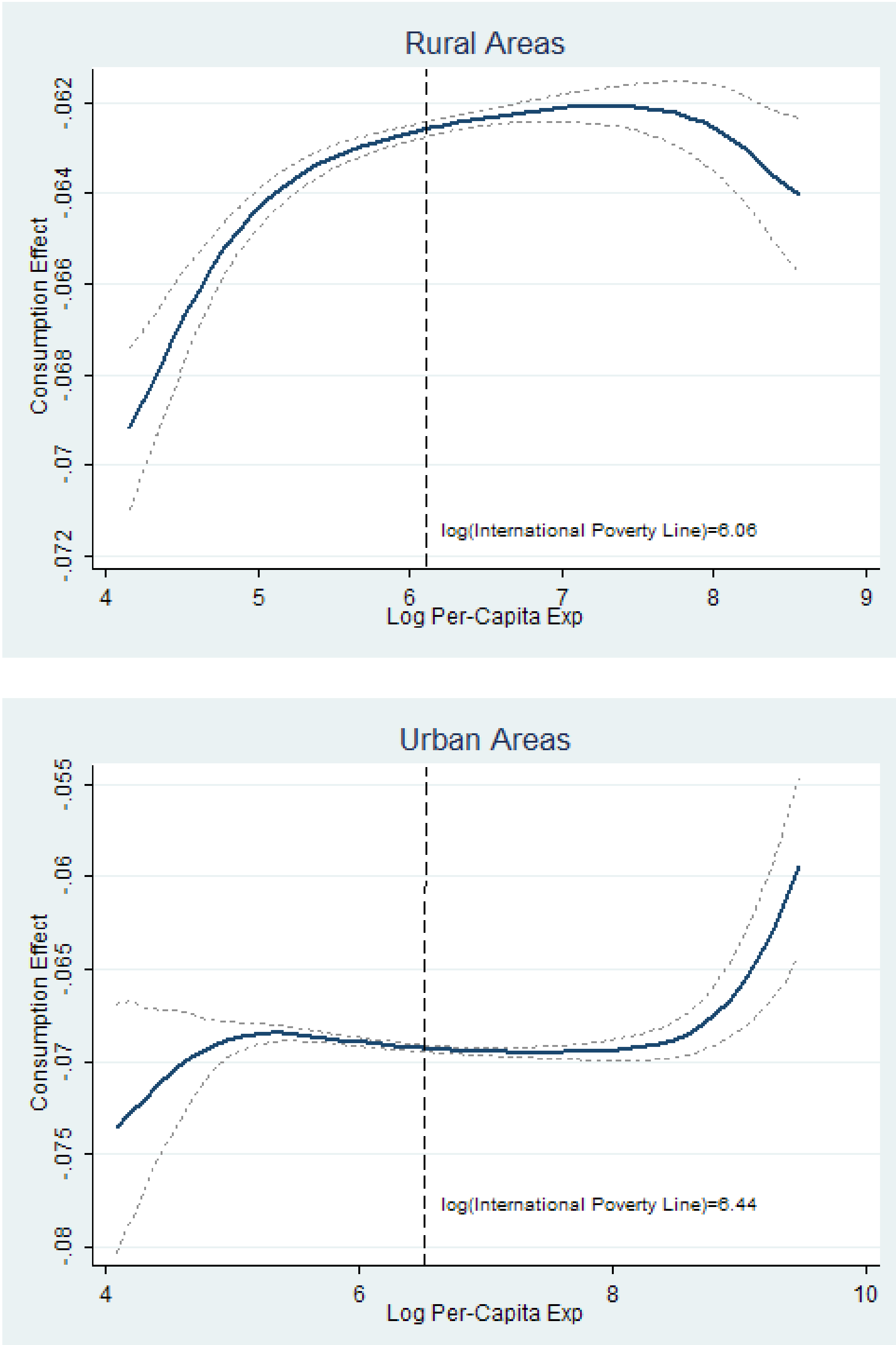
In order to analyze the distribution of consumption effects across households with different income levels, we estimate a nonparametric local linear regression. At each point in the expenditure distribution, the following expression is minimized for parameters a and b:

$$\sum_{k} (dlnW_k - a - bx_k)^2 K\left(\frac{x_k - x}{s}\right) \tag{11}$$

where x_k is the log of per capita expenditure for household k, $K(.)$ is the Epanechnikov kernel function, and s is the bandwidth. The parameters a and b define the linear relationship between the consumption effect CE_k and expenditure x_k within each neighborhood around the evaluation point x, where the size of the neighborhood is defined by the bandwidth. As the bandwidth increases, the neighborhood contains a wider segment of the expenditure scale and the estimated line becomes smoother, hence it is also called the smoothing parameter. The procedure uses the kernel function to determine the weights in the estimation of the average welfare effect at each evaluation point. The Epanechnikov kernel function is chosen as it provides the most consistent estimates (Lee and Racine, 2007). This method is used for distributional analysis because it does not require an assumption about the functional form and allows the data to determine the shape of the consumption response function over the per capita expenditure spectrum.

The results are presented in Figure 3 separately for rural and urban areas in India. For each household, the x-axis represents the log per capita expenditure and the y-axis shows the percentage welfare loss due to policy induced increase in cost of consumption. The solid line present the nonparametric estimates of the average consumption effects at each point of the expenditure scale, and the dashed lines show the 95 percent confidence intervals. The results suggest that the highest welfare loss due to increase in cost of consumption was experienced by the households at the lowest end of the per capita expenditure distribution in both rural and urban areas. This is mainly due to higher expenditure share of food among these households.

Figure 3: Consumption Effects in Rural and Urban Areas



The consumption effect is regressive in both rural and urban areas, with the exception of the middle-expenditure households in urban areas. In rural areas, the second-order estimate on the left side of the expenditure scale is about –6.9 percent and monotonically decreases to -5.9 percent as we move toward the upper-middle part on the expenditure spectrum. The magnitudes of the effects are somewhat similar in urban areas, because of lower share of food but higher share of fuel in household budget. The maximum welfare loss was -7.5 percent at the low end of the distribution, and decreased to -5.3 percent as we move toward households with higher per capita expenditure. In both rural and urban areas, the average welfare loss is higher for households below the poverty line relative to households above the poverty line.

Table 3: Composition of Welfare Loss through Consumption Effect

	Rural			Urban		
Decile	Food	Fuel	Total	Food	Fuel	Total
1	-0.0596	-0.0061	-0.0649	-0.0651	-0.0068	-0.0700
	(0.0167)	(0.0113)	(0.0187)	(0.0144)	(0.0159)	(0.0170)
2	-0.0569	-0.0074	-0.0635	-0.0624	-0.0080	-0.0685
	(0.0171)	(0.0104)	(0.0191)	(0.0127)	(0.0127)	(0.0157)
3	-0.0547	-0.0090	-0.0629	-0.0602	-0.0099	-0.0682
	(0.0171)	(0.0120)	(0.0200)	(0.0132)	(0.0139)	(0.0169)
4	-0.0525	-0.0104	-0.0622	-0.0583	-0.0124	-0.0688
	(0.0171)	(0.0133)	(0.0209)	(0.0132)	(0.0162)	(0.0188)
5	-0.0496	-0.0118	-0.0607	-0.0560	-0.0148	-0.0690
	(0.0176)	(0.0143)	(0.0218)	(0.0136)	(0.0180)	(0.0204)
6	-0.0485	-0.0132	-0.0610	-0.0539	-0.0166	-0.0688
	(0.0171)	(0.0151)	(0.0221)	(0.0135)	(0.0182)	(0.0203)
7	-0.0468	-0.0150	-0.0611	-0.0512	-0.0204	-0.0699
	(0.0173)	(0.0169)	(0.0233)	(0.0136)	(0.0196)	(0.0217)
8	-0.0446	-0.0176	-0.0615	-0.0491	-0.0230	-0.0704
	(0.0171)	(0.0195)	(0.0248)	(0.0142)	(0.0205)	(0.0224)
9	-0.0427	-0.0209	-0.0629	-0.0459	-0.0269	-0.0712
	(0.0169)	(0.0215)	(0.0264)	(0.0139)	(0.0231)	(0.0244)
10	-0.0377	-0.0266	-0.0637	-0.0375	-0.0319	-0.0681
	(0.0173)	(0.0269)	(0.0311)	(0.0149)	(0.0290)	(0.0315)
Overall	-0.0494	-0.0138	-0.0624	-0.0539	-0.0171	-0.0693
	(0.0183)	(0.0179)	(0.0231)	(0.0158)	(0.0208)	(0.0214)

Notes: Deciles are determined by the logarithm of the per capita household expenditure for each household. Standard deviations within each decile are presented in parenthesis.

These impacts can be investigated further in Table 3 which shows the distribution of the welfare loss due to the consumption effect across log per capita expenditure deciles. The results suggest that the distributional effects of food and fuel prices on the cost of consumption act in opposite directions. The households in the lowest decile are impacted the most through the cost of food, and this effect declines almost monotonically as we move towards higher deciles. On the other hand, the impact of the increase in price of fuel is lowest for the poorest households, and increases as we move up on the distribution, indicating a progressive distributional effect. The magnitude of the fuel effect is, however, smaller, leading to a regressive total consumption effect in both rural and urban areas.

Income Response

Households that are net sellers of agricultural products, as well as wage earners in these industries are expected to benefit from food price increases. Neglecting these effects may lead to a first-order bias in the estimates. The NSS Employment Survey records the industry affiliation by 5-digit NIC categories for each labor market activity undertaken by an individual. There are about 460 thousand observations for rural areas and 226 thousand observations for urban areas. Approximately 14 percent of the individuals in rural areas and 7 percent of individuals in urban areas record more than one activity. These activity-specific industry codes are matched to the food product categories used in the calibration model, namely rice, wheat, sugar, meat, other food and fuel. The matching is straightforward, and can be seen from Appendix D.

Overall, approximately 53 percent of individuals in rural areas and 15 percent of individuals in urban areas are affiliated with industries that are impacted by the price increases. The concentration of industries such as services and manufacturing are higher in urban areas, and individuals affiliated with these industries are not likely to experience changes in their incomes due to increased cost of food and fuel. Because approximately 75 percent of the population lives in rural areas, the total number of individuals impacted is almost half of the total population of the country.

Table 4 shows that a large portion of these individuals living in rural areas are in farming or crop production. In urban areas, the largest share is in transportation, although the magnitudes are relatively small. This suggests that the positive wage effects experienced by wage earners are likely to mitigate poverty impact relatively more in rural areas.

Table 4: Distribution of Employment by Sector

Decile	Crops	Sugar	Meat & Dairy	Other Food	Fuel	Other Non-food
Rural Areas						
1	41.06	0.49	2.13	3.32	1.82	51.19
2	44.76	0.53	1.97	4.12	3.78	44.84
3	43.42	0.65	1.89	4.09	4.47	45.47
4	42.96	0.58	1.64	4.07	4.56	46.18
5	41.28	0.75	1.78	4.26	5.24	46.69
6	40.56	0.77	2.05	4.63	4.66	47.33
7	40.98	0.81	1.92	4.87	4.86	46.56
8	39.40	1.03	2.05	4.96	4.00	48.56
9	38.14	1.51	1.63	5.39	3.77	49.56
10	36.73	2.00	1.41	6.04	3.49	50.33
Overall	41.29	0.83	1.87	4.46	4.08	47.47
Urban Areas						
1	5.10	0.00	1.09	0.97	4.90	87.94
2	6.76	0.06	1.24	0.92	9.33	81.69
3	6.26	0.09	1.29	1.40	10.70	80.26
4	5.04	0.03	1.38	1.46	10.48	81.62
5	5.92	0.00	1.37	1.16	10.91	80.64
6	6.04	0.05	1.40	1.29	9.85	81.38
7	4.61	0.11	1.12	0.86	9.41	83.89
8	4.57	0.10	1.32	1.06	8.15	84.80
9	3.32	0.07	0.85	1.03	6.97	87.76
10	2.10	0.12	0.57	0.92	4.76	91.53
Overall	4.60	0.07	1.10	1.08	8.17	84.98

Notes: Log expenditure deciles are determined by the logarithm of the per capita household expenditure of each individual. Employment in each of the product categories are determined by the 5-digit NIC affiliation in the principal activity of the individual. The lists of industries under each product group are given in the Appendix B. Other non-food category includes all product groups with zero change in their prices.

Income Effects

Equation (9) suggests that the effect of price changes on households will be proportional to the share of total wage income of all members of the households in total household expenditure, $\theta_{w_i}^h$. In addition, it will be proportional to the shares of agricultural profit in the household expenditure, $\theta_{\pi_i}^h$. The total income effect of the price change denoted by IE is thus given by:

$$IE = \sum_h \sum_i \theta_{w_i}^h \hat{\varepsilon}_{w_i} dlnp_i + \sum_h \sum_i \theta_{\pi_i}^h \varepsilon_{\pi_i} dlnp_i \qquad (14)$$

Some of the above terms can be directly recovered from the data. At the individual level, $\theta_{w_i}^h$ is the share of wage income of member h in industry i.These shares are then matched to the wage-price elasticity in industry i, $\hat{\varepsilon}_{w_i}$, and the predicted price increase, $dlnp_i$. This paper provides estimations of wage-price elasticities based on two rounds of NSS Employment and Unemployment Survey. The estimation methodology of these elasticities, and the results are provided in Appendix C. These individual level wage effectsare then aggregated up to the household level, incorporating differential wage effects within households at the individual level. The second term above aggregates profits across households in an analogous fashion.

Neither the NSS Employment Survey nor the NSS Expenditure Survey provides information about production in household farms. This may be an important component of household income, especially for agricultural households and given that our focus is on food commodities. In addition, it is possible that some members of the household are working for wages while others are receiving income from sales of agricultural products. Although agricultural profits are not explicitly recorded, it is possible to identify agricultural workers and their industry affiliations based on their reported activities. A worker is assumed to be an agricultural worker if the following conditions are all satisfied: he/she reports that they work as a “self-employed worker”; their reported industry code indicates that they are affiliated with an agricultural industry, but they report no wage incomes.[13] These individuals are assumed to have received their entire income from profits through agricultural activities, and their incomes will be directly affected by the increase in commodity prices.

[13] NSS data distinguishes between own-account workers and employers. We include both in our definition of an agricultural worker (i.e. usual activity codes 11 and 12).

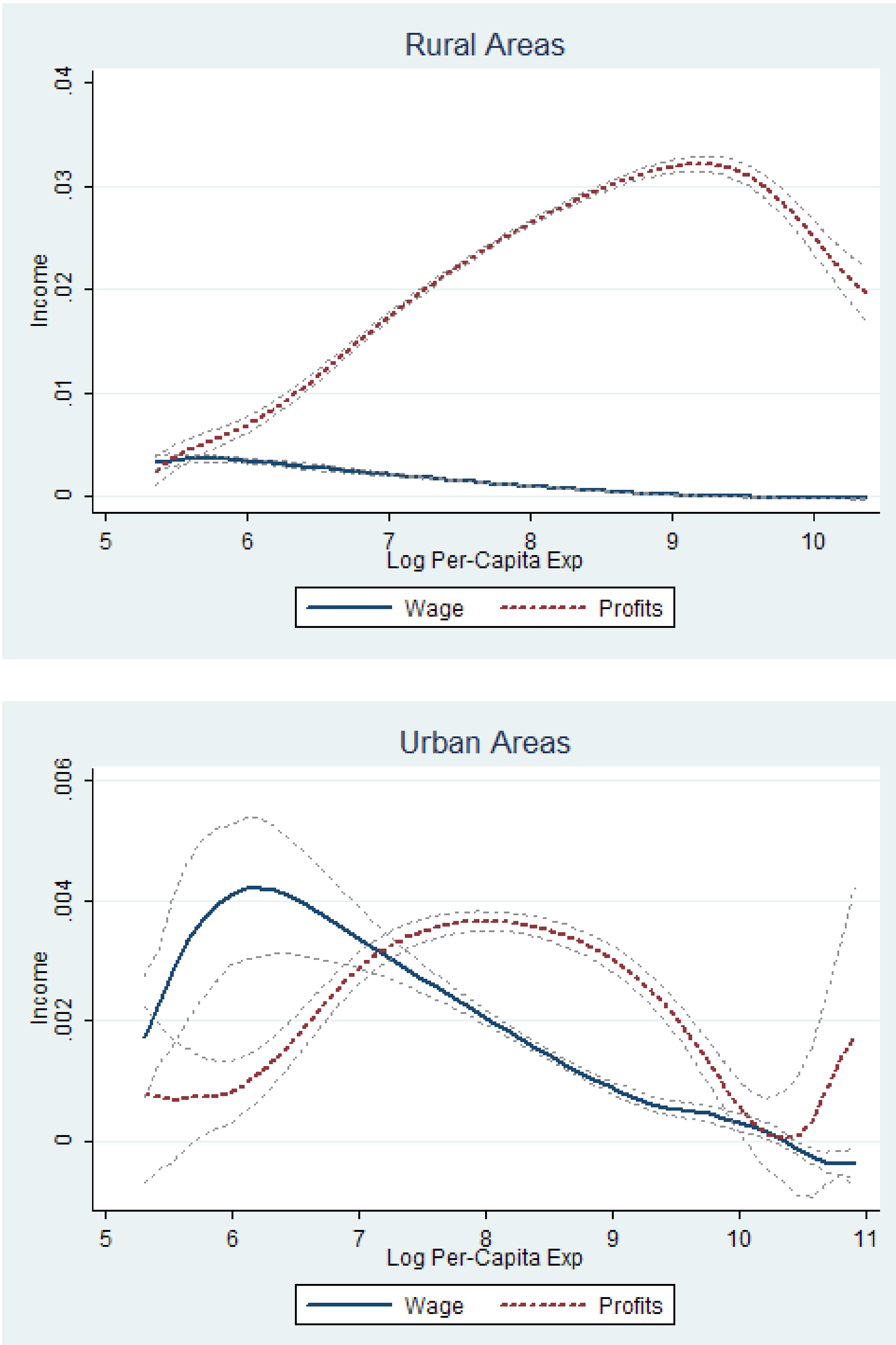
Once agricultural workers are identified, the increase in their income is assumed to be proportional to price increases, and they are aggregated across individuals for each household. That is, the income-price elasticities $\varepsilon_{\pi_i}$are set to unity and an average increase in prices $dlnp_i$ is computed within the each household to approximate the household-level increase in agricultural income. Although we cannot estimate the price elasticities for the agricultural profit channel due to data restrictions, we capture the highest possible income effect through this channel using these assumptions. This approximation is expected to give us an upper bound for the income effect through agricultural profits, and thus a lower bound for poverty effects.

The results for wage income and profits are presented in Figure 4, and are derived from local linear regressions that are evaluated at each point of the per-capita expenditure spectrum. The effect on wage incomes turns out to be pro-poor in both rural and urban areas, due to the fact that the proportion of wage-earners in agricultural industries is higher at the lower end of the expenditure distribution. The magnitude of the effect is much smaller in urban areas, although it is still pro-poor. The positive effect on profits, on the other hand, is increasing as we move to the right of the distribution. Because the proportion of individuals who own land and operate farms is higher among high per-capita expenditure households, this channel turns out to have a pro-rich effect. In urban areas, the maximum increase in profits is experienced by middle-income households. High-income urban households are mostly affiliated with manufacturing and services, and therefore, the effect on profits is relatively small at the right end of the distribution.

Net Impact of Price Changes

The consumption, wage and income effects are combined according to Equation (9) in order to assess the net effect of the US biofuel mandate. Because the impacts are different for rural and urban areas, we aggregate them separately. The distributions of these impacts from the local linear regressions conditional on per capita expenditure are presented in Figure 5. The effect is negative for all households and generally regressive both for both rural and urban areas. The poorest households experience the highest level of welfare loss. These households need to be compensated 7 percent in of their initial expenditure in rural areas, and 7.5 percent of their initial expenditure in urban areas, in order to have the same utility they have in the baseline scenario with no biofuel mandate. The effect diminishes almost linearly in rural areas as we move towards households with higher per capita expenditure. The smallest welfare loss (of 2.9 percent) at the peak of the distribution is experienced by rural households at the upper-middle section of the expenditure distribution.

Figure 4: Income Effects in Rural and Urban Areas



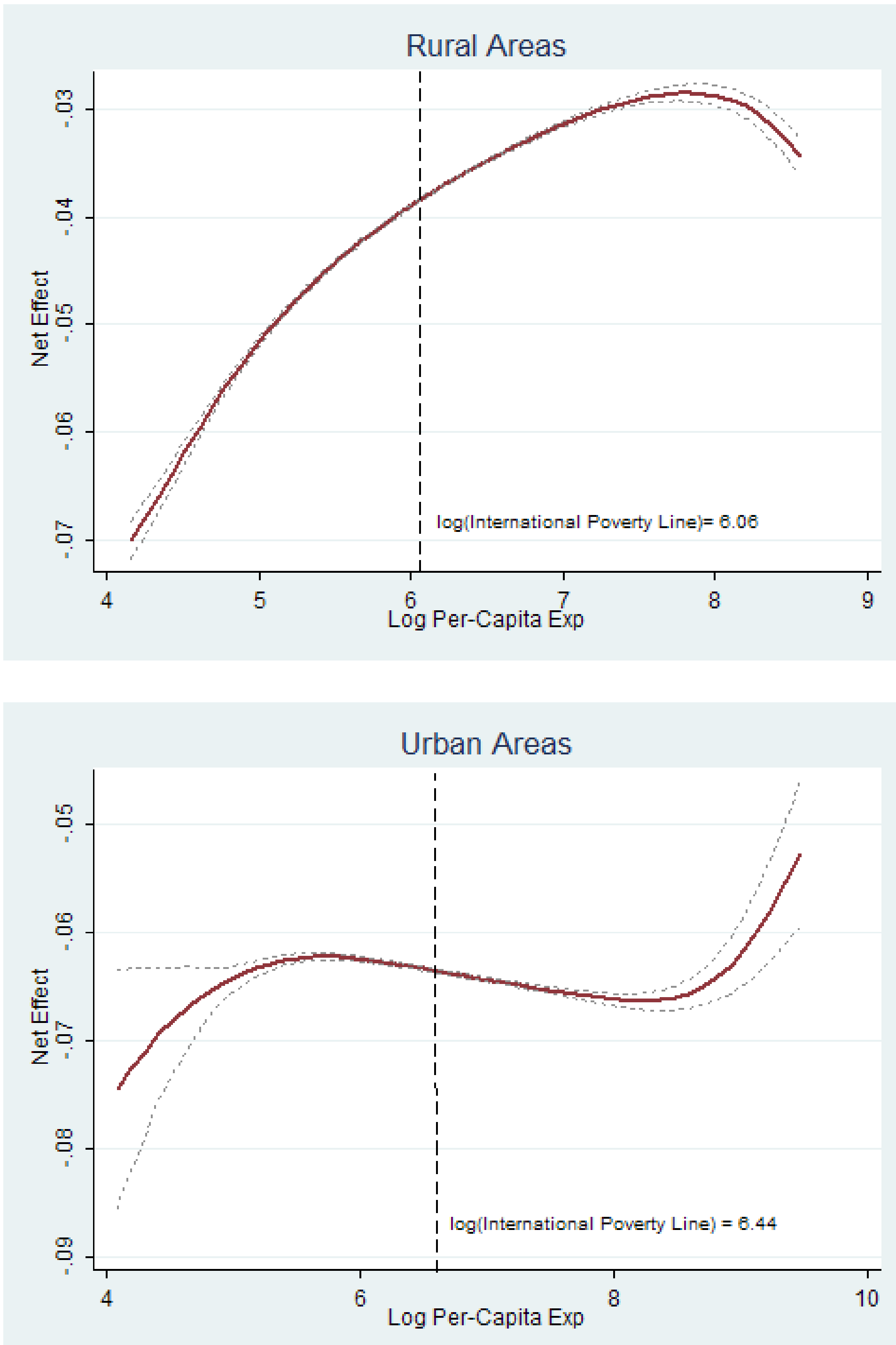
It is useful to keep it in mind that the income effects are very small for urban households, hence the distributional effects are driven by the increase in cost of consumption. Because the consumption effect is regressive through food, but progressive through fuel, these effects partly compensate each other in terms of their distribution, and lead to a relatively distribution-neutral impact for middle-expenditure households. In rural areas, we observe the regressive effect throughout the distribution due to a smaller expenditure share of fuel-related consumption. However, the magnitude of the net effect is relatively small at the highest end of the distribution, as these households tend to generate income from agricultural profits, which are expected to increase with prices. The welfare effects of profits at the high-end of the distribution are small for urban households, as more of these households work in the services and manufacturing sector.

Table 5 presents the mean net effects within each expenditure decile. The households within the lowest decile experience a 4.7 percent net loss from their initial expenditure, on average. The poorest urban households are hurt relatively more in terms of their net effects due to the higher share of transportation and other fuel-related expenditures in their budget, and less reliance on income through activities that are directly related to food and fuel. The distributional effects are regressive in both rural and urban areas, although it is somewhat muted in the middle section of the distribution in urban areas.

In order to incorporate the imperfect price transmission mechanism from world prices onto domestic prices, this paper estimates the pass-through elasticities for each commodity using time series data. The details of this estimation, as well as the results are provided in Appendix B. It is important to note that the period for which the time series data is available, between 2005 and 2011, is an unusual period with world food price crisis in 2008 and very heavy government intervention in India to the transmission mechanism. We thus interpret these results as lower bounds of welfare and poverty effects. Meat and wheat have insignificant pass-through elasticities, therefore their prices are not expected to be affected under this scenario. Because the calibration model predicts the domestic fuel price, a pass-through elasticity of unity is assigned to fuel. Therefore, under this scenario, the role of food is relatively less important compared to perfect price transmission scenario. This translates to a lower net loss estimate for rural households under imperfect transmission. For example, households in the highest decile take a

3.6 percent hit under perfect transmission but only a 0.2 percent loss under imperfect transmission. However, the net effect on urban households is reduced by a half under imperfect transmission, although it is still large.

Figure 5: Net Effect of the Price Increase



Variation in Welfare Effects

The analysis so far was based on heterogeneity across households in terms of their consumption baskets, their relative reliance on different sources of income, industry affiliation, skill endowments as well as their rural/urban location. These sources of variation, however, are expected to be correlated with other socio-economic characteristics of the households. It is possible that certain groups are impacted more or less than others due to their characteristics such as dietary practices or geographical concentration. In this section, we regress the net effect and its three components - consumption, wage income and profit on a vector of household characteristics in order to determine whether or not there are systematic distributional impacts that are a function of household characteristics. These regressions are presented in Tables 6 and 7 for rural and urban households, respectively.

The results suggest that the magnitude of welfare impacts is positively correlated with per capita expenditure of the household, that is, relatively better-off households experience smaller losses, indicating a regressive distributional effect for both rural and urban households. This is consistent with the results of the nonparametric regressions shown in Figure 5. A one percent increase in per capita expenditure is associated with a 0.92 percentage point smaller net loss for rural households and 0.12 for urban households. Although the wage income effect is generally progressive, as indicated by negative coefficient on this variable, the magnitude of the effect was smaller. The coefficient is also negative for agricultural profits, indicating a progressive effect, although the direct correlation with no control variables indicates a positive correlation.

As expected, land owners experience smaller losses.[14] A one percent increase in land ownership is associated with a 0.11 and 0.26 percentage point smaller loss for rural and urban households, respectively. Households with more land tend to gain from the increase in prices especially in rural areas, and experience smaller increases in their cost of consumption, which is indicated by a positive coefficient on this variable. For land-owning households, wage gains tend to be smaller as most of them are not wage-earners.

[14] The dependent variables are negative for the first two columns, therefore a positive coefficient indicates a smaller than average loss, ceteris paribus; while they are positive in last two columns where a positive coefficient indicates higher than average gain.

Table 5: Distribution of Net Effects

	Rural Households			Urban Households		
Decile	Decile cutoffs in rupees per capita/month	Perfect transmission	Imperfect transmission	Decile cutoffs in rupees per capita/month	Perfect transmission	Imperfect transmission
1	<306	-0.0472	-0.0216	<388	-0.0644	-0.0334
		(0.0193)	(0.0130)		(0.0179)	(0.0136)
2	306-370	-0.0425	-0.0163	388-477	-0.0619	-0.0302
		(0.0196)	(0.0126)		(0.0163)	(0.0114)
3	370-427	-0.0409	-0.0143	477-567	-0.0627	-0.0306
		(0.0204)	(0.0120)		(0.0173)	(0.0117)
4	427-485	-0.0382	-0.0113	567-675	-0.0623	-0.0295
		(0.0212)	(0.0121)		(0.0193)	(0.0126)
5	485-547	-0.0337	-0.0067	675-810	-0.0622	-0.0282
		(0.0223)	(0.0122)		(0.0209)	(0.0132)
6	547-619	-0.0322	-0.0044	810-986	-0.0634	-0.0291
		(0.0225)	(0.0121)		(0.0206)	(0.0129)
7	619-716	-0.0306	-0.0022	986-1217	-0.0639	-0.0282
		(0.0238)	(0.0130)		(0.0220)	(0.0139)
8	716-859	-0.0299	-0.0004	1217-1536	-0.0653	-0.0294
		(0.0253)	(0.0132)		(0.0226)	(0.0150)
9	859-1143	-0.0312	-0.0002	1536-2084	-0.0675	-0.0309
		(0.0269)	(0.0133)		(0.0246)	(0.0156)
10	>1143	-0.0356	-0.0019	>2084	-0.0654	-0.0295
		(0.0313)	(0.0149)		(0.0315)	(0.0165)
Overall		-0.0362	-0.0079		-0.0639	-0.0299
		(0.0242)	(0.0147)		(0.0218)	(0.0138)

Notes: Deciles are determined by the logarithm of the per capita household expenditure for each household. Net effects are estimated as in Equation 9 and incorporate wage income, profit and consumption effects. Imperfect transmission estimates are based on a price vector that is multiplied by the long-run price transmission elasticities in Table 5. Standard deviations are presented in parenthesis.

Larger households experience smaller losses, and this effect increases with size. This can be explained by the consumption effect – larger households spend a lower share on food and fuel. Households with more children are affected less overall. The wage income for these households declines with more children, but that may be due to the fact that non-agricultural households tend to have a smaller number of children, and their wages do not increase as much as the farm households. The share of females in the household is negatively correlated with wage effects for rural households, and both wage income and consumption effects for urban households.. A one percentage point increase in the share of females in the household is associated with a 0.36 and 0.58 percentage points higher net loss for rural and urban households, respectively. Productivity related characteristics of the head of the household turn out to be important determinants of who loses more from the increase in prices. Households with older heads tend to experience smaller welfare losses through the consumption channel, but this effect diminishes with his (or her) age. Somewhat counter-intuitively, more educated households experience higher losses. This effect is mainly driven by consumption impacts, and may be due to higher fuel expenditure among more educated individuals. On the income side, highly educated households gain through increase in their wage incomes, especially in urban areas, and experience smaller than average increases in agricultural profits. This is to be expected as more educated households are likely to be wage earners and less likely to generate income from farm profits.

Social characteristics of the households are also turned out to be quite significant, especially in rural areas. Tribal households experience smaller net losses, and they gain less through the profit channel relative to non-tribals, simply because they do not own significant assets. On the other hand, rural households that are members of a caste experience higher losses, while this effect is not observed among urban residents. Compared to Hindus, Muslim households are hurt significantly more while other non-Hindu households are impacted less in rural areas. Because we control for other household characteristics, these effects are likely to be driven by dietary practices and lifestyles that affect food and fuel consumption patterns.

Finally, the regional differences are more pronounced for rural households. Households living in the East and North of the country experience smaller losses, and households in the Northeast and South experience higher losses than the control group, where the control group is the households living in the Western region of the country. The effect was only significant for urban households in the North. Agricultural profit effects appear to be highest in the rural Western states, as the coefficients on other regions are negative and significant.

Table 6: Variation in Net Effect: Rural Households

	(1) Net Effect	(2) Consumption	(3) Wages	(4) Profits
Expenditure (monthly per capita, log)	0.0092***	0.0026***	-0.0004***	-0.0024***
	(0.000)	(0.001)	(0.000)	(0.001)
Household Size	0.0021***	0.0020***	-0.0001***	-0.0013***
	(0.000)	(0.001)	(0.000)	(0.000)
Land Owned (hectares, log)	0.0026***	0.0025***	-0.0002***	0.0081***
	(0.000)	(0.000)	(0.000)	(0.000)
Household Size ^2 / 100	0.0040***	0.0049***	0.0009***	0.0036***
	(0.000)	(0.001)	(0.000)	(0.001)
Share of Children	0.0013***	0.0012***	-0.0016***	0.0040***
	(0.000)	(0.000)	(0.000)	(0.001)
Share of Females	-0.0036***	-0.0032***	-0.0013***	0.0001
	(0.001)	(0.001)	(0.000)	(0.001)
Age of Household Head	0.0002***	0.0002***	-0.0000	0.0007***
	(0.000)	(0.000)	(0.000)	(0.000)
Age of Household Head ^2 /100	-0.0001***	-0.0001***	-0.0000	-0.0008***
	(0.000)	(0.000)	(0.000)	(0.000)
Education of the Household Head (control group: 'illiterate')				
Primary and Below	-0.0012***	-0.0016***	-0.0001	0.0015
	(0.000)	(0.000)	(0.000)	(0.001)
Middle	-0.0019***	-0.0025***	-0.0001	0.0001
	(0.000)	(0.000)	(0.000)	(0.001)
Secondary	-0.0045***	-0.0050***	0.0000	0.0007
	(0.000)	(0.000)	(0.000)	(0.001)
Higher Secondary and Above	-0.0103***	-0.0101***	0.0001*	-0.0070***
	(0.000)	(0.001)	(0.000)	(0.001)
Social Group of the Household (control group: 'other')				
Scheduled Tribe	0.0028***	0.0032***	0.0000	-0.0026**
	(0.000)	(0.001)	(0.000)	(0.001)
Scheduled Caste	-0.0008***	-0.0007*	0.0001*	-0.0049***
	(0.000)	(0.000)	(0.000)	(0.001)
Religion of the Household (control group: 'hindu')				
Islam	-0.0019***	-0.0020**	0.0002**	-0.0072***
	(0.000)	(0.001)	(0.000)	(0.001)
Other non-Hindu	0.0035***	0.0032**	-0.0000	-0.0095***
	(0.000)	(0.001)	(0.000)	(0.001)
Regional Indicators (control group:'west')				
East	0.0020***	0.0023	-0.0003**	-0.0016
	(0.000)	(0.002)	(0.000)	(0.002)
North	0.0018***	0.0026*	-0.0002	-0.0010
	(0.000)	(0.002)	(0.000)	(0.001)
Northeast	-0.0038***	-0.0035*	-0.0002	-0.0031**
	(0.000)	(0.002)	(0.000)	(0.001)
South	-0.0061***	-0.0053***	0.0001	-0.0042***
	(0.000)	(0.002)	(0.000)	(0.001)
Observations	78,785	78,785	74,561	74,561
R-squared	0.120	0.156	0.019	0.202

Note: Dependent variables are indicated as column names and they are defined as they enter Equation 9. Share of children is defined as the number of members in the household divided by the household size. Share of female is defined as number of female divided by the household size. Land owned by the household is the total of land owned, possessed and leased-in minus the land leased-out. The Indian Ministry of Home Affairs definitions are used for categorization of states into regions. All standard errors are clustered at the district level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Variation in Net Effect: Urban Households

	(1) Net Effect	(2) Consumption	(3) Wages	(4) Profits
Expenditure (monthly per capita, log)	0.0012**	0.0027***	-0.0012***	-0.0025***
	(0.001)	(0.001)	(0.000)	(0.000)
Household Size	0.0071***	0.0071***	-0.0009***	0.0004**
	(0.001)	(0.001)	(0.000)	(0.000)
Land Owned (hectares, log)	0.0011***	0.0011***	-0.0001*	0.0035***
	(0.000)	(0.000)	(0.000)	(0.000)
Household Size ^2 / 100	0.0064***	0.0067***	0.0051***	-0.0025**
	(0.001)	(0.001)	(0.002)	(0.001)
Share of Children	0.0007***	0.0006***	-0.0010***	0.0016**
	(0.000)	(0.000)	(0.000)	(0.001)
Share of Females	-0.0058***	-0.0053***	-0.0053***	0.0010
	(0.001)	(0.001)	(0.002)	(0.001)
Age of Household Head	0.0002***	0.0002***	0.0002***	0.0001**
	(0.000)	(0.000)	(0.000)	(0.000)
Age of Household Head ^2 /100	-0.0002**	-0.0002**	-0.0002***	-0.0002***
	(0.000)	(0.000)	(0.000)	(0.000)
Education of the Household Head (control group: 'illiterate')				
Primary and Below	-0.0010***	-0.0011***	-0.0002	-0.0012
	(0.000)	(0.000)	(0.000)	(0.001)
Middle	-0.0007*	-0.0009**	0.0007***	0.0000
	(0.000)	(0.000)	(0.000)	(0.001)
Secondary	-0.0021***	-0.0023***	0.0005*	-0.0001
	(0.000)	(0.000)	(0.000)	(0.001)
Higher Secondary and Above	-0.0058***	-0.0057***	0.0013***	-0.0029***
	(0.001)	(0.001)	(0.000)	(0.001)
Social Group of the Household (control group: 'other')				
Scheduled Tribe	0.0030**	0.0029**	-0.0003	0.0013
	(0.001)	(0.001)	(0.000)	(0.001)
Scheduled Caste	0.0003	0.0004	0.0000	-0.0018***
	(0.000)	(0.000)	(0.000)	(0.000)
Religion of the Household (control group: 'hindu')				
Islam	-0.0022***	-0.0020***	-0.0003	-0.0024**
	(0.000)	(0.000)	(0.000)	(0.001)
Other non-Hindu	-0.0012	-0.0012	-0.0006	-0.0033***
	(0.001)	(0.001)	(0.000)	(0.001)
Regional Indicators (control group: 'west')				
East	0.0017	0.0018	0.0003	-0.0048***
	(0.002)	(0.002)	(0.000)	(0.001)
North	0.0037**	0.0039**	0.0012**	-0.0035**
	(0.002)	(0.002)	(0.000)	(0.001)
Northeast	0.0014	0.0014	0.0001	-0.0031**
	(0.002)	(0.002)	(0.000)	(0.001)
South	-0.0007	-0.0006	0.0003*	-0.0034**
	(0.002)	(0.002)	(0.000)	(0.001)
Observations	44,717	44,717	31,200	31,200
R-squared	0.044	0.043	0.007	0.130

Notes: Dependent variables are indicated as column names. Consumption effect is the negative of the percentage change in cost of consumption. Share of children is the number of members in the household younger than 15 divided by the household size. Share of female is the number of female divided by the household size. Land owned by the household is the total of land owned, possessed and leased-in minus the land leased-out. The Indian Ministry of Home Affairs definitions are used for definition of regions. All standard errors are clustered at the district level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

5. The Effect on Poverty

The impact of the above price changes on poverty is analyzed by comparing the proportion of individuals below the poverty line defined by z after the policy change to the proportion before the policy change. Define the headcount ratio (HCR) as:

$$HCR = \frac{1}{N}\sum_{k=1}^{N} I(x_k \leq z) \quad (15)$$

Where N is the total number of individuals, x_k is per capita expenditure, $I(\cdot)$ is an indicator function that picks up the households for which $x_k \leq z$. After the policy change, per capita expenditures of households are impacted through adjustments in their wage incomes and profits. Households that are net producers of these goods will experience an increase in their per capita expenditure, and if they were marginally poor prior to the price increase, they may get out of poverty *ex-post* of the policy change. This may happen if the budget share of profits obtained by selling these goods, $\sum_h \theta_{\pi_i}^h$, or the wage incomes of household members affiliated with these industries $\sum_h \theta_{w_i}^h$, are relatively high. Note that there is significant heterogeneity across households with respect to these income shares. Households that profit from selling these goods are more likely to be land-owners or renters who are relatively better off. On the other hand, landless workers with low per-capita expenditures are more likely to be wage-earners in these industries.

A second effect on the poverty rate is through a shift in the poverty line z. The poverty line is the cost of consuming a certain basket of goods. An increase in the cost of consumption will therefore, proportionately move the poverty line upwards. The change in the poverty line is given by:

$$dz = \sum_i \bar{\theta}_i dlnp_i + \frac{1}{2}\sum_i \sum_j \varepsilon_{ij}\bar{\theta}_i (dlnp_i)(dlnp_j) \quad (16)$$

where $\bar{\theta}_i$ is defined as the average expenditure share of the marginal poor within a 5 percent range of the poverty line (de Janvry and Sadoulet, 2010). For poverty analysis, household expenditures are adjusted for incomes, but not for the cost of consumption. Instead, the increase in the cost of consumption is reflected in a shift in the poverty line as in de Janvry and Sadoulet (2010) and Porto (2010).

The extent to which biofuel policy affects the poverty rate depends on the expenditures of the households that are initially close to the poverty line, and change their status once prices increase. Therefore, the estimates are sensitive to the impacts on marginally poor individuals only. Although poverty analysis is a useful way to summarize the distributional impacts, it is important to recognize that poverty estimates are likely to ignore the effects on the very poor individuals, which may be significantly higher than the effects on marginally poor individuals.

Table 8 presents these results. The poverty line will increase by dz as a result of the increase in prices. This shift is proportional to the budget share of the consumption items and the cross-price elasticities which govern the rate at which households substitute across different consumption goods (see (10)). Our results suggest that the poverty line for rural households will increase by 6.7 percentage points in rural areas and 5.9 percentage points in urban areas. . Simultaneously, the incomes of agricultural workers and land owners will increase as a result of the price increase. Assuming that the expenditure shares of these commodities remain the same over time, some of the marginal non-poor households will now move below the poverty line due to the shift in the poverty line from the increased cost of consumption. Therefore, the headcount ratio (HCR) poverty rates will go up proportionately. The rural poverty rate is estimated to increase by 3.4 percentage points and the urban rate by 2.8 percentage points. As a result, 26.53 million rural individuals and 8.95 million urban individuals will move below the $1.25 international poverty line. According to the national poverty line, the corresponding number of new poor is estimated to be 26.46 million and 7.88 million, respectively. The two estimates are quite similar.

As the world prices of agricultural commodities change, India may implement policies that limit the pass-through of world prices to the domestic market. The most aggressive policies were implemented during the food price spikes in 2008. We re-estimate the poverty impacts by using the pass-through elasticities presented in Appendix B. These estimates can serve as a lower bound for poverty impacts, as they are based on costly short-term policy interventions in food markets and may not be feasible in the long run. The results are presented in the second panel of Table8. The rural poverty rate increases by 1.08 percentage points and urban poverty rate by 1.46 points, using the $1.25 poverty line. This translates into 15.54 million newly poor individuals.

Table 8: Poverty Impacts

	Rural		Urban	
	Pre-Policy	**Post-Policy**	**Pre-Policy**	**Post-Policy**
Population (millions)	883.70		410.49	
PANEL 1: PERFECT PRICE TRANSMISSION				
Poverty ($1.25, PPP)				
Poverty Line	429.00	457.50	628.00	665.08
Headcount Ratio	39.71	43.10	28.44	31.29
Number of poor (millions)	350.92	380.88	116.74	128.44
Increase in poverty rate		3.39		2.85
New poor (millions)		29.96		11.70
Total new poor (millions)		**41.66**		
Poverty (National Poverty Line)				
Poverty Line	356.30	379.97	538.60	570.40
Headcount Ratio	24.45	27.87	20.12	22.54
Number of poor (millions)	216.07	246.29	82.59	92.52
Increase in poverty rate		3.42		2.42
New poor (millions)		30.22		9.93
Total new poor (millions)		**40.16**		
PANEL 2: IMPERFECT PRICE TRANSMISSION				
Poverty ($1.25, PPP)				
Poverty Line	429.00	444.60	628.00	647.81
Headcount Ratio	39.71	40.79	28.41	29.87
Number of poor (millions)	350.92	360.46	116.62	122.61
Increase in poverty rate		1.08		1.46
New poor (millions)		9.54		5.99
Total new poor (millions)		**15.54**		
Poverty (National Poverty Line)				
Poverty Line	356.30	369.25	538.60	555.59
Headcount Ratio	24.45	25.45	20.08	21.33
Number of poor (millions)	216.07	224.90	82.43	87.56
		1.00		1.25
New poor (millions)		8.84		5.13
Total new poor (millions)		**13.97**		

Notes: PPP-corrected poverty line based on daily expenditure is obtained from the World Bank, and converted to monthly expenditure assuming 30-day months. Population projections in rural and urban areas are obtained from the United Nations, and reflect the population in 2015. Results with imperfect pass-through assumption are based on the price transmission elasticities. Changes in per capita expenditure incorporate price increases as well as wage and agricultural income increases. Poverty line increases are based on the expenditure shares of the marginal poor who are defined as households within five percent of poverty line.

The estimate with respect to the national poverty line, which is based the calorie intake of individuals, is 13.97 million.

Biofuel Policy and the Magnitude of Poverty Impacts

These poverty impacts are significant, even though the price increases we have used are quite modest – of the order of 10% for most commodities. Many studies in the literature predict larger impacts on food prices, and they may well be more accurate, especially in the short-run, when supply-side adjustments have not had a major impact. For this reason, we consider an alternative scenario, where food prices are assumed to increase by 25 percent for all the commodities we have studied in the paper, namely rice, wheat, sugar, meat and dairy and fuel. The same exercise is repeated by estimating the income effect of this price increase for each household, and estimating dz using the expenditure shares of the marginal poor. The poverty rates are then computed with and without the price increase. The results presented in Table 9. They suggest that international poverty rates increase by approximately 7 percentage points with perfect pass-through, increasing the number of poor individuals in India by 87 million. This estimate goes down to 2 percentage points with imperfect pass-through, which translates to about 27 million new poor. The estimates with national poverty lines are similar; 83 million and 25 million with perfect and imperfect pass-through, respectively.

An immediate question that arises is the role of the biofuel mandate on world poverty. How big would the numbers be? Of course, this would depend on a list of factors that may be country-specific, such as the composition of diets, domestic policies that mitigate these global impacts, domestic institutions, and initial conditions. This analysis needs to be done, but is quite beyond the scope of our research. However, a simple extrapolation of our estimates for India can be done to get some crude estimates of global poverty caused by the biofuel policy. If we combine our rural and urban estimates by using population shares as weights, the poverty rates in India are estimated to be between 1.15 and 6.78 percentage points higher than the benchmark poverty rates with no change in the biofuel policy, which correspond to between 83.77 and 493.88 million individuals globally.[15]

[15] The projected population in 2015 is 7,284 million individuals (Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects)

Table 9: Poverty Impact: 25 Percent Increase in Prices

	Rural		Urban	
	Pre-Policy	Post-Policy	Pre-Policy	Post-Policy
Population (millions)	883.70		410.49	
PANEL 1: PERFECT PRICE TRANSMISSION				
Poverty ($1.25, PPP)				
Poverty Line	429.00	457.50	628.00	665.08
Headcount Ratio	39.71	46.58	28.44	35.02
Number of poor (millions)	350.92	411.63	116.74	143.75
Increase in poverty rate		6.87		6.58
New poor (millions)		60.71		27.01
Total new poor (millions)		**87.72**		
Poverty (National Poverty Line)				
Poverty Line	356.30	379.97	538.60	570.40
Headcount Ratio	24.45	31.13	20.12	26.03
Number of poor (millions)	216.07	275.10	82.59	106.85
Increase in poverty rate		6.68		5.91
New poor (millions)		59.03		24.26
Total new poor (millions)		**83.29**		
PANEL 2: IMPERFECT PRICE TRANSMISSION				
Poverty ($1.25, PPP)				
Poverty Line	429.00	444.60	628.00	647.81
Headcount Ratio	39.71	41.37	28.41	31.36
Number of poor (millions)	350.92	365.59	116.62	128.73
Increase in poverty rate		1.66		2.95
New poor (millions)		14.67		12.11
Total new poor (millions)		**26.78**		
Poverty (National Poverty Line)				
Poverty Line	356.30	369.25	538.60	555.59
Headcount Ratio	24.45	26.10	20.08	22.73
Number of poor (millions)	216.07	230.65	82.43	93.30
Increase in poverty rate		1.65		2.65
New poor (millions)		14.58		10.88
Total new poor (millions)		**25.46**		

Notes: PPP-corrected poverty line based on daily expenditure is obtained from the World Bank, and converted to monthly expenditure assuming 30-day months. Population projections in rural and urban areas are obtained from the United Nations, and reflect the population in 2015. Results with imperfect pass-through assumption are based on the price transmission elasticities. Changes in per capita expenditure incorporate price increases as well as wage and agricultural income increases. Poverty line increases are based on the expenditure shares of the marginal poor who are defined as households within five percent of poverty line.

6. Concluding Remarks

Many countries including the US, China, India and members of the European Union have adopted policies to promote biofuels and reduce their dependence on imported oil. Most of the literature on the effect of biofuel policies has focused on estimating the effects of diverting crops away from food to energy on food prices. In general these models suggest price increases of 30% or more in the short-run, caused by the diversion of crops from food to fuel. In this paper, we use a model with differential land quality to estimate the effects of US biofuel policy on the price of selected commodities, namely rice, wheat, sugar and meat and dairy, all of which are important suppliers of nutrition in developing countries. Our framework, which allows for land-use changes in response to price increases, predicts a modest effect on world food prices, of the order of 10-12%.

More importantly, we then use these price predictions to estimate welfare effects for households in a developing country, India which has a significant part of the population below the poverty line. These estimates include both the direct negative impacts of the rise in food prices as well as the positive impacts through higher agricultural wages and farm incomes. The net welfare impacts are shown to be regressive both in rural and urban areas. The consumption effect through food expenditure is especially higher in the former since the rural poor spend more of their household budget on major food commodities such as rice and wheat. The wage effects benefit the poor since a larger proportion of them work as wage labor in the food sector. However the positive income effects mainly accrue to the rural middle and high income groups, who own most of the agricultural assets. Richer urban households tend to own more non-agricultural capital and are less impacted.

With perfect price pass-through to the Indian market, we show that about 35 million people in India may become poor, mostly those living in rural areas. However, if domestic policy prevents the pass through of world prices, then the estimates are much lower, about 14 million. Of course, interventions in the domestic market to prevent the transmission of world prices have significant welfare costs and may have their own poverty impacts.

The main point of the paper is that the effect of the US biofuel mandate may lead to an increase in the number of poor by about 14-35 million, in one major country. If one considers other developing countries in Asia and Africa, the conclusion from this analysis is that the effect of biofuel policies may be quite significant and regressive, i.e., affecting poorer people the most. We have not taken into account energy mandates adopted by other countries such as the EU and China, which may increase these estimates significantly by diverting more crops from food to energy. Both of them have significant biofuel mandates that will further raise food prices. Obviously, it is difficult to predict the welfare impacts on the poor in other countries, without a detailed analysis. But if the same percent of people become impoverished in other countries as in India, the number of new poor created globally may be much larger.

Future extensions of this work will involve estimation of the effect of these clean energy policies on malnutrition among individuals and in households. Each consumption item in the NSS data can be hand-matched to its calorie, fat and protein content using the FAO nutritional database. The biofuel policy induces a change in the price vector, and therefore alters the consumption structure for each household. Nutritional changes can be estimated by computing the nutritional intake before and after the price change. We can then estimate the number of individuals (if any) that will move below the recommended minimum daily nutritional intake and isolate its effects on segments of the population, such as women and children.

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APPENDIX

Appendix A: Data used to calibrate the simulation model

Demand for final products

Regional demands (for rice, wheat, sugar, other crops, meat and transportation fuel) are modeled using a Cobb-Douglas specification, which are functions of regional per capita income and population. Thus demand D_l for each final product l takes the form

$$D_l = A_l P_l^{\alpha_l} \prod_{-l} P_{-l}^{\alpha_{-l}} w_l^{\beta_l} N \qquad (1A)$$

Where P_l is the output price of good l in dollars, P_{-l} is the output price of goods other than good l, α_l is the regional own-price elasticity, α_{-l} is the regional cross-price elasticity, β_l is the income elasticity for good l, w is regional per capita income, N is regional population and A_l is the constant demand parameter calibrated from data.[16] Demand for food products is expressed in kilograms per capita per year while the demand for the transport fuel is in Vehicles Miles Travelled (VMT).

Table 1A reports the cross and own-price elasticities for food products in India. These elasticities are also used to estimate the distributional effects of biofuel policy (see equation 9). Demands are exogenously driven by population and per capita income. Projections of population are taken from United Nations Population Division (UNDP 2010).[17] India's population is expected to increase to around 1.3 billion people in 2015. GDP per capita is non-stationary and is assumed to increase at an exogenous and declining rate. We assume US GDP per capita to be increasing at an annual rate of 1.5%. Indian GDP per capita is assumed to rise annually by 4.5%.

Land Use

Land can be used to produce one of the five food products or to produce energy. Since land quality differs across geographical areas, we define three different land classes using the FAO-IIASA database (Fischer *et al.* 2002), based on soil and climate characteristics, land class 1 being the most productive. Data base on land classes defined by FAO-IIASA distinguishes four land

[16] Cross-price elasticities are only defined for food commodities.
[17] The United Nations (UN Population Division, 2010) defines different scenarios for future population projections. We use the medium term scenario.

classes based on their climate and soil characteristics. We only consider three land classes suitable for agricultural production. For each land class, the data base gives information on the area available as well as the yield for each crop. In addition, the definition of the land classes is conditional on the level of technology and the use of irrigation.

Crop yields are land-class specific. Available land as well as yields per land class are reported in the Table 2A. Crop production is just yield times the land area, given by $k_i^j L_i^j$ where k_i^j represents production per unit of land for use j and L_i^j is the acreage from land class i allocated to use j.

Table 1A: Own and Cross Price Elasticities for India

	Rice	Wheat	Sugar	Other food	Meat/ Dairy	Fuel
Rice	-0.20	0.10	0.05	0.05	-0.10	0
Wheat	0.10	-0.37	0.05	0.05	-0.10	0
Sugar	0.05	0.05	-0.14	0.05	-0.10	0
Other crops	0.05	0.05	0.05	-0.20	-0.10	0
Meat/Dairy	-0.10	-0.10	-0.10	-0.10	-0.20	0
Fuel	0	0	0	0	0	-0.21

Notes: Data is obtained from FAPRI, GTAP and USDA. Demand for transportation is separable from demand for food products. We assume that the cross-price elasticities are symmetric. Own-price elasticities are from Hertel *et al.* 2008 and FAPRI. Cross-price elasticities are adapted from Regmi *et al.* (2001).

Table 2A: Crops Yields by Land Class and Region (tons per hectare)

		Wheat	Rice	Sugar	Other crops
USA	1	6.8	7.1	86	4.5
	2	5.0	5.1	62	3.5
	3	2.9	3.5	45	2.5
India	1	4.0	3.2	79	2.0
	2	1.8	2.8	60	1.5
	3	1.5	3.0	42	1.0
ROW	1	2.8	4.0	70	2.2
	2	1.8	3.0	60	1.8
	3	0.8	2.0	50	0.9

Notes : The data source is FAO-IIASA.

Area under crop cultivation can be expanded by converting bringing new land under production. The initial stock of available land at $t = 0$ is denoted by $L_i^s(0)$. At each period, $l_i^s(t)$ units of new land may be brought into cultivation. The corresponding relationship is given by

$L_i^s(t) - L_i^s(t-1) = -l_i^s(t)$. The land constraint for each land class at period θ is given by $\sum_j L_i^j(\theta) \leq \bar{L} + \sum_{t=0}^{\theta} l_i^s(t)$ where $j$denotes land use. The initial global endowment of agricultural land is 1.5 billion hectares (FAOSTAT). About 1.6 billion hectares of land are available for conversion to farming, most of it located in Africa, Latin America and in Eastern Europe (FAO 2008).[18] In the US, nearly 170 million hectares (Mha) are under crop cultivation (FAOSTAT) and another 10.5 Mha is available for cultivation (Chen *et al.* 2012). In India, about 140 Mha are currently allocated to crop production. We make the plausible assumption that no new land in India is available for crop production (Ravindranath *et al.* 2011).

The cost of converting marginal lands is assumed to be increasing and convex with respect to the acreage converted. Land is brought into cultivation in the model when the endogenous land rent is higher than the cost of conversion. We adopt the same functional form as in Gouel and Hertel (2006) given by:

$$C_s = -\psi_1 \ln\left(\frac{L_i^s(0) - l_i^s}{L_i^s(0)}\right) + \psi_2 \quad \text{(2A)}$$

The parameters are region specific but independent of land class. Their values are reported in the Table 3A. We assume that once new land is converted, its productivity is the same as from land already cultivated.

Table 3A: Parameters of the cost of conversion

	ψ_1	ψ_2
USA	430	431
India	200	200
ROW	26	26

Notes : The parameters are from Gouel and Hertel (2006).

Improvements in agricultural productivity are allowed to vary by region and land category. All regions exhibit increasing productivity over time, mainly because of the adoption of biotechnology (e.g., high-yielding crop varieties), irrigation and pest management. *Ceteris*

[18] Forests under plantation or under legislative protection are not included in the model.

paribus, the rate of technical progress is likely to be lower for the lowest land quality. Biophysical limitations such as topography and climate reduce the efficiency of high-yielding technologies and tend to slow their adoption in low quality lands (Fischer *et al*. 2002).

The total cost of crop production (for food or biofuel) in each region is assumed to be increasing and convex. The higher the production, the more likely that cultivation moves into lower quality lands (van Kooten and Folmer 2004). Total production cost for product j in a given region is defined as:

$$C_j(\sum_i k_i^j L_i^j) = \eta_l \left[\sum_i k_i^j L_i^j\right]^{\eta_2} \tag{3A}$$

where $\sum_i k_i^j L_i^j$ is the aggregate output of product j, and $\eta_1$and $\eta_2$are regional cost parameters.

Transportation fuel

Energy in the model is provided by oil and biofuels. We consider an upward sloping curve for gasoline supply. Biofuel supply is region-specific, with a representative biofuel for each region. This assumption is quite reasonable since only one type of biofuel dominates in each region. 94% of production in the US is ethanol from corn (EIA 2011). In India, sugarcane ethanol is the main source of biofuel. The main producer in the ROW region is Brazil where ethanol is again produced from sugar cane. Table 4A shows the representative crop for each region and its production cost. Second generation biofuels are only available in the US. We only consider cellulosic ethanol since it has been identified as the most promising second generation biofuel in the US (IEA 2009). Since these crops are less demanding in terms of land quality, we assume that their yields are uniform across different land qualities. Around 2,000 gallons of ethanol per hectare are produced from cellulosic ethanol (IEA 2009). The unit production cost of second generation biofuels is $3.5 per gallon.[19] Transportation energy q_e is produced from gasoline and biofuels in a convex linear combination using a CES specification, as in Ando *et al.* (2010) given by:

[19] IEA (2010) defines a range for production costs for cellulosic ethanol between three to five dollars per gallon.

$$q_e = \lambda \left[\mu_g q_g^{\frac{\rho-1}{\rho}} + (1-\mu_g)(q_{bf}+q_{bs})^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho-1}{\rho}} \quad (4A)$$

Where λ is a constant, μ_g the share of gasoline in transportation energy, ρ the elasticity of substitution, and q_g, q_{bf} and q_{bs} are the respective input demands for gasoline, first generation and second generation biofuels. The parameters λ and μ_g are calibrated from observed data. The elasticity of substitution is region-specific and depends upon the technological barriers for displacing gasoline by first gen fuels in each region. We use the estimates made by Hertel *et al.* (2010).

Table 4A. Unit Cost of First Generation Biofuels

	US	India	ROW
Representative crop	Corn (94%)	Sugar (76%)	Sugar (80%)
Unit cost of production ($/gallon)	1.01	1.66	0.74

Notes: The data source for production costs (FAO 2008; Ravindranath *et al.* 2011); the numbers in parentheses are the percentage of first-generation biofuels produced from the representative crop (e.g., corn).

Appendix B: Transmission of World Prices

This section analyzes the extent to which world prices are transmitted to Indian domestic prices. Domestic policies and trade costs, such as trade barriers and transportation costs, can reduce the transmission of world prices and keep Indian households isolated from the price changes in the world market. Table 1B shows that, between January 2005 and May 2011, the percentage increases in domestic prices have been similar to that of world prices for some commodities, while there were significant deviations for other commodities. For rice and meat, the domestic price changes were somewhat similar to world prices with approximately 6 and 15 percentage point deviations, respectively. However, there were substantial differences between the increases in the world and domestic prices for wheat and sugar. This can be seen more clearly in Figure 1B which shows the price series for all four commodities. Movements in the world prices are transmitted to the domestic market but definitely not to the full extent. This suggests that the pass-through mechanism of the world prices needs to be estimated in order to incorporate this imperfect transmission mechanism that varies across commodities.

Table 1B: Price Increases of Commodities

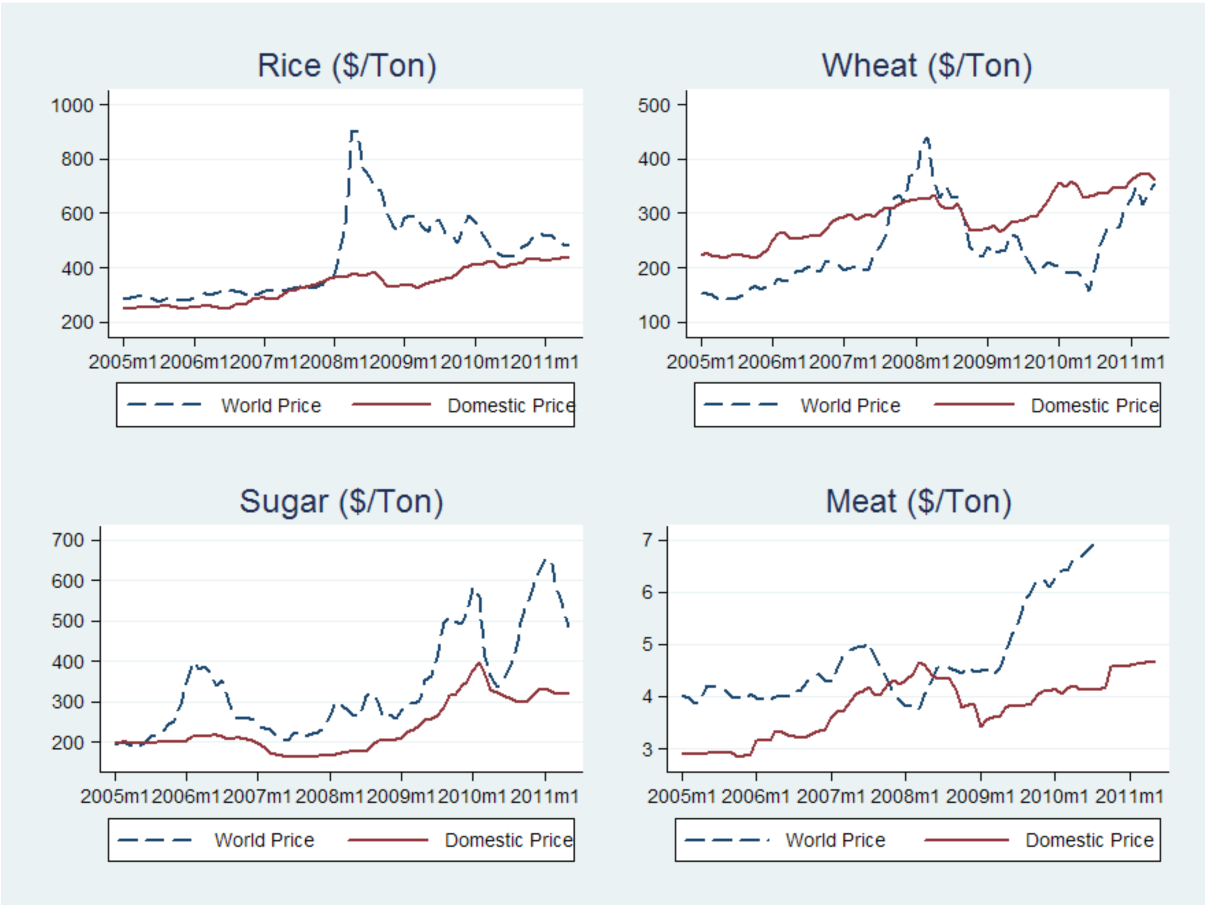
	Rice	Wheat	Sugar	Meat
World	67.74	131.31	151.72	74.33
Domestic	61.86	61.16	64.11	59.16

Notes: Domestic prices for rice, wheat, and sugar are obtained from the Indian Ministry of Public Affairs. They reflect average end-of-month prices across different regions of India. Meat prices are obtained from the Indian Ministry of Agriculture. All world prices are obtained from the World Bank Commodity Price database. The prices are first converted to USD by using the exchange rates are from the Federal Reserve Bank of India. The numbers presented in the table are between January 2005 and May 2011, the longest period available for all four commodities.

Different techniques can be used to estimate the transmission elasticity. De Janvry and Sadoulet (2010) interpret the ratio of growth rates in domestic and world prices as transmission elasticity. If we follow this approach, we find a 91.3 percent pass-through elasticity for rice. However, this approach does not control for other factors such as exchange rates and trade policy. Another method is to estimate a model in levels instead of differences (e.g. Mundlak 1993). We find higher and significant elasticities for all goods using this approach. However, Augmented Dickey-Fuller tests suggest that the price series are integrated of degree one, and therefore the pass-through coefficients estimated on levels may reflect arbitrary correlation between the series.

In addition, the Johansen test suggests that we cannot reject the null hypothesis of no cointegration for most of our series.

Figure 1B: Domestic and World Prices for Major Crops in current US Dollars



Given these considerations. the pass-through elasticities are estimated using a single equation framework, similar to the approach used by Campa and Goldberg (2005) and Campa and Minguez (2006). The estimating equation is:

$$\Delta \ln p_t^d = \sum_k \beta_k \Delta ln p_{t-k}^w + \gamma \Delta \ln(1+\tau_t) + \delta \Delta ln e_t + \varepsilon_t \tag{5}$$

where p_t^d represents the domestic price vector expressed in domestic currency (rupees) for month t; k denotes the set of lags where $k = 0,3,6,9$, and 12; p_t^w is the world price, τ_t is the tariff rate of the commodity, e_t is the exchange rate, and ε_t is an *i.i.d.* error term at time t.[20] Because the

[20] Summary statistics on domestic and world prices are reported in Table 4.

paper uses projected prices for distributional analysis, it is important to distinguish long and short term elasticities. Therefore, we include the contemporaneous change in world prices, Δlnp_t^w as well as the quarterly lags in the model, Δlnp_{t-k}^w where k denotes the lag for each quarter. The reason for choosing the quarterly lags is the dimensionality problem: given the length of our data series, it is not possible to estimate the model with all 12 lags. The short term elasticity for the commodity is thus given by the coefficient on the contemporaneous price level β_0. The long-term elasticity captures the effect within one year and is defined as the sum of the coefficients, $\sum_{i=0}^{12} \beta_i$. The results are presented in Table 2B.

The results suggest that during 2005-2011, changes in sugar and rice prices were significantly transmitted to domestic prices, although the magnitude of the pass-through transmission elasticity was small. A one percent increase in the world price of sugar led to a 0.219 percent increase in the domestic price in the short run and 0.383 percent in the long run. The magnitude of the rice transmission elasticity was also significant, but smaller in magnitude. The transmission elasticities for meat and wheat were statistically insignificant.

Table 2B: Price Transmission Elasticities of World Prices into Domestic Prices

	Short Run	Long Run
Sugar	0.219***	0.383***
	(0.043)	[16.40]
Rice	0.057***	0.181***
	(0.021)	[7.97]
Wheat	0.008	0.006
	(0.035)	[0.01]
Meat	-0.023	0.056
	(0.068)	[0.06]

Notes: Elasticity estimates are based on monthly price data between January 2005 and May 2011. Long term elasticities represent price transmission within one year. Standard errors for short run elasticities are reported in parenthesis and F-statistics for long run elasticities are reported in brackets. *** denotes p<0.01, **p<0.05 and *p<0.1.

Appendix C: Wage-Price Elasticities

The response of wage to price changes is given by:

$$w = w(p, \gamma) \tag{1C}$$

where p is the vector of commodity prices, given a set of personal characteristics γ such as education, age, marital status, or location. Since we plan to isolate the effect of prices on wages, a reduced from Mincerian wage model is estimated. The elasticity of wages with respect to prices is therefore given by $\beta = \partial lnw / \partial lnp$.

The main issue in estimating wage-price elasticities is the availability of price data that reflects the economic activity by district over time. Employment surveys often do not offer time variation that is sufficient to identify elasticities for specific product groups as they are conducted infrequently. In order to deal with this problem, we use the unit values in the 55th and 61st rounds of the NSS Household Expenditure Survey and aggregate them to the district level. We then merge these unit values with the corresponding rounds of the NSS Employment Survey by district and use them as a proxy for the price levels of each product within that district. This technique is similar to what has been used in the literature, such as Deaton (1997), Porto (2006, 2010) and Ravallion (1990).

The sub-sample on which the wage equation is estimated includes workers in the informal sector as well as self-employed individuals, such as household farm workers, who are between the ages of 15 and 65. Since our goal is to focus on the distributional aspects of labor market responses, this model is estimated for skilled and unskilled workers separately, where a skilled worker is defined as someone with at least a middle school education.[21] We estimate the following double-log model for each skill level:

$$ln\, w_{idt}^{l} = \alpha + \beta ln\ p_{dt}^{l} + \delta \gamma_{idt}^{l} + \mu_t + \varepsilon_{idt} \tag{2C}$$

where the variable $ln\, w_{idt}^{l}$ is the logarithm of the hourly wage rate of individual i in district d at time t, employed in industry l; β is the wage-price elasticity estimated for each industry l; lnP_{dt}^{l} is the logarithm of the price of product l in district d at time t and γ_{idt}^{l} is a vector of individual

[21] Estimates are largely robust to changes in the cut-off skill level to primary or secondary education. Note that approximately one third of individuals in these industries are classified as illiterate.

characteristics that includes age, age-squared as well as indicator variables for male workers, married workers, education level, the geographical region in which they are located and whether they live in a rural area. [22]

Some adjustments needed to be made for this estimation. The number of workers in the *sugar* industry is insufficient to obtain meaningful elasticities, therefore they are combined with the *other food* category. Second, the industry affiliations in the NSS survey do not distinguish between rice and wheat workers, but it classifies them under the general category called *crop production*. Therefore, these two elasticities are estimated on a common sample. Third, unit prices are not available for *fuel for transportation* as the NSS Household Expenditure Survey does not record the quantity consumed for this item. We set the wage-price elasticity for this industry to unity in order to obtain results that are as conservative as possible. However, the impact of this assumption is likely to be small due to the low number of workers employed in this industry.

The results of the wage-price estimation are shown in Table 1C. The wages of workers who are affiliated with crop production are more responsive to changes in rice prices than wheat prices. A one percent increase in the price of rice increases wages (both skilled and unskilled) by 0.68 percent, whereas a one percent increase in wheat prices increases wages by 0.37 percent for skilled workers and 0.17 percent for unskilled workers. These elasticities are estimated to be 0.16 for skilled meat and dairy workers, insignificant for unskilled meat workers and approximately 0.13 for sugar and other food workers. *Ceteris paribus*, male workers earn between 34 and 50 percent more than their female counterparts. An additional year of experience increases wages by 2 to 9 percent, whereas skilled married workers who are engaged in crop production earn 3 percent less than their unmarried counterparts. Education indicators have the expected coefficients and returns to education increase with the degree obtained (primary and secondary), for both skilled and unskilled workers.

[22] A work day is assumed to be 8 hours.

Table 1C. Results for Wage-Price Elasticity Estimation

	Rice		Wheat		Meat & Dairy		Sugar / Other	
	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled	Skilled	Unskilled
	(1)	(2)	(3)	(4)	(5)	(6)	(9)	(10)
log (price)	0.679***	0.682***	0.367***	0.172***	0.157**	0.083	0.128**	0.125***
	(0.108)	(0.071)	(0.064)	(0.059)	(0.063)	(0.056)	(0.051)	(0.035)
Male	0.358***	0.361***	0.380***	0.378***	0.391**	0.499***	0.337***	0.288***
	(0.021)	(0.011)	(0.022)	(0.011)	(0.170)	(0.069)	(0.048)	(0.038)
Age	0.025***	0.019***	0.024***	0.019***	0.091***	0.055***	0.015	0.021***
	(0.005)	(0.002)	(0.005)	(0.001)	(0.023)	(0.015)	(0.013)	(0.005)
Age-Squared	-0.000***	-0.000***	-0.000**	-0.000***	-0.001**	-0.001***	0.000	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Married	-0.035***	-0.001	-0.031***	-0.004	-0.040	-0.003	-0.026	0.003
	(0.010)	(0.004)	(0.010)	(0.004)	(0.052)	(0.032)	(0.027)	(0.010)
Below Primary		0.061***		0.057***		0.385***		0.151***
		(0.013)		(0.014)		(0.051)		(0.038)
Primary		0.095***		0.098***		0.454***		0.203***
		(0.013)		(0.013)		(0.065)		(0.039)
Secondary	0.059***		0.066***		0.064		0.084*	
	(0.019)		(0.019)		(0.075)		(0.045)	
Graduate	0.348***		0.318***		0.324*		0.688***	
	(0.070)		(0.066)		(0.187)		(0.139)	
Observations	4,881	30,141	4,879	30,139	306	1,279	933	4,422
R-squared	0.264	0.278	0.257	0.243	0.328	0.355	0.381	0.252

Notes: Regressions are based on 55th and 61th rounds of the NSS Employment and Unemployment Surveys. 5-digit NIC codes are used to determine industry affiliations, and the details are provided in Appendix D. Prices are computed using the 55th and 61th rounds of the NSS Consumer Expenditure Surveys and are defined as the average unit values of products within districts. A skilled worker is defined as a worker with at least middle school education. Illiterate individuals for unskilled regressions, middle-school educated individuals for skilled regression are used as control groups. Rice and wheat models are based on individuals who work in the industry. All regressions include a constant as well as year, rural and regional indicators. All standard errors are clustered at the district level and reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

<u>**Appendix D: Matching between Commodities, Expenditure Categories and Industries**</u>

Products	**NSS Categories**		**5-Digit NIC 1998 Categories**	
	Codes	Description	Codes	Description
(1)	(2)	(3)	(4)	(5)
Rice	101, 102	Rice	01111	Growing of food grain crops (cereals and pulses)
	103	Chira	01403	Activities establishing a crop, promoting its growth or protecting it from disease and insects. Transplantation of rice in rice fields.
	104	Khoi, lawa	01404	Harvesting and activities related to harvesting, such as preparation of crop cleaning, trimming, grading, drying.
	105	Muri		
	106	Other rice products		
Wheat	107, 108	Wheat, atta	01111	Growing of food grain crops (cereals and pulses)
	110	Maida	01403	Activities establishing a crop, promoting its growth or protecting it from disease and insects. Transplantation of rice in rice fields.
	111	Suji, rawa	01404	Harvesting and activities related to harvesting, such as preparation of crop cleaning, trimming, grading, drying.
	112	Sewai, noodles		
	113	Bread, bakery		
	114	Other wheat products		
Sugar	269	Sugar (sub-total)	01115	Growing of sugarcane or sugar beet
Meat & Dairy	160	Milk: liquid (litre)	01407	Activities to promote propagation, growth and output of animals and to obtain
	161	Baby food	01409	Other agricultural and animal husbandry service activities, n.e.c.
	162	Milk: condensed/ powder	01211	Farming of cattle , sheep, goats, horses, asses, mules and hinnies; dairy farming
	163	Curd	01212	Rearing of goats, production of milk
	164	Ghee	01213	Rearing of sheep; production of shorn wool
	165	Butter	01214	Rearing of horses, camels, mules and other pack animals.
	166	Ice-cream	01221	Raising of pigs and swine
	167	Other milk products	01222	Raising of poultry (including broiler) and other domesticated birds; production of eggs and operation of poultry hatcheries Raising of bees; production of honey
	180	Eggs (no.)	01223	Raising of bees; production of honey
	181	Fish, prawn	01224	Raising of silk worms; production of silk worm cocoons (production of raw silk is classified under class 1711) Farming of rabbits including angora rabbits
	182	Goat meat/mutton	01225	Farming of rabbits including angora rabbits

Meat & Dairy	183	Beef/ buffalo meat	01229	Other animal farming; production of animal products n.e.c. (Includes: raising in captivity of semi domesticated or wild live animals including birds and reptiles,
	184	Pork	01500	Hunting, trapping and game propagation including related service activities
	185	Chicken	05001	Fishing on commercial basis in ocean, sea and coastal areas
	186	Others: birds, crab, oyster, tortoise, etc.	05002	Fishing on commercial basis in inland waters.
			05003	Gathering of marine materials such as natural pearls, sponges, coral and algae.
			05004	Fish farming, breading and rearing including operations of hatcheries for fin an shell fish
			05005	Service activities related to marine and fresh water fisheries and to operators of
Other Food	115-122	Jowar, bajra, maize, barley, small millets, ragi and other cereal	01112	Growing of oilseeds including peanuts or soya beans
	139	Cereal substitutes: tapioca, jackfruit, etc.	01119	Growing of other crops, n.e.c. (Includes growing of potatoes, jams, sweet
	159	Pulses & pulse products	01121	Growing of vegetables
	179	Edible oil (sub-total)	01122	Growing of horticultural specialties including: seeds for flowers, fruit or
	229	Vegetables (sub-total)	01131	Growing of coffee or cocoa beans
	249	Fruits (fresh, sub-total)	01132	Growing of tea or mate leaves including the activities of tea factories associated
	259	Fruits (dry, sub-total)	01133	Growing of edible nuts including coconuts
	289	Spices (sub-total)	01134	Growing of fruit: citrus, tropical pome or stone fruit; small fruit such as berries;
	290-293	Tea and coffee	01135	Growing of spice crops including: spice leaves (e.g. bay, thyme, basil); spice
Fuel	500	Air fare	60100	Transport via railways
	501	Railway fare	60210	Other scheduled passenger land transport
	502	Bus/tram fare	60221	Other non-scheduled passenger land transport by motor vehicles
	503	Taxi, auto-rickshaw fare	60222	Other non-scheduled passenger land transport by other
	504	Steamer/boat fare	60231	Freight transport by motor vehicles
	508	Petrol	60232	Freight transport by other
	510	Diesel	60300	Transport via pipelines
	511	Lubricating oil	61100	Sea and coastal water transport
	512	School bus/van	61200	Inland water transport
	513	Other conveyance expenses	62100	Scheduled air transport
			62200	Non-scheduled air transport

Notes: The table presents NSS and NIC codes under each product group. The price vector is merged to the NSS Consumer Expenditure Survey according to the expenditure categories in column (2), and merged to the NSS Employment Survey according to the 5-digit NIC industry categories according to the column (4).