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The impact of a large rice price increase on welfare and poverty in Bangladesh*

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Abstract

This paper studies the effect of a sharp rice price increase on welfare and poverty in Bangladesh. We employ household expenditure information to estimate the welfare loss induced by the price increase. Our findings suggest that we underestimate the proportionate welfare loss for the rice producing households and overestimate that of the households who do not produce rice, if we ignore indirect effects arising from a change in household consumption and production behaviour. Our estimates further support the hypothesis of a quadratic relationship between welfare loss and permanent household income. We also demonstrate that higher rice prices either increase or decrease the poverty head-count ratio, depending on the choice of the poverty line. However, if we consider the per capita income gap as a measure of poverty, we always observe that higher rice prices unambiguously increase poverty.

JEL-Classification: O13, O53, Q12, D12, I32
Keywords: Welfare; Poverty; Rice Price Increase; Semiparametric Regression; Bangladesh

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1 Introduction

The recent experience with world food price shocks brings back the spotlight on the study of such events, especially on low-income agricultural economies. For example, between January 2007 and April 2008, the price of coarse rice in Bangladesh almost doubled (World Bank, 2010). Such an event may have a considerable negative impact on the welfare of low income households. Protecting households from the negative consequences of food price increases requires knowledge about the precise impact of price changes on welfare and poverty. At the same time, an identification of the income groups most affected requires an investigation of the relationship between welfare loss and income.

This paper studies the effect of a strong rice price increase on welfare and poverty in Bangladesh using a recent wave of household survey data. When calculating household welfare, our analysis is based on household expenditure instead of household income as the latter usually suffers from greater measurement error. We include both the direct effect of a higher rice price, which lowers the entitlement of net rice buyers and increases the entitlement of net rice sellers, as well as the indirect effect arising from the adjustment of households' production and consumption behaviour.[1] Using household expenditure as a proxy for permanent household income, we investigate its' relationship to welfare loss.[2] We further address the endogeneity of household expenditure in our model by using household non-farm income as an instrument. Finally, we analyse the impact of a higher rice price on consumption based poverty.

Studying the welfare effects of a higher rice price in Bangladesh is important for several reasons. First, the share of rice in total expenditure is very high. Second, the cross price elasticity of rice demand with respect to the price of wheat is very low, indicating little substitutability of wheat for rice (Dorosh and Shahabuddin, 2002).[3] Third, as a net importer of food grains, Bangladesh depends on imported rice for fulfilling its domestic demand (Ministry of Finance, 2012). The country also depends on the harvest for its food security. Altogether, these may make the country vulnerable to rice price shocks, originating either from international or domestic sources. Furthermore, like many other developing countries, Bangladesh exhibits a large proportion of low income households (Bangladesh Bureau of Statistics, 2012). While the majority of these low income households are net rice buyers, a

[1]The direct effect is also known as the distributional effect or the first round/order effect of a higher rice price. The rice price increase also results in some behavioural responses. In particular, it may reduce rice consumption and increase rice farming. This adjustment is known as the indirect or second round effect.

[2]By permanent household income we refer to the long-run income of the household. The advantage of using household expenditure, compared to household income, as a proxy for permanent household income, is provided in (Meyer and Sullivan, 2012).

[3]Wheat constitutes the second largest item in household food expenditure in Bangladesh.

significant proportion of them are also associated with rice farming. Hence, it is interesting to investigate how a higher rice price affects the household welfare in Bangladesh.

The literature on higher food prices and welfare losses suffers from several limitations. First, the estimates of welfare losses induced by higher food prices are usually imprecise because most studies (e.g., Deaton, 1989; Ravallion, 1990; Ivanic and Martin, 2008) only consider the first round effect. Ignoring the second round effect results in an imprecise estimate of welfare loss, particularly when the price change is large.[4] Moreover, when estimating welfare losses, most studies (e.g., Mghenyi, Myers, and Jayne, 2011; Myers, 2006) rely on a household income measure, which is typically prone to measurement error in household surveys. Second, when studying the relationship between welfare loss and household income, many studies rely on transitory rather than permanent income measures. Semiparametric models may further suffer from endogeneity (e.g., Mghenyi et al., 2011). In addition, many studies use a subjective scale to convert household income into adult equivalent income. Third, since household expenditure is a much more robust welfare measure than household income, poverty estimates usually rely on household expenditure (Ravallion, 1992). Hence, the use of household expenditure also seems appropriate for poverty comparisons. However, studies on poverty ordering/dominance (e.g., Mghenyi et al., 2011; Chen and Duclos, 2011), are mostly based on household income.[5]

This paper contributes to the literature on welfare effects of higher food prices in several ways. First, we improve the estimate of proportionate welfare loss by using household expenditure and by capturing the second round impact. Second, when analysing the relationship between welfare loss and household income, we employ a rich semiparametric modelling framework, which allows us to control for endogeneity and permits the use of household expenditure, equivalised by a semiparametrically estimated equivalence scale. Third, we analyse the impact of a higher rice price on poverty in Bangladesh, using the idea of poverty dominance in combination with household expenditure.

Our empirical analysis generates some important findings. First, using an equivalent variation measure of welfare change, we find that accounting for behavioural responses in household production and consumption is important when estimating the welfare effect of low income households. Second, we typically find a quadratic relationship between the welfare loss and permanent household income. Third, a higher rice price may either increase or decrease the poverty head-count ratio, depending on the choice of the poverty line. However,

[4]The second round effect, which is much smaller than the first round effect, may be ignored when the price change is small, resulting in a small first round effect.

[5]Poverty ordering/dominance indicates whether, for a particular class of poverty measure (such as head-count ratio or per capita income gap), the poverty level is higher or lower in one distribution compared to another.

if we consider the per capita income gap as a measure of poverty, we find that poverty increases with a higher rice price. Overall, the results based on household expenditure are more consistent with theory than those obtained from using household income.

The paper is structured as follows. Section 2 provides a description of the data. Section 3 discusses the estimation of the proportionate welfare loss. Section 4 addresses the relationship between welfare loss and household income. The impact of a higher rice price on poverty is discussed in Section 5. Section 6 concludes.

2 Data

We use the 2010 wave of the Bangladesh Household Income and Expenditure Survey (HIES) to perform our analysis. The HIES is a repeated cross-sectional household survey conducted every 3 to 5 years and is designed to generate nationally representative socioeconomic information at the household and individual level. The selection of households in the HIES uses a two-stage stratified random sampling approach under the framework of an integrated multi-purpose sample design. The HIES includes detailed regional and socioeconomic information, including data on household production, income, and consumption. The total number of households in the 2010 round of HIES is 12,240 (Bangladesh Bureau of Statistics, 2011, 2012).

Repeating the research with the 2005 round of HIES does not affect our main findings qualitatively. We prefer the results obtained from the 2010 wave for two reasons. First, some questionnaires of the survey have been modified between 2005 and 2010. Second, the 2010 HIES interviews a larger number of households and makes extensive uses of information and communication technology to reduce errors (Bangladesh Bureau of Statistics, 2011, 2012).

The data show that household expenditure shares of rice range from 11 to 20% in urban and from 18 to 29% in rural areas. There is, however, no significant variation in rice prices across divisions, indicating a well integrated rice market. Rice farming and thus the welfare effect of a higher rice price vary across regions of Bangladesh primarily due to the quality of land, climate, average land ownership, proximity to metropolitan areas, technology orientation, and input availability. Geographical factors (e.g., rainfall and soil quality) influencing rice farming appear to be similar within each division. Therefore, we conduct our analysis at the divisional level. For each division, the proportions of households producing and selling rice together with household's cultivable land holding, household income, household income from rice farming, household expenditure, and household expenditure on rice consumption are presented in Table 1, below.[6]

[6]Input costs for a particular agricultural product are difficult to identify and vary with the methodology

<insert Table 1 around here>

Household income usually suffers from measurement error which is typically severe in survey data from agrarian economies (Bhalotra and Attfield, 1998). In our data, we observe a significant number of households with negative or very low income. For example, 10% of the households in our sample report an income that is 60% lower than their consumption expenditure; for 25% of the households it is 40% lower; the income of almost 50% of the households is lower than their consumption expenditure, suggesting that the household income measure in our data is quite unreliable.[7]

3 The impact of a large rice price increase on welfare

3.1 Theoretical model

The effect of a price change on household welfare may be explained by the use of an indirect utility function.[8] Since the private savings rate of a low income country like Bangladesh is usually low, we may ignore savings in our model.[9] Consequently, we can write the indirect utility function of household i, whose income depends on the rice price p_{ir}, as follows

$$u_i \equiv v_i(p_i, x_i) = v_i[p_i, y_i + \pi_i(p_{ir})], \tag{1}$$

where for each household i, v_i is the indirect utility function, p_i is the price vector, x_i represents gross income, y_i represents non-rice income, and π_i represents income from rice farming.[10]

Since Bangladesh remains a net importer of rice until today, rice prices typically move with international rice prices. If we ignore regional variation and assume that all households face the same price, equation (1) can be written as

$$u_i = v_i[p, y_i + \pi_i(p_r)]. \tag{2}$$

Empirical studies widely use two monetary measures of welfare change, equivalent variation (EV) and compensating variation (CV). EV describes the change in the consumer's

used. Therefore, we use gross income from rice farming.

[7]See Deaton (1997) for a discussion of measurement errors in household income.

[8]Our discussion follows Deaton (1997) and Mghenyi et al. (2011).

[9]Savings in low-income countries are mostly precautionary due to inadequate income, dependency on agriculture, and absence of credit and insurance markets (Rosenzweig, 2001). Hence, expenditure levels of low-income households deviate only marginally from income levels.

[10]The validity of such a utility function rests on the assumption of perfect substitutability between household and hired labour in family farms. Assuming separability of goods and leisure in preferences is a standard practice (Deaton, 1997) and makes the model tractable for our analysis.

net wealth that would have an equivalent welfare impact as the price change. CV describes the amount of income compensation required to keep the consumer as well off after the price change as she was before (Mas-Colell, Whinston, and Green, 1995). We employ the EV measure that is based on the initial price vector for estimating changes in welfare. Our conclusions, however, remain unchanged if we use the CV measure instead.[11]

With the utility function in (2), the EV measure of welfare loss for an individual i due to a rice price increase is given by

$$EV_i = e(p^0, u_i^1) - e(p^0, u_i^0), \tag{3}$$

where p^1 and p^0 represent the aggregate price vector with and without a change in the rice price; $e(p^k, u_i^j)$ denotes the minimum expenditure required to achieve a utility u_i^j at price p^k, while $u_i^0 = v_i[p^0, y_i + \pi_i(p^0)]$ and $u_i^1 = v_i[p^1, y_i + \pi_i(p^1)]$ measure indirect utility with associated prices and income.

With m_i denoting the proportional change in household i's welfare, we define EV_i as a proportional EV measure such that $EV_i \equiv m_i e(p^0, u_i^0)$. Hence, we can write (3) as

$$(1 + m_i)e(p^0, u_i^0) = e(p^0, u_i^1). \tag{4}$$

Therefore, at price p^0, the expenditure levels in (4) provide identical utility, implying that

$$v_i[p^0, (1 + m_i)e(p^0, u_i^0)] = v_i[p^0, e(p^0, u_i^1)] = u_i^1. \tag{5}$$

Now, from the definition of u_i^1 and using the fact that $e(p^0, u_i^0) = y_i + \pi_i(p^0)$, we get

$$v_i\left\{p^0, (1 + m_i)[y_i + \pi_i(p^0)]\right\} = v_i[p^1, y_i + \pi_i(p^1)]. \tag{6}$$

Taking a second-order Taylor approximation of (6) at $(p^1, m_i) = (p^0, 0)$, using Roy's identity and Hotelling's lemma, and solving for m_i yields

$$\begin{aligned} m_i \approx\ & (s_i^s - s_i^d)\lambda - 0.5[s_i^s \xi_i^{ps} - s_i^d \xi_i^{pd}]\lambda^2 + \\ & 0.5\{(R_i - \xi_i^{yd})[(s_i^d)^2 - 2s_i^d s_i^s] + R_i(s_i^s)^2\}\lambda^2, \end{aligned} \tag{7}$$

where for each household i, s_i^s denotes the share of rice farming in total income and s_i^d denotes the proportion of expenditure on rice to total income; λ is equal to $(p^1 - p^0)/p^0$; ξ_i^{ps}, ξ_i^{pd}, ξ_i^{yd} and R_i denote the price elasticity of rice supply, the price elasticity of rice demand, the income elasticity of rice demand, and the coefficient of relative risk aversion (CRRA),

[11] The derivation of the welfare change with the CV measure is discussed in Appendix A.

respectively.[12] The first part on the right hand side of equation (7) constitutes the first round effect, whereas the remaining parts denote the second round effect of a change in the rice price on household welfare. Equation (7) reveals that the proportionate welfare loss caused by a higher rice price does not only depend on the surplus rice farming status, but also on other behavioural parameters.

Our estimates of the welfare impact of a price change include both the first round effect (or the immediate effect on the entitlement of households) as well as the consumption and production response to price changes, the second round effect. An analysis that is based entirely on the first round effect is appropriate if the price change is small or if other parameters in (7) do not differ between households. Typically some parameters differ between urban and rural households and therefore limiting the analysis to the first round impact may produce an imprecise estimate of the individual welfare loss if the price change is large.

3.2 Methodology

In our analysis, we employ an innovative approach of calculating the welfare loss caused by a higher rice price. In contrast to previous studies such as Mghenyi et al. (2011), we use household expenditure instead of household income which is likely to suffer from measurement error, to estimate the welfare loss. Household expenditure in our data is also less variable than household income. In addition, we capture the second order welfare effect of a price increase, while previous studies typically focus only on the first order impact. To capture the second order welfare effect of the rice price increase, we use base values for the price elasticity of supply (ξ_i^{ps}) and the price elasticity of demand (ξ_i^{pd}) of 0.30 and 0.45, respectively. In case of the income elasticity of demand (ξ_i^{yd}), we assume a value of 0.60 for rural households, and 0.40 for urban households. In addition, throughout the analysis, we use a value of 1.0 for the coefficient of relative risk aversion, CRRA (R_i).[13] Values for these parameters are taken from World Bank (2010). Our entire analysis of welfare changes is based on a 50% rise in the rice price, as such a high price rise, while not unprecedented, is necessary to demonstrate the contribution of the second round effect on welfare loss.

3.3 Results

Households' proportionate welfare losses (m_i) across divisions are presented in Table 2. Means of the first round proportionate welfare loss in Rajshahi and Rangpur, which are

[12] The second-order Taylor approximation is provided in Appendix B.

[13] The second round impact is lower for lower values of CRRA. However, CRRA values do not affect our conclusions qualitatively.

characterized as rice exporting divisions, are much lower than those of other divisions. The second round proportionate welfare changes are a significant proportion of the first round welfare change, varying from 9 to 17%. For most of the divisions, the second round impact offsets part of the welfare lost in the first round. However, the second round impact intensifies the proportionate welfare loss in Rajshahi and Rangpur. Therefore, any analysis based entirely on the first round impact underestimates the proportionate welfare loss for the rice exporting divisions, and overestimates that of other divisions. However, we find a lower proportionate welfare loss among households in rice exporting divisions, indicating that households associated with rice production suffer least from the rice price increase. Importantly, using household income generates a similar but proportionately higher second round impact.[14]

<insert Table 2 around here>

4 Relation between income and welfare loss

4.1 Empirical model

When analysing the relationship between income and welfare loss, studies like Deaton (1989) typically follow a nonparametric technique assuming independence between income and other explanatory variables. To relax the restriction of statistical independence of household income, Mghenyi et al. (2011) use the following semiparametric regression model

$$m_i = F(x_i) + Z_i\beta + u_i, \tag{8}$$

where for each household i, m_i represents the proportionate welfare change, x_i represents adult equivalent income, Z_i is a vector of demographic and socioeconomic variables that enter the model linearly, β is a vector of parameters, F is an unknown function, and the error term $u_i \sim NID(0, \sigma^2)$.

In our model, we employ explanatory variables such as the electricity connection status, mobile phone ownership, suffering from a disaster, expenditure on chemical fertilizer, expenditure on pesticides, and input expenditure on fuel and electricity.[15] Some studies also control for the highest number of years of education in the household, which may be inappropriate in our specification because the returns to education can be non-linear. Therefore,

[14] Results are available from the author upon request.

[15] Suffering from a disaster may be endogenous when it is self-reported. Nevertheless, specifying the disaster type in the questionnaire reduces the likelihood of a simultaneous relation between the welfare loss and reporting a disaster.

we consider dummies for educational categories for household heads and spouses.[16] Means and standard deviations of the independent variables in the model are presented in Table 3 below.

<insert Table 3 around here>

4.2 Methodology and Semiparametric regression

We make several methodological changes to the approach of Mghenyi et al. (2011) when studying the relationship between welfare loss and household income. First, since we are interested in studying the relationship between welfare loss and permanent household income, we use household expenditure as a proxy for permanent income to estimate our semiparametric model. Our use of household expenditure is motivated by the permanent income hypothesis, which argues that for certain life events or for changes in savings or debt, expenditure is more stable over time and therefore constitutes a better measure of welfare and economic well-being of the household than household income (Friedman, 1957). Consumption in household expenditure also captures flows from the ownership of durable goods, the insurance value of government programmes, access to credit and the accumulation of assets, while income cannot. Furthermore, compared to household income, household expenditure is less likely to suffer from measurement error at low income levels (Meyer and Sullivan, 2012).

Unfortunately, the proportionate welfare loss and household expenditure may be jointly determined and thus the latter can be endogenous in our model.[17,18] We control for the endogeneity of household expenditure by using non-farm household income as an instrument. For that, we follow a methodology outlined in Newey, Powell, and Vella (1999), which involves the generation of residuals through the non-parametric regression of the endogenous variable on instruments and the use of the residuals as an additional covariate in the semiparametric model. The advantage of this methodology is that it can generate consistent estimates of the covariates, while the significance of the residuals provides a test of endogeneity.

Second, the indirect utility function, which we use throughout the analysis, is a function of commodity price and household income. More realistically, households utility depends on

[16]Unfortunately, our data do not include information on the distance to the next motorable road, used in some earlier studies. However, Dawson and Dey (2002) find that Bangladesh has a well-integrated and therefore competitive and efficient rice market. Therefore, we may expect little impact of the distance to the next road in our model. Mghenyi et al. (2011) find that the effect of the distance to the next motorable road is only significant in two out of seven disaggregated zones of rural Kenya.

[17]For instance, a higher rice price may increase total household expenditure and increase/reduce welfare. Using a model that includes the rice price to control for the endogeneity of household expenditure provides similar results.

[18]Similar arguments are also applicable to household income in models used by Mghenyi et al. (2011).

adult equivalent income rather than household income. Therefore, we estimate equation (8) replacing adult equivalent income with (log of) adult equivalent expenditure. Earlier studies like Mghenyi et al. (2011) use adult equivalent income for such an analysis. However, this study provides no hint regarding the identification of the equivalence scale. In contrast, we employ a recent semiparametric estimate of the equivalence scale for Bangladesh provided in Hasan (2012).

For our semiparametric estimation, we employ the local linear regression technique, using the Kernel method. We choose the local linear regression because of its performance at the boundary as well as its consistency and optimal conversion rate (Yatchew, 2003). In semiparametric models, the selection of an appropriate bandwidth is important because the results are sensitive to the choice of the bandwidth (Yatchew, 1998). Higher bandwidths lead to a larger bias with smaller variance, while smaller bandwidths generate larger variance with smaller bias. Both cases imply a higher residual sum of squares and thus a higher mean squared error (MSE). One way of choosing an optimal bandwidth is to minimizes the MISE, the integrated version of the MSE. Optimal bandwidths in our semiparametric models are based on the cross-validation approach. The approach is asymptotically equivalent to minimizing a discrete sample approximation of MISE (Hardle and Marron, 1985). We use the Epanechnikov kernel, which constitutes the optimal kernel (Cameron and Trivedi, 2005).[19]

4.3 Results

The welfare loss caused by a rise in the rice price depends on permanent household income. Table 4 shows that the mean welfare loss declines as household expenditure increases, which is a proxy for permanent household income. The joint distribution of the proportionate welfare loss with regard to household expenditure, presented in Figure 1, reveals that the proportionate welfare change is positively correlated with household expenditure. The non-parametric regression of the proportionate welfare change on household expenditure also indicates a positive association between the two.

<insert Table 4 around here>

<insert Figure 1 around here>

Since other explanatory variables of the proportionate welfare loss can be correlated with household income, we perform a semiparametric (SP) regression. The residuals in our SP models, used to control for the endogeneity of household expenditure, are significant for

[19]The semiparametric model estimation technique is described in Appendix C.

three divisions indicating that household expenditure may be endogenous in our models. The estimates of the SP regressions are presented in Table 5. They show that important variables such as expenditure on chemical fertilizer, agricultural asset value, rural/urban status, suffering from disaster, and cultivable land holding are significant for most divisions.[20]

<insert Table 5 around here>

The welfare loss may have a quadratic relationship to permanent household income. In particular, using socioeconomic survey data for 1981-82, Deaton (1997) finds that the rice price increase in Thailand benefited the rural middle class. We present the SP regressions together with a quadratic fit in Figure 2. A visual inspection reveals that the quadratic fit may reasonably approximate the SP fit for most divisions. Following Hardle and Mammen (1993), we perform a specification test against a semiparametric alternative to investigate if a quadratic fit can reasonably approximate the semiparametric fit. The Hardle and Mammen test results, which are presented in Table 6, indicate that we cannot reject the null hypothesis in six out of the seven cases.[21] However, we reject the quadratic fit for the country as a whole. In contrast to our analysis with equivalent household expenditure, we cannot reject the null for any division or for the whole country when we use the per capita expenditure. There are two possible explanations for failing to reject the quadratic fit. First, richer households that are associated with agriculture benefits from selling rice at a higher price. Second, richer households that are not associated with agriculture may only lose marginally as their expenditure share on rice is usually low.

<insert Figure 2 around here>

<insert Table 6 around here>

A similar test using household income (equivalised with the semiparametric scale) rejects the quadratic fit in three out of seven divisions as well as for the whole country. On the other hand, an analysis exclusively based on first round impacts rejects the quadratic fit in two out of seven divisions but cannot reject the quadratic fit for the whole country. These results indicate that the use of household expenditure provides conclusions that are more consistent with expectations, compared to the conclusions engendered from using household income or ignoring the second round effect.

[20]We repeat SP regressions with per capita expenditure, household expenditure and adult equivalent expenditure (equivalised using either the OECD scale or the square root of family size). All models produce similar results which are available from author upon request. However, we only present the results for the model in which we use the semiparametrically estimated scale to equivalise household expenditure because the scale is identified following a methodology consistent with consumer theory.

[21]All tests are conducted at a 5 percent significance level.

A quadratic relation between welfare change and permanent household income indicates that the middle income household typically suffers less from the higher rice price. This highlights the need for intensified income support programmes for the poor in the face of a food price shock.

5 The impact of the rice price increase on poverty

5.1 Poverty dominance

In addition to the effect of rice price increases on welfare, policy makers are often interested in the direct and indirect effect on poverty. For that reason, we analyse the impact of a higher rice price on poverty. To study poverty, we employ the poverty measures proposed by Foster, Greer, and Thorbecke (1984) (FGT from hereon), which satisfy the property of additive decomposability. Specifically, let F: $R_+ \rightarrow [0,1]$ represent the distribution of ordered real income such that $F(z)$ is the proportion of the population, p, with an income below or equal to z.[22] Then for each $\alpha \geq 1$, a poverty index P_α is given by

$$P_\alpha(F, z) = \frac{1}{z^{\alpha-1}} \int_0^{F(z)} \left[z - F^{-1}(p)\right]^{\alpha-1} dp, \quad (9)$$

where the measure P_1 is the poverty HCR, P_2 is the per capita income gap (a normalized measure of poverty gap), and P_3 is the weighted sum of income shortfalls of the poor.

Uncertainty in comparing the extent of poverty arises from the disagreement about poverty lines, z, or disagreement about the poverty measures, P_α (Fields, 2002). Therefore, some broader criteria are useful for ordering distributions. We follow the poverty ordering outlined in Foster and Shorrocks (1988a,b) in which the poverty ordering P_α is such that for two distributions F and G with the same population size n

$$\begin{aligned} FP_\alpha G \text{ if and only if } & P_\alpha(F;z) \leq P_\alpha(G;z) \text{ for all } z \in R_{++} \\ \text{and } & P_\alpha(F;z) < P_\alpha(G;z) \text{ for some } z \in R_{++}, \end{aligned} \quad (10)$$

where $FP_\alpha G$ indicates that the distribution F implies a lower poverty level than the distribution G with respect to the poverty index P_α for all possible poverty lines. In other words, distribution F 'poverty dominates' distribution G, for a given α.

Therefore, the statement 'distribution F poverty dominates distribution G of first degree' implies that $F(z) - G(z) \leq 0$ for all poverty lines z with strict inequality for at least one z.

[22] The inverse function $F^{-1}(p)$ thus gives the income that defines the proportion of people p as poor.

Similarly, 'distribution F poverty dominates distribution G of second degree' implies that $\int_0^z [F(p) - G(p)]dp \leq 0$ for all poverty lines z with strict inequality for at least one z.[23] First degree poverty dominance of a distribution F on a distribution G implies that distribution F unambiguously has less poverty HCR than distribution G. Similarly, second degree poverty dominance of a distribution F on a distribution G implies that distribution F unambiguously exhibits a lower per-capita income gap than distribution G.[24] Furthermore, poverty orderings of lower order imply poverty dominance of higher order, i.e., poverty orderings are nested. Finding no dominance means that the effect of the price change on poverty is conditional on the poverty lines used.

5.2 Methodology

In our calculation of poverty, we replace household income with household expenditure that is a much robust measure of household welfare. Next, incorporating the proportionate welfare loss in household expenditure, we generate a new distribution, which may represent the income distribution with the higher rice price. For convenience, we name the distribution without change in rice price as F and the distribution with the rice price change as G. We then compare distributions F and G to confirm if one distribution poverty dominates the other. Starting with the first order, we repeat our analysis for the second order if we do not find first order poverty dominance. As before, we conduct our analysis at the divisional level as well as for the whole country. Additionally, we investigate the impact of the higher rice price on the poverty headcount ratio (HCR) using official poverty lines in Bangladesh.

5.3 Results

Our analysis provides no evidence of first order poverty dominance for the whole country, when we consider poverty lines of up to Tk5,000.[25] However, the distribution without the change in the rice price, F, dominates the distribution with increased rice price, G, for poverty lines of up to Tk3,566. As expected, critical values are lower for the rice exporting divisions compared to other divisions. This is because more than the proportionate number of surplus rice farmers in rice exporting divisions benefit from the higher rice price. With the difference between the two cumulative distributions in the vertical axis, Figure 3 shows no absolute first order poverty dominance of one distribution over another.

<insert Figure 3 around here>

[23]Some additional properties of poverty dominance are discussed in Appendix D.
[24]For our purpose we confine our analysis only on first and second order poverty dominance.
[25]This corresponds to about 2.5 - 4 times the divisional poverty lines.

In the next step, we look for second order poverty dominance and find that for all the divisions and therefore for the whole country, distribution F poverty dominates distribution G. This implies that, if we consider the per capita income gap as a measure of poverty, the increase in the rice price unambiguously lowers the welfare level for the whole country. Second order poverty dominance is presented in Figure 4, in which the vertical axis denotes the difference between the FGT indices. It shows that distribution F second order poverty dominates distribution G, i.e., distribution F exhibits a lower per capita income gap than distribution G.

An alternative analysis that is only based on the first round impact provides lower critical values for the rice exporting divisions at which distribution G first order poverty dominates distribution F and vice-versa. Most importantly, such exclusive use of the first round impact reveals no absolute second order poverty dominance for one rice exporting division, Rangpur. These findings highlight the importance of capturing the second round impact. Furthermore, repeating the analysis with household income suggests no absolute second order poverty dominance for some divisions, including one rice importing division. The poor performance of household income supports the use of household expenditure as a poverty measure.

<insert Figure 4 around here>

Finally, we calculate the poverty HCR associated with distributions with and without a change in the rice price, using official poverty lines for each division. The results are presented in Table 7. With a higher rice price, the poverty HCR increases in all divisions, but increases more in rice exporting divisions. This may seem paradoxical given that the critical values, at which the distribution with a higher rice price start to poverty dominate the distribution without a change in rice price, are lower for the rice exporting divisions. The data reveal that the means of household income and household expenditure are lower in rice exporting divisions than in other divisions. With many households around the poverty line, a small reduction in income now defines a significant proportion of households as poor, which confirms the dependency of the poverty HCR on the poverty line used.

<insert Table 7 around here>

Our analysis emphasises the usefulness of the notion of poverty dominance for the comparison of distributions. In particular, we may obtain completely different conclusions regarding the incidence of poverty when using different poverty lines. Therefore, using poverty lines in assessing the successes or failures of the public intervention programmes may provide wrong indications to the policy makers. In addition, poverty related policies that rely on household expenditure may provide better outcomes than those that rely on household income.

6 Conclusion

This paper studies the effect of a sharp rice price increase on welfare and poverty in Bangladesh. Our analysis assesses the importance of using household expenditure as well as capturing the behavioural responses to the price change when estimating the welfare loss. We also examine the relationship between permanent household income and welfare loss due to a higher rice price. Finally, we investigate the impact of a higher rice price on poverty.

Our study improves the estimate of welfare losses resulting from a higher rice price as we use household expenditure instead of household income which usually suffers from measurement error. We find that including the behavioural responses to price change also significantly improves the estimates of proportionate welfare loss. As a result, differences in welfare loss across regions are determined by the surplus rice farming status as well as other behavioural parameters. We investigate the relationship between welfare loss and permanent household income that is proxied by household expenditure. In our analysis we use a semiparametric framework in which we control for endogeneity and equivalise household expenditure by a semiparametrically estimated equivalence scale. In our analysis, the relationship between welfare change and household income appears quadratic. We further analyse the impact of the higher rice price on poverty. For that, we again use household expenditure, a better measure of household welfare than household income. We find that changes in the head-count ratio due to a higher rice price are not invariant to the choice of the poverty line. However, when we consider the per capita income gap measure of poverty, we find that the distribution without a change in the rice price generates less poverty than the distribution with a higher rice price. In both cases, our conclusions applies to all divisions or for the whole country.

We propose an improved way of estimating the proportionate welfare loss. In our method, we use household expenditure instead of household income and capture the behavioural responses to the price change. In addition, we employ a better methodological framework for examining the relationship between welfare loss and permanent household income. Such models recommend a progressive income support for the poor when food prices rise. Our analysis also suggest that the success or failure of public intervention programmes may be judged better by the ranking of distributions with respect to poverty rather than by poverty estimates based on a specific poverty line. The use of household expenditure may be appropriate for poverty policy, compared to the use of household income.

Tables and Figures

Table 1: Means (SD in parenthesis) of analysis sample (weighted), 2010

	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Rangpur	Sylhet	Bangladesh
Net rice seller	0.09	0.09	0.09	0.16	0.19	0.23	0.12	0.13
Self-sufficient in rice	0.12	0.10	0.10	0.15	0.14	0.15	0.11	0.12
Net rice buyer	0.79	0.80	0.81	0.68	0.67	0.62	0.77	0.75
Rice farmers	0.31	0.30	0.27	0.44	0.46	0.52	0.36	0.36
Non-rice farmers	0.69	0.70	0.73	0.56	0.54	0.48	0.64	0.64
Current household	10,632	17,668	14,997	12,100	10,477	9,178	14,013	13,476
income	(13,150)	(30,329)	(21,077)	(48,109)	(14,156)	(10,710)	(21,328)	(26,092)
Current household	760	785	806	1,210	1,641	1,926	1,409	1,126
income from rice farming	(1,783)	(2,063)	(2,292)	(2,339)	(4,019)	(3,642)	(3,302)	(2,803)
Household	9,684	14,302	11,534	9,251	9,167	8,265	11,971	10,926
consumption expenditure	(8,002)	(12,950)	(9,585)	(7,008)	(6,911)	(6,303)	(9,323)	(9,451)
Household	1,862	1,849	1,827	1,798	1,742	1,894	2,418	1,856
expenditure on rice	(891)	(1,006)	(949)	(862)	(927)	(935)	(1,430)	(980)
N	973	2,194	3,523	1,790	1,555	1,280	856	12,171

Note: 1. Net seller, Net buyer, Autarky, Rice farmer and Non-rice farmer are dummy variables and thus indicate their proportions in our sample.
2. We define autarky households as those who produce 60-140% of their consumption of rice.

Table 2: High rice price and households' proportionate welfare loss (weighted)

	1st round (Δ_1)				2nd round (Δ_2)				Δ_2/Δ_1
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.	(%)
Barisal	-0.0752	0.0912	-0.3279	0.6890	0.0024	0.0137	-0.1522	0.0226	-10.8849
Chittagong	-0.0494	0.0782	-0.2725	0.9266	0.0058	0.0113	-0.1857	0.0180	-16.5463
Dhaka	-0.0604	0.1114	-0.2909	2.3671	0.0030	0.0168	-0.3630	0.0180	-14.5099
Khulna	-0.0484	0.1308	-0.3231	1.6797	-0.0015	0.0190	-0.1983	0.0217	-10.7546
Rajshahi	-0.0333	0.1957	-0.2754	3.8340	-0.0026	0.0271	-0.5836	0.0180	-9.4643
Rangpur	-0.0367	0.1772	-0.3183	1.3230	-0.0067	0.0247	-0.2446	0.0209	-8.7385
Sylhet	-0.0606	0.1319	-0.2834	1.5697	-0.0004	0.0198	-0.2430	0.0180	-10.7081
Bangladesh	-0.0514	0.1333	-0.3279	3.8340	0.0008	0.0195	-0.5836	0.0226	-12.6046

Note: 1. $\Delta_1 = (s_i^s - s_i^d)\lambda$ and $\Delta_2 = -0.5[s_i^s\xi_i^{ps} - s_i^d\xi_i^{pd}]\lambda^2 + 0.5\{(R_i - \xi_i^{yd})[(s_i^d)^2 - 2s_i^d s_i^s] + R_i(s_i^s)^2\}\lambda^2$.
2. The total proportionate welfare loss is approximated by the sum of the first round (Δ_1) and the second round (Δ_2) proportionate welfare loss.

Table 3: Means (SD in parenthesis) of independent variables (weighted)

	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Rangpur	Sylhet	Bangladesh
Family size	4.57	4.97	4.39	4.27	4.15	4.28	5.50	4.50
	(1.80)	(2.05)	(1.78)	(1.63)	(1.72)	(1.67)	(2.47)	(1.87)
Household head's age	48.00	46.41	45.28	45.52	44.75	45.53	47.53	45.75
	(14.51)	(14.21)	(13.77)	(13.25)	(13.80)	(14.00)	(14.14)	(13.90)
Household cultivable	0.62	0.50	0.47	0.62	0.67	0.69	0.70	0.57
land (acre)	(1.42)	(1.53)	(1.51)	(1.39)	(1.57)	(1.45)	(2.14)	(1.53)
Household own a mobile phone	0.60	0.71	0.72	0.61	0.60	0.42	0.61	0.64
Lean season	0.16	0.15	0.22	0.19	0.16	0.21	0.13	0.19
Female headed household	0.07	0.07	0.06	0.04	0.06	0.06	0.05	0.06
Household input	43	56	74	212	192	166	72	113
expenditure on fertilizer	(159)	(236)	(328)	(437)	(516)	(408)	(214)	(365)
Household input	14	14	14	31	53	34	16	24
expenditure on pesticides	(58)	(64)	(148)	(85)	(205)	(98)	(65)	(128)
Household input	14	14	14	31	53	34	16	24
expenditure on electricity	(58)	(64)	(148)	(85)	(205)	(98)	(65)	(128)
Household	7,339	2,908	2,451	8,751	7,869	5,373	6,175	4,887
agricultural asset value	(76,656)	(22,724)	(16,259)	(32,280)	(43,351)	(33,163)	(29,746)	(33,252)
N	973	2,194	3,523	1,790	1,555	1,280	856	12,171

Note: HH own a mobile phone, lean season and female headed household are dummy variables with means indicating their proportions.

Table 4: Proportionate welfare loss (%) and expenditure quintiles by division (weighted)

	Household expenditure quintiles					**All**
	Quintile-1	Quintile-2	Quintile-3	Quintile-4	Quintile-5	**household**
Barisal	-12.1	-10.8	-8.5	-6.1	-2.9	-7.3
Rural	-12.3	-10.7	-8.5	-6.1	-2.4	-7.4
Urban	-11.1	-12.1	-8.4	-6.2	-3.9	-6.5
Chittagong	-7.0	-8.4	-6.6	-5.3	-2.2	-4.4
Rural	-7.1	-8.5	-6.6	-5.2	-1.8	-4.5
Urban	-6.9	-7.8	-6.7	-5.9	-2.9	-4.1
Dhaka	-11.6	-9.0	-7.2	-5.1	-2.7	-5.7
Rural	-11.6	-8.8	-6.6	-3.6	-2.0	-5.8
Urban	-11.5	-9.8	-9.0	-7.1	-3.1	-5.6
Khulna	-11.2	-7.4	-6.0	-3.2	-0.9	-5.0
Rural	-11.3	-6.9	-5.2	-2.2	0.1	-4.5
Urban	-10.0	-10.2	-8.7	-6.9	-2.8	-6.8
Rajshahi	-9.9	-7.4	-5.7	-2.3	4.3	-3.6
Rural	-9.7	-6.7	-5.1	-1.5	6.2	-2.9
Urban	-11.0	-10.8	-8.8	-6.2	-2.3	-7.0
Rangpur	-12.7	-9.8	-5.2	1.4	5.4	-4.3
Rural	-12.9	-9.6	-4.8	2.6	8.3	-4.1
Urban	-8.0	-11.2	-8.3	-6.5	-1.3	-5.9
Sylhet	-11.4	-10.3	-9.0	-5.5	-2.5	-6.1
Rural	-11.5	-10.2	-9.2	-5.6	-2.4	-6.5
Urban	-10.5	-13.0	-7.2	-5.4	-2.6	-4.2
Bangladesh	-11.3	-8.8	-6.6	-4.1	-1.2	-5.1
Rural	-11.3	-8.5	-6.1	-3.2	0.2	-4.9
Urban	-10.6	-10.2	-8.6	-6.7	-2.9	-5.6

Note: Author's own calculation based on HIES, 2010.

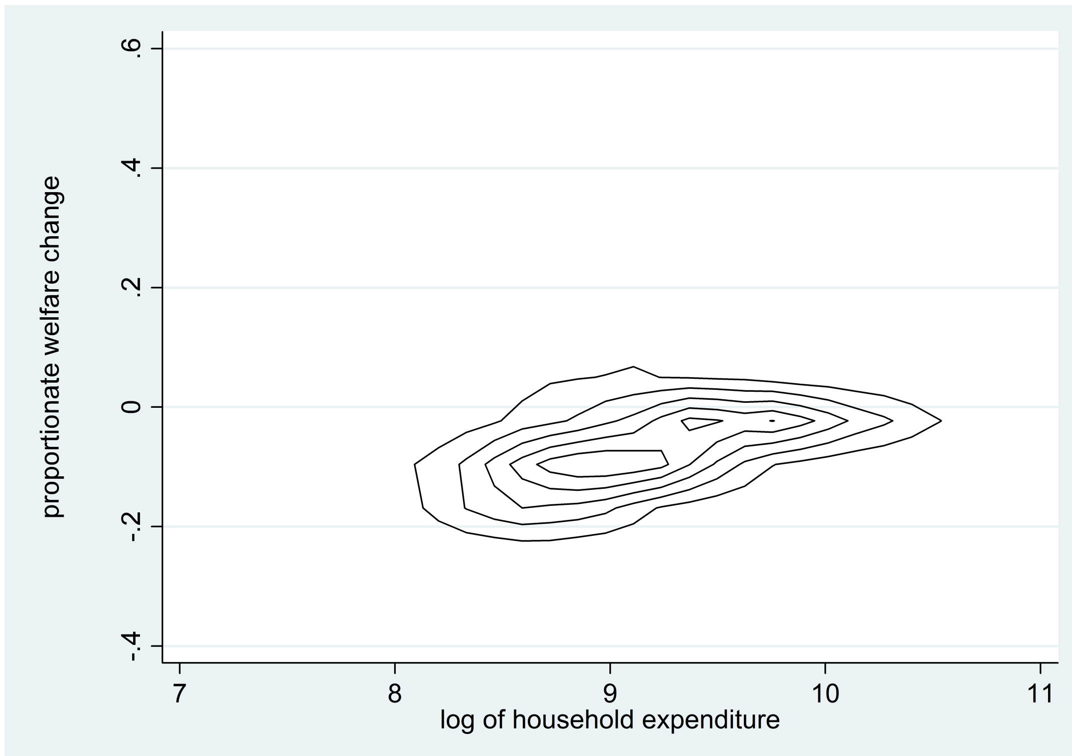

Figure 1: Contourlines of proportionate welfare change and household expenditure

Table 5: Impact of independent variables on proportionate welfare change (m)

	Barishal	Chittagong	Dhaka	Khulna	Rajshahi	Rangpur	Sylhet	Bangladesh
Household input	0.019***	0.011***	0.006	0.011***	0.014***	0.007**	0.035***	0.011***
expenditure on fertilizer	(0.007)	(0.001)	(0.004)	(0.002)	(0.002)	(0.003)	(0.004)	(0.002)
Household	0.000	0.000	0.000**	0.000**	0.000**	0.000	-0.000	0.000***
agricultural asset value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Lean season	-0.592	-0.161	-0.026	0.283	-1.637**	0.008	1.179	-0.072
	(0.519)	(0.292)	(0.357)	(0.538)	(0.662)	(0.786)	(0.775)	(0.199)
Household suffered	1.051	0.332	1.618*	0.861	2.106*	3.670***	-1.821**	1.429***
from disaster	(0.718)	(0.584)	(0.854)	(0.552)	(1.245)	(0.948)	(0.866)	(0.413)
Female headed	0.932	-0.267	-0.849**	2.281	5.195	0.305	-1.218	0.565
household	(0.628)	(0.404)	(0.377)	(2.192)	(4.032)	(1.047)	(0.754)	(0.601)
Urban Area	0.074	-0.435*	-1.419***	-0.395	-1.796***	-1.861**	0.953	-1.009***
	(0.431)	(0.224)	(0.347)	(0.417)	(0.481)	(0.877)	(0.674)	(0.186)
Household cultivable	0.593***	0.610***	1.060***	0.537**	0.735*	2.660***	-0.229	0.850***
land (acre)	(0.181)	(0.172)	(0.358)	(0.222)	(0.387)	(0.655)	(0.305)	(0.204)
Household head's age	-0.027	-0.002	0.008	-0.043	-0.183	-0.117	0.067	-0.047
	(0.080)	(0.041)	(0.057)	(0.129)	(0.160)	(0.132)	(0.095)	(0.036)
Square of household	0.000	0.000	0.000	0.000	0.001	0.002	-0.001	0.001**
head's age	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)
Adjusted R^2	0.186	0.238	0.132	0.297	0.277	0.313	0.325	0.224
F	3.667	9.336	14.181	11.784	10.268	13.923	6.911	33.644
N	940	2,134	3,423	1,732	1,497	1,216	828	11,770

Note: 1. The dependent variable is the proportionate welfare change times 100.
2. Standard errors in parentheses.
3.* p <0.10, ** p <0.05, *** p <0.01.

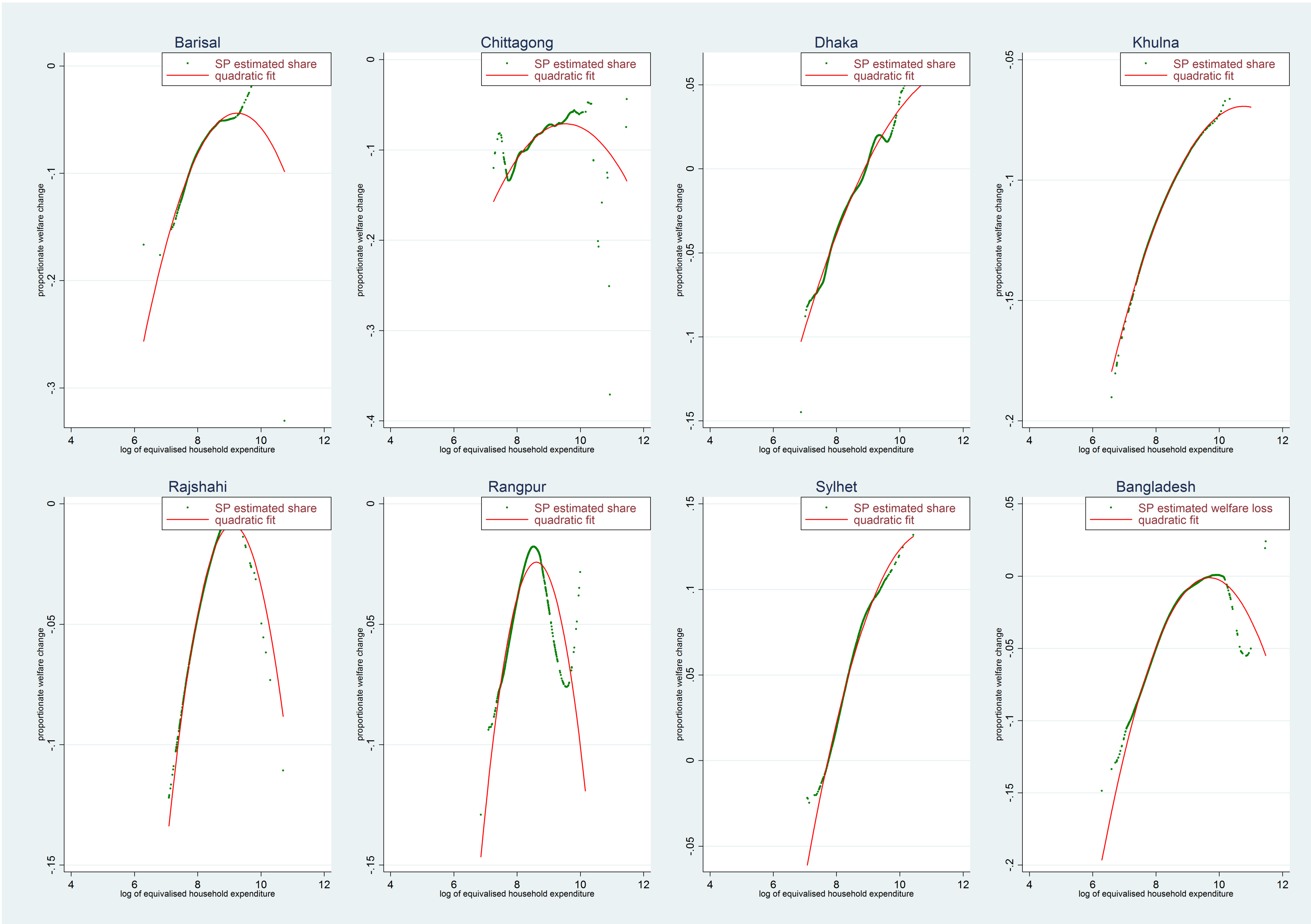

Figure 2: SP regression of welfare loss (with household expenditure equvalised using a SP scale)

Table 6: Hardle and Mammen test results: p-value

	With household expenditure	With per capita expenditure	With equivalent expenditure		
			SP scale	OECD scale	SRFS scale
Barisal	0.05	0.61	0.74	0.55	0.52
Chittagong	0.02	0.62	0.14	0.25	0.03
Dhaka	0.14	0.21	0.12	0.13	0.68
Khulna	0.60	0.14	0.17	0.11	0.22
Rajshahi	0.35	0.86	0.32	0.18	0.11
Rangpur	0.00	0.38	0.02	0.07	0.17
Sylhet	0.85	0.79	0.07	0.02	0.05
Bangladesh	0.00	0.00	0.00	0.05	0.00

Note: H_0 : Nonparametric fit can be approximated by a parametric adjustment of order 2, H_1 : Nonparametric fit cannot be approximated by a parametric adjustment of order 2. A low p-value rejects the quadratic fit and vice-versa. For detail, see Hardle and Mammen (1993).

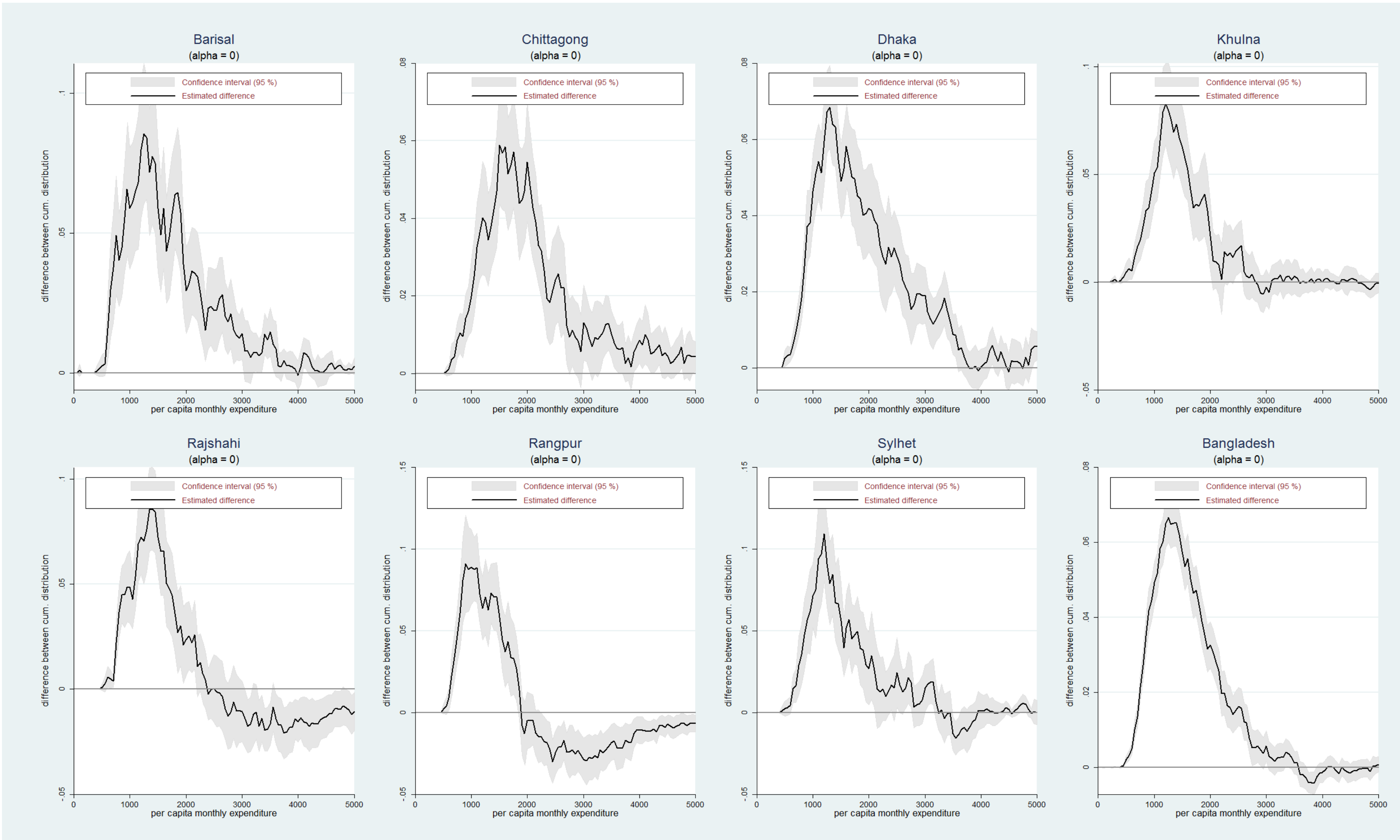

Figure 3: First order poverty dominance

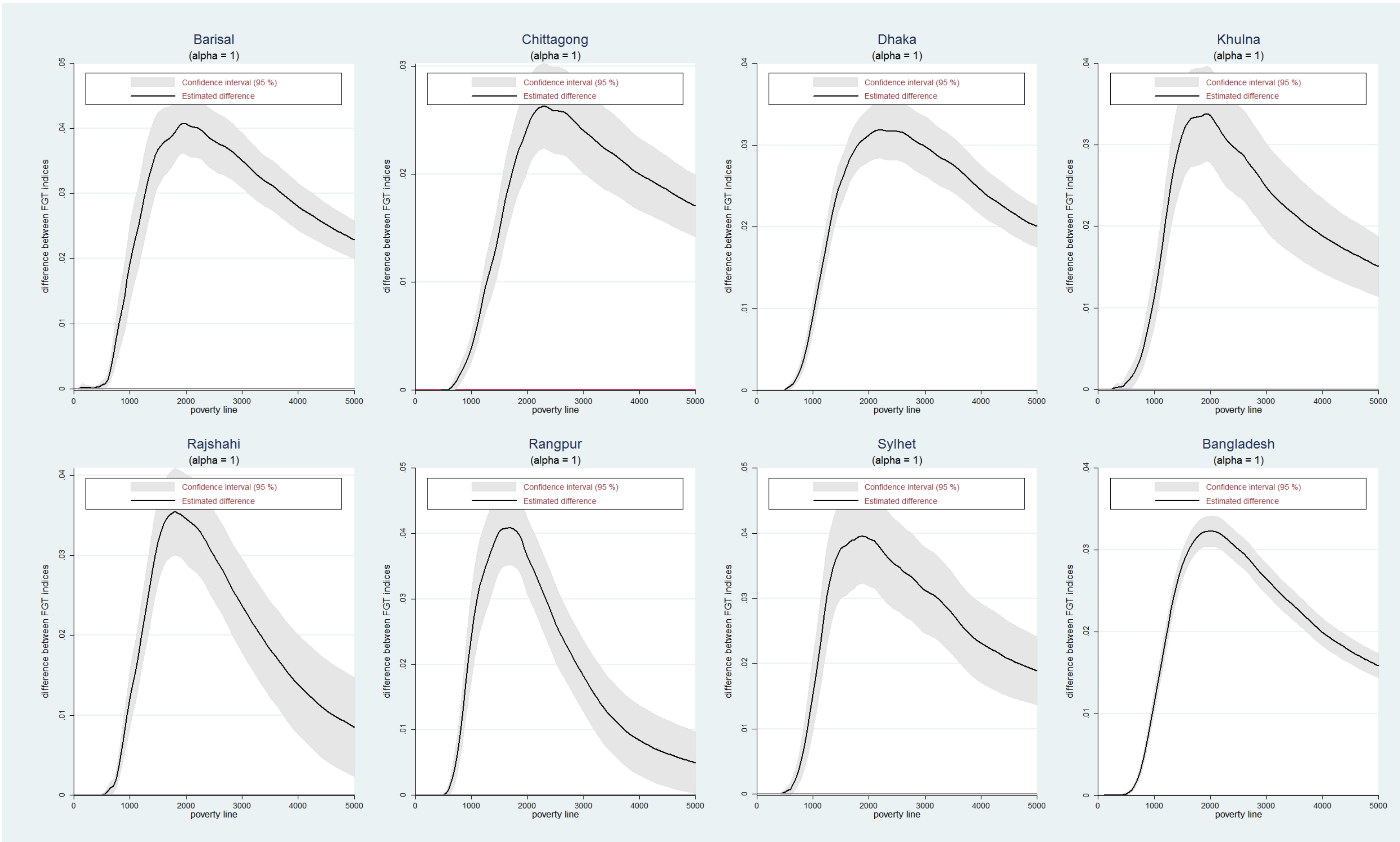

Figure 4: Second order poverty dominance

Table 7: Higher rice price and change in headcount (percent, weighted)

	Upper poverty line			**Lower poverty line**		
	Without price change	With price change	Difference	Without price change	With price change	Difference
Barisal	36.0	41.9	5.8	24.2	31.5	7.2
Rural	36.3	42.1	5.8	24.8	32.8	8.0
Urban	35.0	41.0	6.0	21.3	24.7	3.3
Chittagong	22.3	27.8	5.5	10.7	14.8	4.2
Rural	26.9	32.8	5.9	13.4	18.3	4.9
Urban	9.5	13.9	4.4	3.2	5.2	2.0
Dhaka	28.3	34.3	5.9	13.5	20.3	6.8
Rural	35.9	41.8	5.9	20.6	30.1	9.5
Urban	17.5	23.5	6.0	3.3	6.2	2.9
Khulna	30.0	36.7	6.7	14.5	22.3	7.8
Rural	29.4	36.2	6.9	14.5	22.4	7.9
Urban	32.3	38.3	6.0	14.2	21.9	7.7
Rajshahi	29.1	36.9	7.8	15.4	22.6	7.2
Rural	28.6	36.4	7.7	15.4	22.4	7.0
Urban	31.1	39.4	8.4	15.3	23.4	8.0
Rangpur	40.5	47.9	7.4	25.5	33.6	8.0
Rural	42.7	49.9	7.2	27.1	35.6	8.4
Urban	25.8	34.2	8.4	14.7	20.0	5.3
Sylhet	25.3	32.9	7.5	18.9	28.0	9.1
Rural	27.8	36.0	8.2	21.7	31.9	10.2
Urban	12.6	16.7	4.0	4.5	8.1	3.5
Bangladesh	29.4	35.8	6.5	15.7	22.6	6.8
Rural	32.9	39.5	6.6	19.0	26.9	7.9
Urban	19.9	25.9	6.0	6.8	10.7	3.9

Note: Poverty estimates are with official poverty lines.

Appendix A Welfare change with CV measure

We start with the same utility function in (2). By definition, the CV measure of a welfare loss for an individual i caused by a rice price increase from p_r^0 to p_r^1 is given by

$$CV_i = e(p^1, u_i^1) - e(p^1, u_i^0), \tag{A.1}$$

where p^1 and p^0 represents the aggregate price vector with and without the change in the rice price; $e(p^k, u_i^j)$ gives the minimum expenditure required to achieve the utility u_i^j at price p^k, while $u_i^0 = v_i[p^0, y_i + \pi_i(p^0)]$ and $u_i^1 = v_i[p^1, y_i + \pi_i(p^1)]$ is the indirect utility with associated prices and income.

With m denoting the proportional change in household welfare, we define CV_i as a proportional compensating variation measure such that $CV_i = me(p^1, u_i^1)$. Hence, (A.1) can be written as

$$(1 - m)e(p^1, u_i^1) = e(p^1, u_i^0). \tag{A.2}$$

Therefore, at same price p^1, utility from the expenditures in (A.2) should be identical, given by

$$\begin{aligned} v_i[p^1, (1 - m_i)e(p^1, u_i^1)] &= v_i[p^1, e(p^1, u_i^0)], && \text{(A.3)} \\ \Rightarrow v_i[p^1, (1 - m_i)e(p^1, u_i^1)] &= u_i^0. && \text{(A.4)} \end{aligned}$$

Now from the definition of u_i^0 and using the fact that $e(p^1, u_i^1) = y_i + \pi_i(p^1)$ we get,

$$v_i \left\{p^1, (1 - m_i)[y_i + \pi_i(p^1)]\right\} = v_i[p^0, y_i + \pi_i(p^0)]. \tag{A.5}$$

Taking a second-order Taylor approximation of (A.5) at $(p^0, m_i) = (p^1, 0)$, using Roy's identity, Hotelling's lemma, and solving for m_i gives

$$\begin{aligned} m_i \approx &(s_i^s - s_i^d)\lambda - 0.5[s_i^s \xi_i^{ps} - s_i^d \xi_i^{pd}]\lambda^2 + \\ &0.5\{(R_i - \xi_i^{yd})[(s_i^d)^2 - 2s_i^d s_i^s] + R_i(s_i^s)^2\}\lambda^2, \end{aligned} \tag{A.6}$$

where, as previous ξ_i^{ps}, ξ_i^{pd}, ξ_i^{yd} and R_i denotes price elasticity of rice supply, price elasticity of rice demand, income elasticity of rice demand and coefficient of relative risk aversion respectively.[26] The difference between EV and CV lies in λ which is now equal to $(p^1 - p^0)/p^1$.

[26] See Mghenyi et al. (2011) for details.

Appendix B Second-order Taylor series approximation

For simplicity, we drop subscripts in (6), which is now given as[27]

$$v\{p^1, (1-m)[y+\pi(p^1)]\} = v\{p^0, y+\pi(p^0)\}. \tag{B.1}$$

Taking a second-order Taylor approximation at $(p^1, m) = (p^0, 0)$, denoting $y + \pi(p^0)$ as x^0 and using subscripts to denote partial derivatives w.r.t the subscripted variable we get,

$$\begin{aligned} &v(p^0) + [v_p + v_y\pi_p](p^1 - p^0) + 0.5[v_{pp} + 2v_{yp}\pi_p + v_y\pi_{pp} + v_{yy}\pi_p^2](p^1 - p^0)^2 \\ &\cong v(p^0) + v_y x^0 m + 0.5 v_{yy}(x^0)^2 m^2. \end{aligned} \tag{B.2}$$

The higher order term m^2 can reasonably be ignored in the case of the second-order approximation. After reorganizing, we can write (B.2) as

$$m \approx \left[\frac{v_p}{v_y x^0} + \frac{\pi_p}{x^0}\right](p^1 - p^0) + 0.5\left[\frac{v_{pp}}{v_y x^0} + \frac{2v_{py}\pi_p}{v_y x^0} + \frac{v_{yy}\pi_p^2}{v_y x^0} + \frac{\pi_{pp}}{x^0}\right](p^1 - p^0)^2. \tag{B.3}$$

With q_{ir}^d denoting the rice consumption by household i, Roy's identity, which shows the effect of prices on utility, is given by

$$\frac{\partial v_i}{\partial p_r} = -q_{ir}^d \frac{\partial v_i}{\partial x_i}, \tag{B.4}$$

Similarly, with q_{ir}^s denoting the production of rice by household i, Hotelling's lemma, which shows the effect of prices on profits, is given by

$$\frac{\partial \pi_i}{\partial p_r} = q_{ir}^s. \tag{B.5}$$

Now, using Roy's identity and Hotelling's lemma and denoting $\lambda = (p^1 - p^0)/p^0$, we can write the following

$$\left[\frac{v_p}{v_y x^0} + \frac{\pi_p}{x^0}\right](p^1 - p^0) = (s_i^s - s_i^d)\lambda. \tag{B.6}$$

Denoting a household's coefficient of relative risk aversion by $R = v_{yy}x^0/v_y$, we can show

[27] This section borrows from Mghenyi et al. (2011).

that the following relationships also hold[28]

$$\frac{v_{pp}(p^0)^2}{v_y x^0} = (s^d)^2(R - \xi^{yd}) + s^d \xi^{pd}, \tag{B.7}$$

$$\frac{v_{py}\pi_p(p^0)^2}{v_y x^0} = -s^d s^s (R - \xi^{yd}), \tag{B.8}$$

$$\frac{v_{yy}\pi_p^2(p^0)^2}{v_y x^0} = R(s^s)^2, \tag{B.9}$$

$$\frac{\pi_{pp}(p^0)^2}{x^0} = -s^s \xi^{ps}. \tag{B.10}$$

Substituting those in (B.3) and reorganising gives (7).

Appendix C Semiparametric estimation technique

The semiparametric estimation technique in this paper follows Robinson (1988). First, we predict the dependent and all the independent variables nonparametrically using household expenditure. Second, for the dependent and all the independent variables, we obtain the difference between actual and predicted values of each variable. Third, we use OLS to estimate the coefficients of the independent variables, by regressing the differenced dependent variable on the differenced independent variables, which enter the model parametrically. We use the estimated coefficients to estimate the impact of these variables on the dependent variable. Now we subtract these estimated values (impact) from the dependent variable, so that we are only left with the impact of household expenditure on the dependent variable. Finally, we again run a nonparametric regression of the impact free dependent variable on household expenditure.[29]

For notational simplicity, we ignore subscripts i representing individuals. Now, with x representing equivalised household expenditure, our semiparametric model is

$$m = F[log(x)] + Z\beta + \upsilon. \tag{C.1}$$

If $log(x)$ is uncorrelated with the error term, the conditional expectation of (C.1) is give by

$$E[m|log(x)] = F[log(x)] + E[Z|log(x)]\beta. \tag{C.2}$$

The estimates of the conditional moments can be obtained using the local linear regression

[28] See Myers (2006) for details.
[29] This section borrows from Breunig and McKibbin (2012).

technique. Subtracting (C.2) from (C.1) gives

$$m - E[m|log(x)] = (Z - E[Z|log(x)])\beta + \upsilon. \tag{C.3}$$

The vector β can be estimated by OLS using (C.3). We can use these estimates along with the estimated conditional moments in (C.2) to obtain an estimate of $F[log(x)]$,

$$F\widehat{[log(x)]} = E[\widehat{m|log}(x)] - E[\widehat{Z|log}(x)]\hat{\beta}. \tag{C.4}$$

In such models, household expenditure may suffer from endogeneity. To deal with this issue, we predict the residuals from non-parametric estimation of household expenditure on household non-farm income. We then use the residuals as an additional covariate and estimate (C.3) by OLS. This procedure generates consistent estimates of the covariates, while the significance of the residuals may also indicate the presence of endogeneity.

Appendix D Poverty dominance

The curve given by the plot of head-count ratios at all poverty lines (i.e., from lowest to highest income level) is known as the poverty incidence curve.[30] Each point on the curve gives the fraction of the population with an income below the amount given in the horizontal line [Figure D.1(a)]. The area under the poverty incidence curve gives the poverty deficit curve. Each point on the curve gives the sum of the poverty gap at each income level with zero gap for the non-poor [Figure D.1(b)].

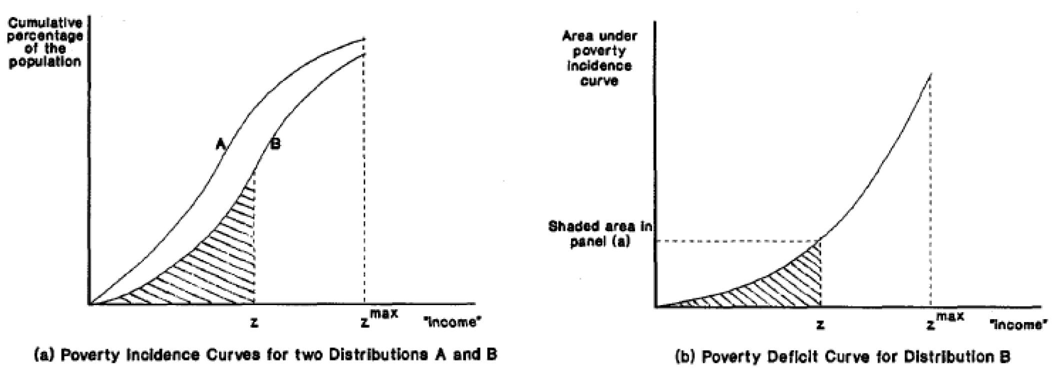

Figure D.1: Poverty dominance (Source: Ravallion, 1992)

If the poverty incidence curve for one distribution F lies nowhere above another distribu-

[30]This section borrows from Ravallion (1992).

tion G, then distribution F first-order poverty dominates distribution G.[31] As we discussed earlier, the confusion of identifying the poverty line makes the poverty dominance idea more suitable for comparing poverty. However, if we have some idea about the maximum possible poverty line – z^{max}, the same analysis can be done up to z^{max}. If we cannot find first-order poverty dominance of a particular distribution over the other, we cannot order distributions by the head-count ratio.

If the poverty deficit curve of a distribution F, given by the area under the poverty incidence curve, is nowhere above of another distribution G at all points up to the maximum poverty line, then distribution F second-order poverty dominates distribution G. Second-order poverty domination order distributions in terms of the per capita income gap measure of poverty.

[31] Following Chen and Duclos (2011), this implies that distribution F generates more social welfare or less poverty than distribution G.

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