Price, Unit Value, and Quality Demanded

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Abstract

Accurate price measures are essential for estimating demand systems and for making inter-temporal and inter-regional comparisons of purchasing power, real income, poverty, and welfare. Because accurate price data are rare, it is now common to rely on "unit value" (commodity group expenditure per unit purchased) from budget surveys as a proxy for price. However, if households respond to price increases by switching to less expensive products, then unit value is an imperfect proxy. Exploiting the structure imposed by weak separability, Deaton (1988) introduces a method for estimating price elasticity using unit values that estimates and compensates for quality effects. This paper draws on rich survey data from Indonesia to test this identification strategy. We obtain estimates of the price elasticity of quantity and quality demanded that differ substantially from those obtained using the Deaton method, resulting in a strong rejection of the restrictions placed on quality effects by the assumption of weakly separable commodity groups. We go on to demonstrate the implications of these results for the estimation of demand systems. Specifically, even when price is perfectly observed, regressions of household budget shares on prices will not yield pure estimates of the price elasticity of quantity demanded, if a change in price induces simultaneous changes in both quantity and quality demanded.

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1 Introduction

Few economic factors more directly affect a population's well-being than the prices of goods and services. Prices determine how far household resources can be stretched and, in developing countries where household production of food is common, prices play a central role in determining household resources. Good measures of prices are, therefore, key for accurately characterizing the opportunities and constraints households face and for interpreting their behaviors as prices change. Moreover, prices are critical for measuring the distribution of poverty and welfare and how real purchasing power varies over time and across space.

In spite of the importance of prices, there is a paucity of high quality data on the prices of commodities that individuals face in combination with information on the behaviors of those individuals. Few household surveys collect data on prices and most price surveys collect no information on the agents facing those prices. Consequently, most studies of household behavior that examine price effects match data on prices to household choices at relatively high levels of geographic aggregation. In the United States, this is often at the region or possibly the state level. Household budget surveys are the exception and they have been used very creatively to estimate demand systems. Although budget surveys rarely elicit prices directly, they often collect information on total expenditure and physical quantity consumed by commodity group. Dividing the former by the latter, one obtains a proxy for the price known as the "unit value".

Deaton (1988) points out a potential drawback of using unit value as a proxy for price. If a commodity group (e.g., chicken) contains several commodities of varying qualities (e.g., different cuts of chicken meat), then changes in the unit value will reflect the influence of both changes in the price and changes in the quality of goods within the group. As a result, when the quality of goods consumed varies over time or across regions, unit values will be an error-ridden indicator of prices. To the extent those errors (reflecting changes in quality) are uncorrelated with unobserved characteristics in the model, estimated price effects will be unbiased. However, it is possible and even likely that quality and price are correlated. For example, if the price of chicken increases and households respond by switching to cheaper cuts of chicken meat, then the change in unit value for chicken will understate the original price increase.

Under the assumption that household preferences have a particular functional form, namely that utility is weakly separable in the commodity groups, Deaton (1988) addresses this issue for the estimation of a demand system, deriving a method for imputing the effect of a price change on the quality purchased. This method is remarkable in that it does not require price data, instead using the relationship between unit value and household resources to infer the effect of a price increase on quality. Deaton (1988) concludes that the quality of goods consumed by individuals is not very sensitive to price changes and that estimates of price elasticity that correct for quality effects are quite similar to estimates that do not. This conclusion is very appealing because it suggests that, at least for some applications, it is unnecessary to correct for quality effects when using unit value data.

Deaton's (1988) result suggests that unit value may be a good proxy for price, but it is predicated on the assumption that household preferences satisfy weak separability. The need to evaluate this assumption was pointed out as early as 1990:

> The method is very close to being exactly identified, and so it is difficult to construct the sort of cross-checks that would lend it greater conviction. Plausibility of demand elasticities is not in itself a very powerful test. It would be extremely desirable to have data with direct measures of market prices against with this method could be compared. (Deaton, 1990)

Nearly twenty years later the Deaton Method has been implemented in a variety of settings, including Côte d'Iviore (Deaton, 1988), Indonesia (Deaton, 1990), the United States (Nelson, 1990), Pakistan and India (Deaton, 1997), Spain (Gracia and Albisu, 1998), Ethiopia (Kedir, 2001), and Papua New Guinea (Gibson and Rozelle, 2002), and the identifying assumption of weak separability remains untested.[1] This paper explicitly tests the identifying restriction implied by weak separability and provides new evidence on the issue, drawing on rich survey data recently collected in Central Java, Indonesia.

The implications of this research are far broader than simply assessing the suitability of unit values as a proxy for price. Over the past several decades it has become increasingly common to use commodity group budget share (commodity group expenditure divided by total expenditure) as the dependent variable when estimating a demand system. But in regressions of commodity group budget share on price, quality effects can generate biased price elasticities *even when price is perfectly observed*. This is because price can impact commodity group budget share either through a change in quantity or through a change in quality. For example, an increase in the price of chicken may cause households to simultaneously decrease the quantity of chicken purchased and consume cheaper cuts of chicken

[1] It is worth noting that Gibson and Rozelle (2002) uses a Living Standards Measurement Study (LSMS) survey from Papua New Guinea to compare price elasticities obtained using the Deaton method with those obtained using traditional price data. When estimating price elasticities with price, however, the authors impose the assumption of no quality elasticity. Our analysis imposes no such assumption.

meat. Both of these effects reduce the share of the household budget devoted to chicken, so the coefficient on the price of chicken cannot be interpreted as a pure measure of the price elasticity of quantity demanded. This paper uses data with measures of both price and unit value to directly measure the relationship between price and quality, allowing us to both assess the suitability of the assumption of no quality effects for typical demand system estimation and to produce estimates of price elasticity that compensate for quality effects. To the author's knowledge, there is no prior research addressing this issue.

The paper proceeds as follows. In Section 2, by way of motivation, we compare price increases (from an urban price survey) with unit value increases (from a household expenditure survey), finding *prima facie* evidence that quality substitution is of first order concern when using unit value as a proxy for price. We review the Deaton model of quantity and quality demand in Section 3, using this structure in Section 4 to discuss the effect of quality substitution on estimates of price elasticity. We introduce our primary data source, the Work and Iron Status Evaluation, in Section 5. In Section 6, we exploit the presence of both unit value and price in this data to directly estimate the nature of quality effects, to compare estimates obtained using the Deaton Method with those obtained in an unrestricted model, to test the restriction imposed on quality responses by weak separability, and to assess the common practice of assuming no quality effects when estimating a demand system with price observed. Section 7 summarizes our conclusions.

2 Application: Inflation

Perhaps the most fundamental application of price data is measuring the cost of living, which is necessary in gauging the real value of a given level of household resources. Such data are key when comparing the incomes of households that live in different environments or at different times, and is thus essential for measuring per capita income growth and for analyzing the extent and distribution of world poverty. When measuring the cost of living, one would ideally have prices for an extensive set of commodities representing all domains of household expenditure. These commodities should also be well defined, ensuring that the difference between two prices obtained at different times or in different regions captures variation in the price of the commodity, rather than variation in the characteristics of the commodity.

When such high quality price data are not available, one alternative is to use unit value data from a budget survey. Despite the aforementioned risks of this approach, unit values typically have several advantages over price data that make them appealing even when price data are available. One such advantage is that budget surveys generally have greater geographic dispersion and are representative at a finer geographic level, whereas price data often only measure prices in large markets and urban centers. Consequently, when merging budget data with prices, it is often necessary to aggregate expenditures to a larger geographic level and/or discard observations that are outside the scope of the price survey sampling scheme. Another advantage to unit value data is that one can look at differences in the prices paid by subgroup, allowing one to see how prices have changed for the quality of goods actually consumed by the group.[2] These advantages have been pointed out and exploited by several recent papers (Deaton and Tarozzi, 2000; Deaton et al., 2004).

Deaton (1988) concludes that unit values can serve as a useful proxy for price when measuring price elasticity, and it is tempting to conclude that prices can similarly be used as a measure of the cost of living. In this section, however, we demonstrate that unit values are not always an ideal proxy for prices. Matching unit value and price data from Indonesia, we show that quality effects are substantively large, are consistent with a simple model of quality substitution, and that this effect has serious consequences when using unit values to calculate inflation.

In order to assess whether unit value serves as a useful proxy for price, we merge prices by city/commodity from the 1999 and 2002 Urban Consumer Price Surveys (Survei Harga Konsumen, HK Series) with unit values from the 1999 and 2002 National Socio-Economic Household Surveys (Survei Sosial Ekonomi Nasional, Susenas).[3] We obtain a sample of over

[2]Of course, if groups respond to price changes by changing the quality consumed, or if there is an exogenous trend in quality, then this asset (that unit value measures price for the quality consumed) is also its greatest liability.

[3]The HK price series is a survey of prices at markets in 27 provincial capitals and 17 other large Indonesian cities. Several hundred prices are obtained from markets in each of these cities, with field workers collecting price information from three to four outlets for each commodity. Prices are obtained for very specific brands and quality levels, in order to mitigate the possibility that regional or temporal price variation is due to changes in quality.

Susenas is a household survey administered each year to a nationally representative cross-section of roughly 200,000 Indonesian households. Every third year, an expenditure module is administered to a sub-sample of approximately 60,000 households. This module collects expenditure for approximately 300 commodity groups and additionally collects quantity consumed for roughly 200 of the food, tobacco, and fuel commodity groups.

To make the geographic level of the Susenas and HK Series data comparable, we compute the average Susenas unit value for each commodity in each city. Since the HK Series is an urban price survey, we restrict the Susenas sample to households living in those cities included in the HK sample. Similarly, we drop several cities from the HK Series data that are not represented in Susenas. In both the Susenas and HK Series data, we drop commodities that have a null or missing price in either 1999 or 2002. Finally, we merge Susenas to the HK Series by city and commodity and calculate inflation rates using both price and unit value data.

2,800 city-commodities that appear in both Susenas and HK-Series. Note that HK-Series prices are obtained for particular products and quality levels, so the HK-Series price for a particular quality of good (for example, the price for a pack of Marlboro Reds) is matched with the unit value for a broader class of goods (for example, the average expenditure per pack of White Tobacco Cigarettes).

Figure (1) shows the result of this merge, graphing the (log ratio) unit value increase for each commodity group against the (log ratio) price increase of the corresponding commodity. Note that the log ratio of unit values and log ratio of prices are positively correlated, with a statistically significant slope of .39. This indicates that the unit values do indeed capture some of the variation in price. Note that the relationship is not perfect, however, and the slope is significantly less than one. This is consistent with an intuitive model of quality substitution in which individuals respond to an increase in the price of chicken, for example, by substituting to lower quality cuts of chicken meat — resulting in unit value changes that understate the true price changes. To see this, note that those city-commodities with higher than average inflation typically lie below the 45°line, indicating that the increase in price is larger than the increase in unit values. Similarly, those city-commodities with lower than average inflation typically lie above the 45°line, indicating that the decrease in price is larger than the increase in unit values.

Given that the goods that appear in both surveys only represent 45% of expenditures for the average household, and given that these commodities are not randomly selected, it is clear that unit values will not do a good job of measuring the overall inflation rate — but will unit values do a good job of measuring inflation for the sample of goods that appear in both surveys? To answer this question, inflation rates are calculated using both unit values and prices for the 2,800 city-commodities that appear in both surveys (Table 1). Comparing the unit value inflation rates to the price inflation rates for this sample of city-commodities, we find that the the unit value inflation rates are 12% and 28% higher for the Paasche and Laspeyres methods, respectively.

Initially, it may be surprising that the unit value inflation rates are higher than the

Not all city-commodities can be matched. One reason is that the HK Series price data is missing for some commodities in some cities. Another reason is that the HK Series includes a far more detailed list of commodities, many of which are only represented in Susenas by an other-category (e.g., other fruits, other vegetables, other consumables). Finally, while Susenas collects expenditure data for a wide array of goods, the calculation of unit values requires quantity data, which is only available for food, cigarettes, and fuel. The net effect is to create a sample of city-commodities for which the price increases are smaller than average; while the average increase for all unit values is 21.4% and the average increase in prices is 23.7%, these averages are 18.7% and 16.7% for the sample of city-commodities that appear in both surveys.

price inflation rates for the sample of city-commodities in both surveys, given our prior that changes in unit values will typically understate changes in prices. The explanation for this is that food, which is heavily over-represented in the sample of commodities in both surveys, actually became relatively cheaper over this time period. Official BPS inflation figures indicate that food prices increased by 6.9% over this period, while the overall inflation rate was 24.6%. The unit value is thus understating the price decrease.

This is not to say that unit value inflation will always overstate true inflation. Indeed, given that unit values are generally not obtained for all commodities, the direction of the bias will depend on the commodities for which unit values are available, on the degree of quality substitution for these goods, and on the change in the cost of these goods relative to changes in the cost of other goods. This direct comparison of changes in unit values with changes in prices provides evidence that quality substitution is likely to bias inflation rates calculated using unit values as a proxy for price, and suggests that caution should be exercised when using unit values to measure inflation.

These results also beg a broader question: why would unit values serve as a useful proxy for price when calculating price elasticity, but result in bias when used to calculate inflation rates? One possibility is that price elasticities are simply less sensitive to quality substitution. Another possibility is that the identifying assumptions of the Deaton Method underestimate the quality effect and thus understate the bias resulting from quality substitution. The remainder of this paper will use another Indonesian data source that has both price and unit value data to explore this issue.

3 Model

We begin with a discussion of of the Deaton model of quality and quantity demanded, in order to highlight the role of the assumption of weakly separable commodity groups in identifying quality effects. Following Deaton (1988), we assume that commodities are divided into groups, each consisting of a number of consumption goods. In practice, a group may be quite broad (meat products) or relatively narrow (cooking oils). Household expenditure for group c is given by:

$$E_c = p_c \cdot q_c \tag{1}$$

where p_c and q_c are vectors containing the price and quantity of each consumption good in that group. This price vector can be written as:

$$p_c = \lambda_c p_c^* \tag{2}$$

where p_c^* is a vector capturing the relative price of commodities within the group and λ_c is a scalar capturing the component of price that is common to all commodities in the group. Since the relative prices of commodities within a commodity group will be unknown in our empirical analysis, a key assumption in estimating commodity group price elasticities is that p_c variation is dominated by variation in λ_c rather than variation in p_c^*.

Substituting Equation (2) into Equation (1) we can write group expenditure as:

$$E_c = \lambda_c p_c^* \cdot q_c \tag{3}$$

Multiplying and dividing the right hand side by total group c consumption, $Q_c = \mathbf{1} \cdot q_c$, the sum of all elements in q_c, we obtain:

$$E_c = \lambda_c \frac{p_c^* \cdot q_c}{Q_c} Q_c$$

Let $v_c \equiv \frac{p_c^* \cdot q_c}{Q_c}$, which is a measure of the quality of group c consumption. To see this, hold relative prices within the group (p_c^*) constant. If v_c is higher for one household than another, then the first household is spending more per unit of group c consumption. We interpret this as buying a higher quality of group c goods. Our goal is to develop an expression for the price elasticity of quality demanded for a group ($\frac{\partial \ln v_c}{\partial \ln \lambda_c}$).

Given this definition of quality, group expenditure (E_c) can now be written as the product of group c price (λ_c), quality of the group (v_c), and quantity (Q_c):

$$E_c = \lambda_c v_c Q_c \tag{4}$$

Similarly, since the unit value for group c is group expenditure divided by group consumption ($V_c = \frac{E_c}{Q_c}$), the unit value can be written as the product of price and quality:

$$V_c = \lambda_c v_c \tag{5}$$

This equation captures the fundamental complication with using unit value as a proxy for price when estimating price elasticity. Since unit value is a measure of both price and quality, in order to derive price elasticity from the relationship between quantity and unit value, one must also understand the relationship between price and quality. This concept can be expressed formally:

$$\epsilon_p = \frac{\partial \ln Q_c}{\partial \ln \lambda_c} = \frac{\partial \ln Q_c}{\partial \ln V_c}\frac{\partial \ln V_c}{\partial \ln \lambda_c} = \frac{\partial \ln Q_c}{\partial \ln V_c}\left(1 + \frac{\partial \ln v_c}{\partial \ln \lambda_c}\right) \tag{6}$$

When price is observed, the relationship between unit value and price can be directly estimated, a topic that will be discussed at greater length in the next section. When price is unobserved, however, it is impossible to estimate the price elasticity without imposing more structure on the way in which price changes influence quality demanded.

Deaton (1988) imposed this structure via the assumption that utility is weakly-separable with respect to commodity groups. Weak separability implies that the household utility maximization can be modeled as a two stage process. In the first stage, households select optimal spending on each commodity group (E_c) given total resources (x) and prevailing prices (p). In the second stage, households allocate spending among goods within each consumption group (q_c), and this decision depends only on the resources allocated to that group (E_c) and the prices of goods in that group (p_c). Thus, under weak separability, Marshallian demand can be written as:

$$q_c = f_c(E_c, p_c) \tag{7}$$

Note that prices of other commodity groups have no direct impact on q_c, although they may affect the optimal E_c, thus impacting q_c through an income effect. Substituting Equation (2) into Equation (7) we obtain:

$$q_c = f_c(E_c, \lambda_c p_c^*)$$

Since demand functions are homogeneous of degree zero, this can be written as:

$$q_c = f_c(\frac{E_c}{\lambda_c}, p_c^*)$$

Accordingly, changes in λ_c impact the distribution of goods consumed in group c with exactly the same structure as an (inverse) income effect. The only complexity is that a change in λ_c also influences E_c:

$$\frac{\partial \ln q_c}{\partial \ln \lambda_c} = \frac{\partial \ln q_c}{\partial \ln(\frac{E_c}{\lambda_c})}\frac{\partial \ln(\frac{E_c}{\lambda_c})}{\partial \ln \lambda_c} = \frac{\partial \ln q_c}{\partial \ln E_c}\left(\frac{\partial \ln E_c}{\partial \ln \lambda_c} - 1\right)$$

so the income effect has both an indirect component (caused by the dependence of E_c on λ_c) and a direct component.

Since quality (v_c) is determined by the distribution of goods consumed in the group c (q_c), a similar relationship holds for the price elasticity of quality:

$$\frac{\partial \ln v_c}{\partial \ln \lambda_c} = \frac{\partial \ln v_c}{\partial \ln E_c}\left(\frac{\partial \ln E_c}{\partial \ln \lambda_c} - 1\right) \tag{8}$$

Estimating price elasticity using this formula is complicated by the appearance of E_c, since this variable is endogenous to the model. To substitute E_c out of this equation, first recall that, due to two-stage budgeting, an increase in household resources is first allocated amongst the commodity groups, and this increase in the resources for commodity group c in turn affects quality. That is:

$$\frac{\partial \ln v_c}{\partial \ln E_c}\frac{\partial \ln E_c}{\partial \ln x} = \frac{\partial \ln v_c}{\partial \ln x}$$

Dividing both sides by: $\frac{\partial \ln E_c}{\partial \ln x}$:

$$\frac{\partial \ln v_c}{\partial \ln E_c} = \frac{\frac{\partial \ln v_c}{\partial \ln x}}{\frac{\partial \ln E_c}{\partial \ln x}} \tag{9}$$

Now recall from Equation (4) that E_c is the product of price, quality, and quantity or, in terms of natural logs:

$$\ln E_c = \ln \lambda_c + \ln v_c + \ln Q_c \tag{10}$$

Taking the derivative with respect to $\ln x$ (since $\ln x$ has no effect on $\ln \lambda_c$):

$$\frac{\partial \ln E_c}{\partial \ln x} = 0 + \frac{\partial \ln v_c}{\partial \ln x} + \frac{\partial \ln Q_c}{\partial \ln x} \tag{11}$$

Substituting Equation (11) into Equation (9), we have:

$$\frac{\partial \ln v_c}{\partial \ln E_c} = \frac{\frac{\partial \ln v_c}{\partial \ln x}}{\frac{\partial \ln v_c}{\partial \ln x} + \frac{\partial \ln Q_c}{\partial \ln x}} \tag{12}$$

which gives us an expression for $\frac{\partial \ln v_c}{\partial \ln E_c}$ in terms of exogenous variables.

It is also empirically convenient to eliminate the other appearance of E_c from Equation (8). An expression for $\frac{\partial \ln E_c}{\partial \ln \lambda_c}$ can be obtained by again taking the derivative of Equation (10), this time with respect to $\ln \lambda_c$:

$$\frac{\partial \ln E_c}{\partial \ln \lambda_c} = 1 + \frac{\partial \ln v_c}{\partial \ln \lambda_c} + \frac{\partial \ln Q_c}{\partial \ln \lambda_c} \tag{13}$$

Substituting Equations (12) and (13) into Equation (8) and simplifying, we obtain this equation for the elasticity of quality demanded with respect to price:

$$\frac{\partial \ln v_c}{\partial \ln \lambda_c} = \frac{\frac{\partial \ln v_c}{\partial \ln x}\frac{\partial \ln Q_c}{\partial \ln \lambda_c}}{\frac{\partial \ln Q_c}{\partial \ln x}} \tag{14}$$

This is the key insight of the Deaton Method; if commodity groups are weakly separable, then the relationship between quality and price can be imputed from the income elasticity of quality and quantity and and the price elasticity of quantity.

4 Methodology

We now introduce four methods for estimating price elasticities. One method (Standard Unit Value Method) uses unit values as a proxy for price and assumes zero quality effects, thus ignoring the possibility of quality substitution. The second method (Deaton Method) uses the structure imposed by weak separability to impute quality effects. A third method (Standard Price Method) uses price data, but must still assume zero quality effects since budget share is used as the dependent variable. Finally, we propose a method (Unrestricted Method) that uses the relationship between unit value and price to directly estimate quality effects.

4.1 Standard Unit Value Method

A standard method for estimating price elasticity using unit values prior to Deaton (1988) was to regress quantity on unit value:[4]

$$w_{ci} = \alpha_0 + \beta_0 x_i + \gamma_0 \cdot z_i + \phi_0 \ln V_{ci} + u_{0i} \tag{15}$$

where i indexes the household, w_{ci} is the the budget share $(\frac{Q_{ci}V_{ci}}{x_i})$, and z_i is a vector of household characteristics. Converting from budget shares to quantities by noting that $\frac{\partial \ln V_c}{\partial \ln V_c} = 1$ and $\frac{\partial \ln x}{\partial \ln V_c} = 0$, we have:

$$\frac{\partial \ln Q_c}{\partial \ln V_c} = \frac{\partial \ln \frac{Q_c V_c}{x}}{\partial \ln V_c} - 1 = \frac{\partial \ln w_c}{\partial \ln V_c} - 1 = \frac{\frac{\partial w_c}{\partial \ln V_c}}{w_c} - 1$$

[4]Here we follow the convention adopted by Deaton (1988) and most demand system estimation in using budget share as the dependent variable.

Substituting this into our equation for the price elasticity (Equation 6) gives us:

$$\epsilon_p = \frac{\partial \ln Q_c}{\partial \ln \lambda_c} = \left(\frac{\frac{\partial w_c}{\partial \ln V_c}}{w_c} - 1 \right) \left(1 + \frac{\partial \ln v_c}{\partial \ln \lambda_c} \right) \tag{16}$$

Thus, if one is willing to assume that quality is completely unresponsive to price changes ($\frac{\partial \ln v_c}{\partial \ln \lambda_c} = 0$), then one can estimate price elasticity using only a regression of budget share on unit value:[5]

$$\hat{\epsilon_p^1} = \frac{\hat{\phi_0}}{\bar{w_c}} - 1 \tag{17}$$

This method will be called the Standard Unit Value Method for the remainder of this paper. If quality demanded is responsive to price changes, then this method will produce biased price elasticity estimates. Assuming that w_c is linear in V_c, then the bias at the mean can be seen in the following equation:

$$E(\hat{\epsilon_p^1} | w_c = \overline{w_c}) = \left(\frac{\frac{\partial w_c}{\partial \ln V_c}}{\overline{w_c}} - 1 \right) = \frac{\epsilon_p}{1 + \frac{\partial \ln v_c}{\partial \ln \lambda_c}} \tag{18}$$

4.2 Deaton Method

As discussed in the previous section, Deaton (1988) proposes an alternative solution to the problem of estimating price elasticity when price is unobserved. By assuming that commodity groups are weakly separable, considerable structure is imposed on the nature of quality responses to price changes. Substituting Equation (14) into Equation (16) we obtain:

$$\frac{\partial \ln Q_c}{\partial \ln \lambda_c} = \left(\frac{\frac{\partial w_c}{\partial \ln V_c}}{w_c} - 1 \right) \left(1 + \frac{\frac{\partial \ln v_c}{\partial \ln x} \frac{\partial \ln Q_c}{\partial \ln \lambda_c}}{\frac{\partial \ln Q_c}{\partial \ln x}} \right) \tag{19}$$

Solving for $\frac{\partial \ln Q_c}{\partial \ln \lambda_c}$, this provides a method for estimating price elasticity under the assumption of weak separability. Deaton (1988) recommends a two stage process to estimate the parameters for this equation. First, $\frac{\partial \ln v_c}{\partial \ln x}$ and $\frac{\partial \ln Q_c}{\partial \ln x}$ are estimated using a simultaneous equations model:

$$w_{ic} = \alpha_1 + \beta_1 x_i + \gamma_1 \cdot z_i + f + u_{1i}$$

[5] As Deaton (1988) points out, estimation of ϕ_0 is complicated by the fact that, since unit value is group expenditure divided by consumption, measurement error in quantity consumed will induce a structural correlation between w_c and V_c. Consequently, when estimating this method, we will actually employ the correction suggested by Deaton to rule out the possibility of bias due to measurement error and maintain focus on the role of quality effects.

$$\ln V_{ic} = \alpha_2 + \beta_2 x_i + \gamma_2 \cdot z_i + f + u_{2i}$$

where f is a community level fixed effect. Next, $\frac{\partial w_c}{\partial \ln V_c}$ is estimated by aggregating the (fitted) budget shares and unit values to the cluster level:[6]

$$\tilde{w_c} = \alpha_3 + \phi_3 \tilde{\ln V_c} + u_3$$

where $\tilde{w_c}$ and $\tilde{\ln V_c}$ are the cluster average fitted budget shares and unit values, respectively.

4.3 Standard Price Method

Note that, even when price is observed, elasticities estimated using a regression of budget share on price still implicitly assume that price changes have no impact on quality:[7]

$$w_{ci} = \alpha_4 + \beta_4 x_i + \gamma_4 \cdot z_i + \theta_4 \ln \lambda_{ci} + u_{4i} \tag{20}$$

Converting from budget shares to quantities by noting that $\frac{\partial \ln x}{\partial \ln \lambda_c} = 0$ gives us:

$$\begin{aligned}
\epsilon_p = \frac{\partial \ln Q_c}{\partial \ln \lambda_c} &= \frac{\partial \ln \frac{Q_c V_c}{x}}{\partial \ln \lambda_c} - \frac{\partial \ln V_c}{\partial \ln \lambda_c} = \frac{\partial \ln w_c}{\partial \ln \lambda_c} - \frac{\partial \ln V_c}{\partial \ln \lambda_c} \\
&= \frac{\frac{\partial w_c}{\partial \ln \lambda_c}}{w_c} - \frac{\partial \ln V_c}{\partial \ln \lambda_c} = \frac{\frac{\partial w_c}{\partial \ln \lambda_c}}{w_c} - 1 - \frac{\partial \ln v_c}{\partial \ln \lambda_c}
\end{aligned} \tag{21}$$

Thus, if one is willing to assume that quality is completely unresponsive to price changes ($\frac{\partial \ln v_c}{\partial \ln \lambda_c} = 0$), then one can estimate price elasticity using only a regression of budget share on price:

$$\hat{\epsilon_p^3} = \frac{\hat{\theta_4}}{\bar{w_c}} - 1 \tag{22}$$

This method will be called the Standard Price Method for the remainder of this paper. Again, if quality demanded is responsive to price changes, then this method will also produce biased

[6] The second stage is not ordinary least squares, as Deaton uses the correlation between the first stage residuals to estimate the severity of the measurement error, adjusting the second stage estimates to correct for the structural correlation between quantity and unit value.

[7] If both quantity consumed and community price data are available, then it is possible to obtain price elasticities from a simple regression of log quantity on log price without making assumptions about the relationship between price and quality. However, such data is not available in budget surveys that elicit total expenditure, quantity obtained *in the last transaction*, and total paid *in that transaction*. Even when total quantity consumed is available, it may be desirable to estimate quality elasticity in situations where the policy analyst cares about the quality level consumed. For example, when higher quality goods have higher nutritional value, and one may be interested in the impact of a price change on quality consumed.

price elasticity estimates. Assuming that w_c is linear in λ_c, then the bias at the mean can be seen in the following equation:

$$E(\hat{\epsilon_p^3}|w_c = \overline{w_c}) = \frac{\frac{\partial w_c}{\partial \ln \lambda_c}}{\overline{w_c}} - 1 = \epsilon_p + \frac{\partial \ln v_c}{\partial \ln \lambda_c} \tag{23}$$

4.4 Unrestricted Method

Of course, with prices and unit values observed, there is no need to assume that quality is completely unresponsive, as this relationship can now be directly estimated:

$$w_{ic} = \alpha_5 + \beta_5 x_i + \gamma_5 \cdot z_i + \theta_5 \ln \lambda_c + u_{5i} \tag{24}$$

$$\ln V_{ic} = \alpha_6 + \beta_6 x_i + \gamma_6 \cdot z_i + \theta_6 \ln \lambda_c + u_{6i} \tag{25}$$

Estimation of these equations provide us with estimates of all the parameters necessary for the estimation of Equation (21):

$$\hat{\epsilon_p^4} = \frac{\hat{\theta}_5}{\bar{w}_c} - \hat{\theta}_6$$

This method will be called the Unrestricted Method for the remainder of this paper.

5 Data

The data used for this paper are from the Work and Iron Status Evaluation (WISE), an ongoing study assessing the effect of a randomly assigned iron supplementation on health, productivity, and income (Thomas et al., 2004). The study site is located in the Purworejo District of Central Java, Indonesia. This district is primarily agricultural, and is located on the southern coast of Java near Yogyakarta.

One component of WISE is a detailed longitudinal household and individual survey. This survey was first administered in the first four months of 2002, at which point the sample consisted of approximately 4,600 households. These households were reinterviewed every four months for two years. The survey contains a “short” consumption module which collects information on food purchased and food produced at home for own consumption for 14 food groups and 11 non-food groups. If a purchase was made within the past month, the survey also collects the quantity purchased and the amount paid in the last purchase for seven commodities: rice, tempe, chicken, water spinach, cassava leaves, cooking oil, and sugar.

Unit values will be calculated for these commodities.[8]

Another component of WISE is a price survey administered to a sample of shops, stalls, and community informants. This survey is administered every three months in each WISE community.[9] Prices are collected for many commodities, including the seven commodities listed above: rice, tempe, chicken, water spinach, cassava leaves, cooking oil, and sugar. The simultaneous collection of price and expenditure in these communities present a unique opportunity to test the identification of the Deaton Method.

In order to ensure that prices are obtained for a consistent good, it is desirable to collect prices for particular brands, qualities, and package sizes. A drawback of this technique, however, is that it will result in many missing values if the particular commodities sought are not universally available. For the WISE price survey, we implemented the following technique in order to ensure product consistency without a corresponding increase in missing data. First we look for the price of a well specified commodity, but when the target commodity cannot not be located we look for the price of a series of pre-specified substitute goods of similar quality. This procedure results in price data with both low quality variation and few missing values. In order to further ensure that price data was free of variation due to differenes in the quality or quantity purchased, prices are first regressed on product characteristics and purged of explained variation.

Community average prices are calculated for each community for each wave of the price survey. These prices are made real using the regional price index available from Badan Pusat Statistik (BPS).[10] Monthly prices are interpolated for the months between price surveys and these prices are then merged onto the household data by community and month.

Given that the price survey is only administered in the communities selected for the WISE sample, we do not have price data for those households that moved away from these communities. Consequently, these households are dropped from the analyses for all waves in which they live outside a WISE community. Though attrition may result in biased estimates of the price elasticity, these households are excluded from all the analyses in this paper, and thus do not explain the statistical differences observed between the various estimation

[8]Since results for water spinach and cassava leaves are quite similar, we aggregate these two vegetables together for all the tables in this paper.

[9]Prices are also obtained from markets every three months, but this paper uses only the shop, stall, and informant data. The reason for this is that market data is not at the community level, as markets do not exist in every community.

[10]Unfortunately BPS renormed their price index in January 2004. We join the old and new price indices under the assumption that the change in commodity baskets does not have a significant impact on the price trends.

strategies.

6 Results

We begin by examining elasticities estimated using methods that assume no impact of price changes on quality consumed. For an overview of all identification strategies, see Table (2).

The Standard Unit Value Method regresses budget share on unit value, as in Equation (15), and uses Equation (17) to calculate price elasticity under the assumption that $\frac{\partial \ln v_c}{\partial \ln \lambda_c} = 0$. This method is typical of the papers that used budget data to estimate price elasticities prior to Deaton (1988).[11] Results from this method appear in the first column of Table (3).

The Standard Price Method regresses budget share on community price, as in Equation (20), and uses Equation (22) to compute the price elasticity under the assumption that $\frac{\partial \ln v_c}{\partial \ln \lambda_c} = 0$. This method is a simple representation of the common practice of estimating demand systems with budget share as the dependent variable, implicitly assuming zero quality effects. Results from this method appear in the second column of Table (3).

In this table we see that both standard methods produce estimates of price elasticity that fall in a sensible range, with point estimates between -0.20 and -1.01. Recall that when there is no quality response to price changes, the two standard methods should produce identical results. Reading across the table we see that, at least for some commodities, this is clearly not the case. The third column contains the difference between the price elasticities produced by the two methods and for three of the six commodities (Cooking Oil, Sugar, and Vegetables) the difference is statistically significant. Moreover, from Equations (18) and (23), we know that if individuals respond to price increases by substituting to lower quality goods, then we would expect the estimates from the Standard Price Method to be less than those from the Standard Unit Value Method. This prediction holds, at least for those commodities where price elasticity from the two methods is statistically different. This is an early indication of the importance of allowing for price induced quality responses when calculating price elasticities.

The fact that $\frac{\partial \ln v_c}{\partial \ln \lambda_c} \neq 0$ is further borne out by graphing $\ln V_c$ on $\ln \lambda_c$, shown in Figure (2). While there is a positive relationship between $\ln V_c$ and $\ln \lambda_c$, at least for some commodities,

[11] In estimating the Standard Unit Value Method, however, we employ the same measurement error correction as used in the Deaton Method to eliminate the possibility of bias due to a structural correlation between unit value and quantity

the slopes are less than one. These graphs are consistent with the hypothesis that households substitute to lower quality goods as price increases.

Deaton (1988) was the first paper to point out the potential for quality effects and to introduce a technique to correct for these effects. By assuming that commodity groups are weakly separable, the Deaton Method is able to impute the quality response to price changes from the quality response to income changes. The Deaton Method estimates of the impact of a price change on quality are displayed in the first column of Table (4). Note that the quality effects imputed using this technique are not universally statistically significant and, even for those commodities that do have statistically significant quality responses, with the exception of rice these effects are substantively quite small.

Exploiting the fact that our data source contains information on both price and unit value, we can also directly estimate the relationship between price and quality demanded. Estimates of the quality effect obtained from the Unrestricted Method are displayed in the second column of Table (4). Note that our method yields large quality effects using the Unrestricted Method. These quality effects are statistically significant from zero for all commodities but rice, and they are statistically different from the quality effects obtained using the Deaton Method for all six commodities. For example, chicken has a quality elasticity that is precisely estimated and close to zero under the Deaton Method. Using the Unrestricted Method, however, we find that a 100% increase in the price of chicken results in a (statistically significant) 58% decrease in the average price paid per kilogram of chicken.

Given the central role of quality effects in computing the price elasticities, these dramatic quality effect differences translate into large differences in the resulting price elasticities. Price elasticities for the Deaton and Unrestricted Methods are shown in columns four and five of Table (4), with the difference between the two methods given in column six. The difference between the two methods is statistically significant for all commodities but cooking oil. Again using chicken as our example, we see that the Deaton Method produces a price elasticity of -0.98, while the Unrestricted Method produces a price elasticity that's statistically insignificant from zero. Note that, given the small quality effects produced by the Deaton Method, price elasticities generated using this technique are nearly identical to those obtained when no quality adjustments are made.

That quality elasticities estimated from a regression of unit value on price are dramatically different from those obtained using the Deaton method suggests that the assumption of weakly separable commodity groups may not produce reliable estimates of quality substitution. In order to assess this possibility, we can check whether the parameter estimates obtained in the Unrestricted Method satisfy the restriction implied by weak separability (Equation 14). Recalling the notation of Equation (24) and Equation (25), the null hypothesis can be stated as:

$$\theta_6 - 1 + \left(\frac{\beta_6(\frac{\theta_5}{w_c} - 1)}{1 + \frac{\beta_5}{w_c}} \right) = 0$$

The left hand side of this equation is estimated directly and presented in Table (5). These differences are statistically different from zero for all commodities. We thus strongly reject the quality effect restrictions implied by weak separability.

The panel structure of WISE has enabled this analysis to use both regional and temporal price variation to pin down the effect of price changes on quantity and quality demanded. However, given that the Deaton Method was originally proposed for the analysis of cross-sectional data, one may be concerned that the observed differences between the Deaton and Unrestricted Methods are due to the fact that regional price variation is in some way better suited for the identification of quality and quantity demand. In order to address this concern, a similar analysis was conducted that used time fixed effects to identify quality and quantity elasticities using only cross-sectional price variation (results are available upon request). Despite the reduced price variation, the results from this specification check lead to similar conclusions. Comparing the Deaton Method with the Unrestricted Method we find four commodities that have statistically different quality effects and three commodities with statistically different price elasticities. Furthermore, we are able to reject the restriction implied by weak separability for all six commodities.

The large quality effects observed in the data have implications that go beyond the usefulness of unit values as a proxy for price. When demand systems are estimated by regressing budget shares on prices, quality effects may impair our ability to estimate price elasticities even when price is perfectly observed. This is because, if price changes influence both quantity and quality demanded, then it will not be possible to determine whether a price increase causes a decrease in budget share due to a decrease in the quality consumed or due to a decrease in the quantity consumed. Prevailing demand system estimation implicitly assumes that all correlation is caused by quantity variation. The key feature of having both price and unit value data is that it is no longer necessary to make such an assumption. Results from the Standard Price Method are contrasted with those from the Unrestricted Method in Table (6). The elasticities produced by the Unrestricted Method, which uses the relationship between price and unit value to directly estimate the magnitude of the quality effect, are statistically different from those produced using the Standard Price Method for all commodities but rice, suggesting that current practice may not be robust to quality effects. Future work will test this hypothesis in the context of a more elaborate demand system.

7 Conclusion

There are several conclusions that can be drawn from the results in this paper. At the most basic level, our results raise concerns about the use of unit value as a proxy for price without correcting for quality effects. We have created an example of this by comparing unit values from a large Indonesian expenditure survey with prices from a corresponding price survey, showing that changes in unit values overestimate price changes for commodities that are becoming relatively less expensive — a pattern consistent with a simple model of quality substitution. This example suggests that unit values may produce biased estimates of the inflation rate, and that the direction and magnitude of this bias will be impossible to determine without prior knowledge of the true inflation rate. Moreover, using data from the Work and Iron Status Evaluation, we estimate large quality effects and find that, when one makes no effort to correct for these effects, unit values and prices yield quite different price elasticities. We conclude that quality effects are substantively and statistically significant and that care should be used in using unit values as a proxy for price without explicitly modeling the nature of quality effects.

A second set of conclusions can be drawn by comparing price elasticities obtained using the Deaton Method with those obtained from our Unrestricted Method. Using the structure imposed on quality effects by the assumption of weakly separable commodity groups, the Deaton Method produces estimates of quality responses that are quite small and often statistically insignificant from zero. Exploiting a data source that contains data on both price and unit value, we have shown that these estimates are inconsistent with the observed relationship between price and unit value. Consequently, quantity and quality elasticity estimates obtained with the Unrestricted Method are quite different than those obtained using the Deaton Method and the restriction implied by the assumption of weakly separable commodity groups is strongly rejected.

Our results suggest that the assumption of weak separability may not be appropriate, at least not for these these six commodities in rural Java. A rejection in this context is particularly compelling, as some of these commodity groups are quite homogeneous and rural Java is not an environment in which we would expect to see a great deal of quality variation. More research is needed to determine if similar results would be obtained for other commodities and in other cultures. Regardless, we conclude that less context specific methods for identifying price effects are needed. Given that the development of such methods will require high quality price data, these results underscore the importance of integrating community price data collection into household budget surveys.

A final, broader conclusion to be taken from this paper is that quality substitution has the potential to cause problems when estimating demand systems *even when price is observed*. The reasons for this are that demand systems typically use budget share as the dependent variable, that budget share is a measure of both quality and quantity, and that price may influence both quality and quantity demanded. Consequently, to the extent that quality effects do exist, they will impair the econometrician's ability to separately identify the price elasticity of *quantity* demanded from the price elasticity of *quality* demanded. One possible solution is to use many narrowly defined commodities when estimating demand systems.[12] An alternative solution is to focus greater resources on surveys that collect both price and unit value. Indeed, the central argument of this paper is that, when using data sources that elicit *both* price and unit value, it is possible to directly measure the relationship between price and quality and, consequently, to separately identify quality and quantity responses.

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[12] This solution is not particularly appealing, as it increases the dimensionality of the demand system and, thus, increases the number of goods for which households report zero consumption.

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Table 1: Unit Value versus Price Inflation

Goods In Both Susenas and HK-Series			
	Price	Unit Values	% Diff
Unweighted	18.7%	16.7%	18%
Paasche	12.7%	16.2%	12%
Laspeyres	14.9%	17.5%	28%
N		2,862	

Table 2: Overview of Empirical Strategies

	Theoretical Restriction	**Empirical Implementation**	**Estimate of Price Elasticity**
Standard Unit Value Method	No Quality Response	$w_{ci} = \alpha_0 + \phi_0 V_{ci} + u_{0i}$	$\hat{\epsilon_p^1} = \frac{\hat{\phi_0}}{\bar{w_c}} - 1$
Deaton Method	Weakly Separable Commodity Groups	$w_{ic} = \alpha_1 + \beta_1 x_i + \gamma_1 \cdot z_i + f_c + u_{1i}$ $\ln V_{ic} = \alpha_2 + \beta_2 x_i + \gamma_2 \cdot z_i + f_c + u_{2i}$ $\tilde{w}_c = \alpha_3 + \phi_3 \widetilde{\ln V_c} + u_{3c}$	$\hat{\epsilon_p^2} = \left(\frac{\hat{\phi_3}}{\bar{w_c}} - 1\right)\left(1 + \frac{\hat{\beta_2}\hat{\epsilon_p^2}}{\frac{\hat{\beta_1}}{\bar{w_c}} + 1}\right)$
Standard Price Method	No Quality Response	$w_{ci} = \alpha_4 + \theta_4 \lambda_{ci} + u_{4i}$	$\hat{\epsilon_p^3} = \frac{\hat{\theta_4}}{\bar{w_c}} - 1$
Unrestricted Method	None	$w_{ic} = \alpha_5 + \beta_5 x_i + \gamma_5 \cdot z_i + \theta_5 \lambda_c + u_{5i}$ $\ln V_{ic} = \alpha_6 + \beta_6 x_i + \gamma_6 \cdot z_i + \theta_6 \lambda_c + u_{6i}$	$\hat{\epsilon_p^4} = \frac{\hat{\theta_5}}{\bar{w_c}} - \hat{\theta_6}$

Table 3: Price Elasticities: Assuming No Quality Substitution

	(1)	(2)	(3)
Method	**Standard Unit Value**	**Standard Price**	**Difference**
Rice	-0.95	-0.78	-0.17
	(0.05)	(0.10)	(0.09)
Tempe	-1.01	-0.97	-0.04
	(0.05)	(0.02)	(0.04)
Chicken	-0.99	-0.78	-0.21
	(0.14)	(0.25)	(0.26)
Cooking Oil	-0.29	-0.71	0.42
	(0.11)	(0.08)	(0.11)
Sugar	-0.20	-0.34	0.14
	(0.06)	(0.06)	(0.05)
Vegetable	-0.44	-0.92	0.47
	(0.08)	(0.03)	(0.09)

Table 4: Price Elasticities: Allowing for Quality Responses

	Quality Elasticity			**Quantity Elasticity**		
	(1)	(2)	(3)	(4)	(5)	(6)
Method	**Deaton**	**Unrestricted**	**Diff**	**Deaton**	**Unrestricted**	**Diff**
Rice	-0.21	0.29	-0.51	-0.75	-1.21	0.46
	(0.02)	(0.20)	(0.20)	(0.04)	(0.22)	(0.21)
Tempe	-0.08	-0.82	0.73	-0.92	-0.14	-0.78
	(0.02)	(0.04)	(0.05)	(0.04)	(0.04)	(0.06)
Chicken	-0.01	-0.58	0.57	-0.98	0.04	-1.02
	(0.00)	(0.08)	(0.08)	(0.13)	(0.22)	(0.25)
Cooking Oil	0.00	-0.39	0.39	-0.29	-0.27	-0.02
	(0.00)	(0.03)	(0.03)	(0.11)	(0.08)	(0.11)
Sugar	0.00	-0.25	0.26	-0.20	-0.08	-0.12
	(0.00)	(0.03)	(0.03)	(0.06)	(0.07)	(0.05)
Vegetable	0.02	-0.85	0.86	-0.45	-0.03	-0.42
	(0.01)	(0.03)	(0.03)	(0.09)	(0.04)	(0.09)

Table 5: Test of Separability

	Restriction
Rice	-0.51
	(0.20)
Tempe	0.67
	(0.05)
Chicken	0.57
	(0.08)
Cooking Oil	0.39
	(0.03)
Sugar	0.26
	(0.03)
Vegetable	0.84
	(0.03)

Table 6: Price Elasticities: Evaluating the Standard Price Method

	(1)	(2)	(3)
Method	**Standard Price**	**Unrestricted**	**Difference**
Rice	-0.78	-1.21	-0.43
	(0.10)	(0.22)	(0.22)
Tempe	-0.97	-0.14	0.83
	(0.02)	(0.04)	(0.04)
Chicken	-0.78	0.04	0.82
	(0.25)	(0.22)	(0.15)
Cooking Oil	-0.71	-0.27	0.44
	(0.08)	(0.08)	(0.04)
Sugar	-0.34	-0.08	0.26
	(0.06)	(0.07)	(0.04)
Vegetable	-0.92	-0.03	0.89
	(0.03)	(0.04)	(0.03)

Figure 1: Susenas Unit Values and HK Prices

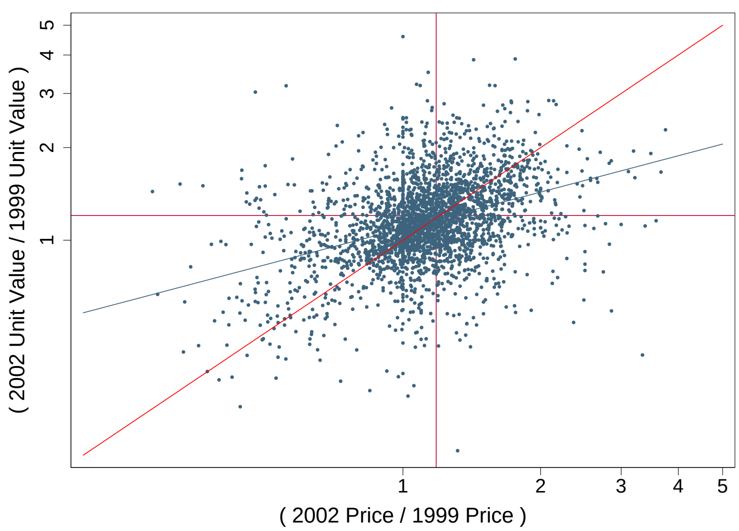

Figure 2: Unit Values and Prices