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Estimating Household Responses to Price Reforms: Trade, Agricultural Income and Labor Supply in Mexico
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Abstract

Economic reforms involving the agricultural sector, such as those being proposed in the WTO Doha Round negotiations, will affect household behavior in developing countries. This paper proposes an empirical methodology to assess the impacts of agricultural price reforms on household outcomes like consumption patterns, sources of income, labor supply, health outcomes, and educational decisions. The method uses an empirical model of demand to extract price information from unit values, and uses this information to estimate the response of households to price changes and price reforms. By correcting unit values for quality effects, the method overcomes the endogeneity and measurement error problems of using unit values as regressors. The methodology is applied to study the responses of household agricultural labor income and labor supply in rural Mexico. I find that higher prices of corn and fruits and vegetables, key goods produced in rural Mexico, significantly increase the agricultural wage income of rural Mexican households. Instead, corn prices do not seem to affect the labor market decision of young adults. It is shown that using unit values instead of prices may lead to inconsistent results, and that the corrections suggested in this paper may be empirically important.

1 Introduction

This paper proposes an empirical method to evaluate price reforms. The method provides an alternative that can be used when natural or quasi experiments (Meyer, 1995) or matching methods (Rosenbaum and Rubin, 1983) are not feasible alternatives. Trade reforms are an example: trade liberalization is often accompanied by other simultaneous reforms and it is often difficult to identify the treatment and control groups. In many instances, in addition, there is an interest, or a need, to explore the effects of a policy that has not yet taken place. The method proposed here accommodates these cases.

Most policy reforms can be linked to price changes. In consequence, one way to evaluate the impacts of economic policies is by estimating the responses of some household behavior to prices and then to link prices with the reforms. Although conceptually attractive, there are several empirical difficulties with this two-step approach. One in the need to estimate structural models so that household responses can be linked to prices through a structural parameter that can be used to simulate policy outcomes.[1] More importantly, there is a need of survey data with sufficient price variation at the household level. This is rarely the case.

The current practice is to proceed with the following alternatives. One is to combine household surveys with official price information. Often times, there is time and regional variation in prices. Examples include Deaton (1997), Porto (2003), Ravallion (1990), and Wolak (1996). In some surveys there are community price questionnaires that provide more variation in prices. Edmonds and Pavcnik papers on Viet Nam are outstanding examples (Edmonds and Pavcnik, 2003, 2004). Another option is to use unit values as measures of prices. In many surveys, households are asked to report expenditures and quantities bought of several goods. The ratio of these quantities, the unit values, provide useful information on prices that can be used to assess price reforms (Balat and Porto, 2004).

The use of unit values in household models has advantages and disadvantages. The main advantage is that, at least for food items, many households provide information on expenditures and quantities, so that unit values are available at the household level. This

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[1] However, even if the parameters are not necessarily structural, there is always something to learn from the causality from prices to behavior.

introduces a lot of cross-sectional variability. However, it has long been argued that unit values are not the same as prices. Deaton (1987), for instance, showed that consumers jointly choose quantity and quality so that unit values combines measures of price and quality. Thus, the use of unit values instead of prices may contaminate the regression model and lead to misleading results in the evaluation of policies.

In a series of seminal papers, Deaton (1987, 1988 and 1990) proposed a methodology to account for the difference between prices and unit values. With the aim of examining tax reforms in developing countries, he applied these methods to estimate demand systems and to recover own- and cross-price elasticities. Deaton's main insight is to model consumer choices of quantity and quality simultaneously in order to extract the right price signals from the data on unit values.

In this paper, I propose a joint estimator of demand price-elasticities and a household outcome price-elasticity (or a household behavior price-elasticity). These parameters could be used to assess a number of policies, including trade liberalization, agricultural reforms, and tax reforms. Suitable household outcomes may include the wage earned by the household head or the agricultural income of different households. Suitable behaviors may include the labor supply of different individuals (including children and women), health status, or education.

The procedure extends the empirical model of demand developed by Deaton by endogenizing how prices determine some household outcome (wage agricultural income) or some household behavior (labor choice, occupational choice). The model of demand allows me to extract price information from unit values, expenditures, and quality choices, as in Deaton's work. My extension shows how to use this price information to estimate the response of household outcomes.

In this paper, I develop the econometric model and I provide the formulas for the general case. After developing the formulas, I put them to work by studying one household outcome and one household behavior in rural Mexico. The household outcome studied here is the response of agricultural wage income to agricultural prices such as corn, wheat, dairy, oils & fats, meat, and fruits & vegetables. The household behavior is the response of the labor

market participation of young adults to those agricultural prices. In order to assess the proposed methodology, I estimate the models of household outcome and household behavior under the assumption that unit values can be correctly used as measures of prices.

I find that higher prices of corn and fruits and vegetables, key goods produced in rural Mexico, significantly increase the agricultural wage income of rural Mexican households. Further, the probability that young adults participate in the labor market depends positively, but not significantly, on the price of corn. It is shown that using unit values instead of prices may lead to inconsistent results, and that the corrections suggested in this paper may be empirically important. Alternative models with partially purged unit values (instead of fully quality corrected unit values) are explored as well. These alternatives, of lower accuracy but easier implementation, seem to work well in practice.

The paper is organized as follows. Section 2 provides a more general motivation of the paper and gives an overview of the methodology. I develop a simplified version of the model with only one good, as in Deaton (1997), to clarify the intuition and the mechanism through which Deaton's method can be extended to identify the effects of price changes on household outcomes. Section 3 develops the full model, with possibly many agricultural prices affecting outcomes. Section 4 applies the method to the Mexican data and reports the empirical results. Section 5 concludes.

2   Motivation

Let's assume that the interest lies in the estimation of the response of agricultural wage income in rural Mexico to the WTO agricultural trade negotiations. The case of Mexico is, in principle, a good case study because of the importance of the agricultural sector and because of the proximity of the country to the United States. More concretely, suppose that the United States and the European Union eliminate production and export subsidies on corn and that, as a result, its international price increases. Corn is a key agricultural good in Mexico and I expect changes in its price to significantly affect outcomes and behavior in rural households. For example, higher corn prices may lead to higher demand for labor

in agricultural activities, such as farm labor and agricultural services. In consequence, the wage agricultural income of rural households may be affected.

A good staring point in the estimation strategy would be to use the Mexican household surveys. These are the Household Income and Expenditure National Surveys, ENIGH (Encuesta Nacional de Ingresos y Gastos de los Hogares).[2] These surveys collect data on expenditure and quantities bought of different agricultural goods, including corn; data on sources of household income is collected, too. Let $\overline{v}_c$ be the average unit value of corn reported by households residing in cluster c. The simplest model would regress agricultural wage income, a_{hc}, on average unit values and additional controls $\mathbf{m}$,

$$(1) \qquad \ln a_{hc} = \alpha + \gamma' \mathbf{m}_{hc} + \lambda \ln(\overline{v}_{gc}) + u_{hc}.$$

In column 1 of Table 1, I report the results of a regression of the agricultural wage income of rural households on a number of household controls (such as household size, demographics, education of the head, and year dummies) and the log of the average unit value spent on corn. I find that a_{hc} is positively and significantly associated with corn prices. The elasticity is 0.75, with a t statistic of 7.6.[3] This is an intuitive result. Since corn is one of the main goods produced in rural Mexico, higher corn prices induce households, farms and firms to devote more resources to corn production and thus labor demand in agricultural activities increases. In the end, the agricultural wage income of rural households will increase.[4]

In column 2 of Table 1, I add the prices of other agricultural goods, such as wheat, dairy, oils & fats, meat and fruits & vegetables. It is still found that the price of corn positively affects agricultural income, with an elasticity of 0.58 and a t statistic of 5.65. Apart from the price of meat, which appears to affect wage agricultural income positively too, the remaining prices are statistically insignificant.

There are three concerns with a regression model such as (1): endogeneity of unit

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[2] See Apendix 1 for a description of the data.

[3] Notice that the standard errors are corrected for clustering since all households in a given cluster face the same averages for the unit values.

[4] Notice that I am estimating equilibrium responses in wage agricultural income. For instace, it may be the case that labor supply increases as a result of higher corn prices, probably causing wages to decline. My findings suggests that, in equilibrium, the upward pressure on wages dominates.

Table 1
Simple Models of Agricultural Wage Income
Using Average Unit Values

| | corn only | | many goods | |
	coef.	std error	coef.	std error
Corn	0.75	(0.09)	0.58	(0.10)
Wheat			−0.05	(0.13)
Dairy			−0.07	(0.06)
Oils & Fats			−0.008	(0.30)
Meat			0.45	(0.20)
Fruits & Vegetables			0.1	(0.18)

Note: estimates from the simple model that uses OLS and average cluster unit values as regressors. The first model includes the price of corn as the only price regressor. The second model includes other agricultural prices. The standard errors (which are cluster corrected) are reported in parenthesis. The regressions include a number of additional controls, such as demographics, education, age, gender and year dummies.

values, bias due to proxy variables, and measurement error. Endogeneity may arise because households choose quantity and quality together; unit values are not a perfect measure of prices. Even when unit values are a good proxy for prices, the model may estimate the vector γ consistently, but λ inconsistently. Measurement error arises if there are inaccurate responses, mainly on quantities consumed. In all these cases, OLS estimation of (1) will lead to inconsistent estimates of the wage agricultural income price-elasticity. The results shown in Table 1 suggest that these problems may indeed be present. Attenuation bias due to measurement error, for instance, may be critical: all the unit value regressors, except for corn and meat, are not statistically significant. Some of these problems could be solved by using an instrumental variable estimator instead of OLS. If finding suitable instruments is difficult, as it probably is since household variation is generally desirable in the instruments, the estimation of (1) will not produce consistent results.

The method proposed in this paper combines a model such as (1), with true unobservable prices instead of average unit values as regressors, with the model of demand and quality shading developed by Deaton (1988). In order to introduce the method, I begin by setting up a simplified version of the model with only one good. No attempt to generality is pursued;

rather, my aim is to provide an intuition for the more difficult formulas derived in Section 3.

The demand for the good is modeled with an equation characterizing budget shares (the implicit assumption is that there are other goods that complete the system). Deaton and Muellbauer (1980) show that a suitable model for the budget share s_{hc} spent by household h in cluster c (a village, for example) is

(2) $\qquad s_{hc} = \alpha_0 + \beta_0 \ln x_{hc} + \gamma_0' \mathbf{z}_{hc} + \theta \ln \pi_c + f_c + u_{hc}^0,$

where x_{hc} is total expenditure, $\mathbf{z}_{hc}$ are household demographic characteristics, such as number of members and demographic composition. π_c is a price level that is assumed to be the same for all households in cluster c; this price is unobservable. f_c is a fixed effect at the cluster level and u_{hc}^0 is a standard error term, with zero mean (for a large number of households in each cluster) and variance σ^{00}.

The endogeneity of unit values may be solved by modeling unit values explicitly. Unit values are not the same as prices; rather, they are function of the price π_c. I assume that

(3) $\qquad \ln v_{hc} = \alpha_1 + \beta_1 \ln x_{hc} + \gamma_1' \mathbf{z}_{hc} + \psi \ln \pi_c + u_{hc}^1.$

Here, unit values v_{hc} are affected by household expenditure x_{hc}. As explained by Deaton, the parameter β_1 is called the "quality elasticity" or the "expenditure elasticity of quality". This parameter β_1 would be zero if there were no quality shading. Demographics $\mathbf{z}_{hc}$ determine unit values, too. The error term u_{hc}^1 has mean zero (for a large number of h in cluster c) and variance σ^{11}. There is no fixed effect in this equation, for identification purposes.

Equations (2) and (3) are modeled exactly as in Deaton (1997). My extension introduces into this model a way to handle the endogenous determination of household wage agricultural income, a_{hc}. I redefine (1) as

(4) $\qquad \ln a_{hc} = \alpha_2 + \gamma_2' \mathbf{m}_{hc} + \lambda \ln \pi_c + u_{hc}^2,$

where $\mathbf{m}_{hc}$ are household characteristics that affect wage agricultural income (probably

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different from the determinants of the budget shares and unit value), such as education, age, or marital status of the income earner; u_{hc}^2 is an error term. There is no fixed effect in this equation either. The coefficient λ measures the price elasticity, or the proportional change in agricultural income brought about by the changes in product prices.

The model is estimated in two stages. If prices π_c were observed, it would be straightforward to estimate the model in (2), (3) and (4). This is a system of equations that can be handled easily with well-known econometric techniques. Prices π_c are not observed though. The identification assumption is that every household in cluster c faces the same prices. This implies that unobserved prices can be controlled for with cluster dummies (which will absorb any fixed effects as well). In the first stage, then, I recover β_0, γ_0, β_1, γ_1 and γ_2 by estimating the model by OLS, after demeaning all variables (s_{hc}, $\ln v_{hc}$, $\ln a_{hc}$, $\ln x_{hc}$, $\mathbf{z}_{hc}$, and $\mathbf{m}_{hc}$) from cluster means.

With estimates $\widehat{\beta}_0$, $\widehat{\gamma}_0$, $\widehat{\beta}_1$, $\widehat{\gamma}_1$ and $\widehat{\gamma}_2$, I construct three variables

$$(5) \qquad \widehat{y}_{hc}^0 = s_{hc} - \hat{\beta}_0 \ln x_{hc} - \hat{\gamma}_0' \mathbf{z}_{hc},$$

$$(6) \qquad \widehat{y}_{hc}^1 = \ln v_{hc} - \hat{\beta}_1 \ln x_{hc} - \widehat{\gamma}_1' \mathbf{z}_{hc},$$

$$(7) \qquad \widehat{y}_{hc}^2 = \ln a_{hc} - \widehat{\gamma}_2' \mathbf{m}_{hc}.$$

Averaging (5), (6) and (7) at the cluster level, I argue that

$$(8) \qquad \widehat{y}_c^0 \xrightarrow{p} \alpha_0 + \theta \ln \pi_c + f_c + u_c^0,$$

$$(9) \qquad \widehat{y}_c^1 \xrightarrow{p} \alpha_1 + \psi \ln \pi_c + u_c^1,$$

$$(10) \qquad \widehat{y}_c^2 \xrightarrow{p} \alpha_2 + \lambda \ln \pi_c + u_c^2,$$

where u_c^0, u_c^1, and u_c^2 are average error terms in cluster c (these averages would be zero for a sufficiently large number of households per cluster).

Notice that

$$(11) \qquad \widehat{cov}\left(\widehat{y}_c^0, \widehat{y}_c^1\right) - \frac{\widehat{\sigma}^{01}}{n_c} = \widehat{\theta}\widehat{\psi}var(\ln \pi_c),$$

$$(12) \qquad \widehat{cov}\left(\widehat{y}_c^0, \widehat{y}_c^2\right) - \frac{\widehat{\sigma}^{02}}{n_c} = \widehat{\theta}\widehat{\lambda}var(\ln \pi_c),$$

where n_c is the number of observations (households) in cluster c, $\widehat{\sigma}^{01}$ is the estimated covariance between the residual in the equation for budget shares and the equation for unit values, and $\widehat{\sigma}^{02}$ is the estimated covariance between the residual in the equation for budget shares and the equation for wage agricultural income. By the same token, notice that

$$(13) \qquad \widehat{var}\left(\widehat{y}_c^1\right) - \frac{1}{n_c}\widehat{\sigma}^{11} = \widehat{\psi}^2 var(\ln \pi_c),$$

$$(14) \qquad \widehat{var}\left(\widehat{y}_c^2\right) - \frac{1}{n_c}\widehat{\sigma}^{22} = \widehat{\lambda}^2 var(\ln \pi_c),$$

where $\widehat{\sigma}^{11}$ and $\widehat{\sigma}^{22}$ are estimates of the variances of the residuals in the equations for unit values and wage agricultural income. By combining (11), (12), (13) and (14), I can identify the ratios $\widehat{\phi}_1 = \widehat{\theta}/\widehat{\psi}$ and $\widehat{\phi}_2 = \widehat{\theta}/\widehat{\lambda}$.

To recover the elasticities, I combine these estimates with a quality shading model. I borrow Deaton's group-separable preference model of demand. Let ϵ_p be the price elasticity of quantity with respect to price π and let ϵ_x be the total expenditure elasticity of the group. Deaton (1988) shows that

$$(15) \qquad \psi = 1 + \beta_1 \frac{\epsilon_p}{\epsilon_x}.$$

While Deaton was interested in the elasticity of demand ϵ_p and the expenditure elasticity ϵ_x, here I am after an estimate of λ, obtaining ϵ_p and ϵ_x as intermediate steps.

I assume that total household expenditure comprises agricultural wage income, a_{hc}, other labor income w_{hc}, and capital income k_{hc}, so that

$$(16) \qquad x_{hc} = a_{hc} + w_{hc} + k_{hc}.$$

Adapting Deaton's formulation, it is possible to show that

$$(17) \qquad \psi = \frac{\theta}{s} + b_w \lambda - \varepsilon_p,$$

where s is the average budget share and b_w is the share of wage agricultural income in total income. Finally, Deaton (1997) shows that

$$(18) \qquad \beta_1 = \frac{\beta_0}{s} + 1 - \varepsilon_x.$$

Using (15), (17) and (18), it follows that

$$(19) \qquad \psi = 1 + \beta_1 \frac{\frac{\theta}{s} + b_w \lambda - \psi}{\frac{\beta_0}{s} + 1 - \beta_1}.$$

This equation can be combined with the estimates of $\widehat{\phi}_1$ and $\widehat{\phi}_2$ to solve for $\widehat{\theta}$, $\widehat{\psi}$ and $\widehat{\lambda}$, the agricultural income price elasticity.

To exemplify how the simplified model works, I estimate it for the case of corn. I find an elasticity of 0.95, with a t statistic of 6.79. These numbers are in line with those reported in Table 1. A generalization to the case of many goods follows.

3   The Full Model

In this section, I provide the formulas needed to implement the full model, with many agricultural goods, cross-price elasticities and several agricultural wage income price-elasticities. To extend the simplified model, I begin by rewriting the general formulas for budget shares, unit values and agricultural wage income. With G goods, the budget share spent on good g by household h (in cluster c) is

$$(20) \qquad s_{hc}^g = \alpha_0^g + \beta_0^g \ln x_{hc} + \gamma_0^{g\prime} \mathbf{z}_{hc} + \sum_{k \epsilon G} \theta_{gk} \ln \pi_c^k + f_c^g + u_{hc}^{g0},$$

where $\ln \pi_c^k$ is the (log) price of good k in cluster c. As before, f_c^g is a fixed effect at the cluster level and u_{hc}^{g0} is the error term, with mean zero and variance σ_{00}^g. This model of demand is similar to the AIDS model of Deaton and Muellbauer (1980b).

The unit value equation for good g is

$$(21) \qquad \ln v_{hc}^g = \alpha_1^g + \beta_1^g \ln x_{hc} + \gamma_1^{g\prime} \mathbf{z}_{hc} + \sum_{k \epsilon G} \psi_{gk} \ln \pi_c^k + u_{hc}^{g1}.$$

Here, the "quality elasticity" for good g is β_1^g. The error term u_{hc}^{g1} has also zero mean and variance σ_{11}^g. This is just the generalization to many goods of equation (3).

There are G equations (20) and (21); instead, there is only one agricultural wage income equation

$$(22) \qquad \ln a_{hc} = \alpha_2 + \gamma_2' \mathbf{m}_{hc} + \sum_{k \epsilon G} \lambda_k \ln \pi_c^k + u_{hc}^2,$$

where u_{hc}^2 is an error term. As argued above, changes in prices, particularly of agricultural goods, will cause some agricultural activities to expand and some others to contract. This, in turn, will lead to changes in agricultural labor demand and supply and, in the end, to changes in the agricultural wage income of rural households. Equation (22) captures these effects.

In the first stage, I demean budget shares, log unit values and log agricultural income to eliminate prices and cluster fixed effects. In principle, there is no problem with the consistent estimation of these parameters if the regressors are exogenous, as in Deaton (1990). Here, however, I am introducing an agricultural wage income equation and agricultural income may be correlated with total expenditure. This means that the model is not identified if there is correlation between the errors of the share or unit value equations with the error of the wage agricultural income equation.

If I assume that this correlation is absent, then the model is triangular and I can estimate it consistently using OLS equation by equation. This assumption is not necessary. It is possible to allow for correlation among u_{hc}^2, u_{hc}^1 and u_{hc}^0 and estimate consistently the

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parameters of the demeaned model using instruments in the share and unit value equations. In particular, since the set of explanatory variables in $\mathbf{m}_{hc}$ is different from the set of explanatory variables in $\mathbf{z}_{hc}$, I use the variables that are in $\mathbf{m}$ but not in $\mathbf{z}$ as instruments. These exclusion restrictions allow me to fully identify the parameters of the first stage. The parameters of the agricultural wage income equation are identified provided $\mathbf{m}$ is exogenous, which I assume.

For each good g, I build the following variables

$$(23) \qquad \widehat{y}_{cg}^0 = \frac{1}{n_c} \sum_h \left(s_{hc}^g - \widehat{\beta}_0^g \ln x_{hc} - \widehat{\gamma}_0^{g\prime} \mathbf{z}_{hc} \right),$$

$$(24) \qquad \widehat{y}_{cg}^1 = \frac{1}{n_c} \sum_h \left(\ln v_{hc}^g - \widehat{\beta}_1^g \ln x_{hc} - \widehat{\gamma}_1^{g\prime} \mathbf{z}_{hc} \right),$$

$$(25) \qquad \widehat{y}_c^2 = \frac{1}{n_c} \sum_h \left(\ln w_{hc} - \widehat{\gamma}_2^{\prime} \mathbf{z}_{hc} \right).$$

The population counterparts are

$$(26) \qquad \widehat{y}_{cg}^0 \xrightarrow{p} \alpha_0^g + \sum_{k \epsilon G} \theta_{gk} \ln \pi_c^k + f_c^g + u_{cg}^0,$$

$$(27) \qquad \widehat{y}_{cg}^1 \xrightarrow{p} \alpha_1^g + \sum_{k \epsilon G} \psi_{gk} \ln \pi_c^k + u_{cg}^1,$$

$$(28) \qquad \widehat{y}_c^2 \xrightarrow{p} \alpha_2 + \sum_{k \epsilon G} \lambda_k \ln \pi_c^k + u_c^2,$$

where u_{cg}^0, u_{cg}^1, and u_c^2 are average error terms in cluster c.

To solve for the parameters of interest (i.e. the price elasticities), I need to extend the quality model to many goods. This is done in Deaton (1988) and Deaton (1990), who shows that

$$(29) \qquad \psi_{gk} = \delta_{gk} + \beta_1^g \frac{\epsilon_p^{gk}}{\epsilon_x^g},$$

where δ_{gk} is the kroeneker delta, ϵ_p^{gk} is the cross price elasticity of g with respect to the price

of good k and ϵ_x^g is the expenditure elasticity. The generalization of equation (19) is

(30) $\psi_{gk} = \dfrac{\theta_{gk}}{s_g} + b_w \lambda_k - \epsilon_p^{gk}.$

Finally, I have that, for each good g

(31) $\beta_1^g = \dfrac{\beta_0^g}{s_a} + 1 - \epsilon_x^g.$

Combining (29), (30) and (31), it follows that

$$\psi_{gk} = \delta_{gk} + \frac{\beta_1^g}{\beta_0^g + s_g(1 - \beta_1^g)} \left[\theta_{gk} + s_g b_w \lambda_k - s_g \psi_{gk} \right].$$

Defining a vector ξ with element $\beta_1^g / (\beta_0^g + s_g(1 - \beta_1^g))$ for good g, and a vector $\mathbf{s}$ of average budget shares, I can write

(32) $\boldsymbol{\Psi} = \mathbf{I} + D(\xi)\boldsymbol{\Theta} + b_w D(\xi)D(\mathbf{s})\boldsymbol{\Lambda} - D(\xi)D(\mathbf{s})\boldsymbol{\Psi},$

where $D(\xi)$ and $D(\mathbf{s})$ are matrices with the elements of vectors ξ and $\mathbf{s}$ on the diagonal (and zero off-diagonal elements). The matrix $\boldsymbol{\Lambda}$ is defined as

(33) $\boldsymbol{\Lambda} = \mathbf{1}_G \otimes \lambda',$

where $\mathbf{1}_G$ is a $G \times 1$ vector of ones and λ is a $G \times 1$ vector of agricultural income price elasticities λ_g.

To solve for λ, I need to manipulate the model and introduce some new notation, as follows. Let π_c be a $1 \times G$ vector of the logarithm of (unobserved) prices in cluster c. Stacking the vectors π_c' for all clusters, I get a $C \times G$ matrix π. I stack observations on average unit values for good g, (24), into a $C \times 1$ vector $\widehat{\mathbf{y}}_g^1 = \mathbf{1}_C \alpha_1^g + \pi\psi_g' + \mathbf{u}_g^1$, where $\mathbf{1}_C$ is a $C \times 1$ vector of ones, ψ_g is the gth row of matrix $\boldsymbol{\Psi}$ and $\mathbf{u}_g^1$ is a vector of residuals. It

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follows that

$$(34) \qquad cov(\widehat{\mathbf{y}}_g^{1\prime}, \widehat{\mathbf{y}}_k^1) = \psi_g' \mathbf{\Pi} \psi_k + E[\mathbf{u}_g^{1\prime} \mathbf{u}_k^1],$$

where $\mathbf{\Pi}$ is the variance-covariance matrix of the vector of good prices (across clusters). Next, I construct a $G \times G$ matrix $\mathbf{V}_1$ with element gk given by (34)

$$(35) \qquad \mathbf{V}_1 = \mathbf{\Psi} \mathbf{\Pi} \mathbf{\Psi}' + \mathbf{\Omega}_{11},$$

where $\mathbf{\Omega}_{11}$ is the matrix with gk element $E[\mathbf{u}_g^{1\prime} \mathbf{u}_k^1]$.

Following the same procedure, I generate the vector $\widehat{\mathbf{y}}_g^0$ by stacking the estimated average budget shares spent on good g by clusters. This vector is $\widehat{\mathbf{y}}_g^0 = \mathbf{1}_C \alpha_0^g + \pi \theta_g' + \mathbf{f}^c + \mathbf{u}_g^0$, where θ_g is the gth row of matrix $\mathbf{\Theta}$, and $\mathbf{u}_g^0$ is a vector of residuals. It follows that

$$(36) \qquad cov(\widehat{\mathbf{y}}_g^{1\prime}, \widehat{\mathbf{y}}_k^0) = \psi_g' \mathbf{\Pi} \theta_k + E[\mathbf{u}_g^{1\prime} \mathbf{u}_k^0].$$

Next, I build a $G \times G$ matrix $\mathbf{V}_{10}$ with element gk given by (36)

$$(37) \qquad \mathbf{V}_{10} = \mathbf{\Psi} \mathbf{\Pi} \mathbf{\Theta}' + \mathbf{\Omega}_{10},$$

where $\mathbf{\Omega}_{10}$ is the matrix with gk element $E[\mathbf{u}_g^{1\prime} \mathbf{u}_k^0]$.

So far, I have shown how estimation of the model of demand delivers algebraic expressions involving the unknown matrices $\mathbf{\Theta}$ and $\mathbf{\Psi}$; these are equations (35) and (37). These equations can be combined to express one of these matrices as a function of the other. For instance, by defining a matrix $\mathbf{B} = [\mathbf{V}_1 - \mathbf{\Omega}_{11}]^{-1} [\mathbf{V}_{10} - \mathbf{\Omega}_{10}]$, it follows that

$$(38) \qquad \mathbf{B}' \mathbf{\Psi} = \mathbf{\Theta}.$$

The next step is to complete the system by developing similar formulas involving the vector λ of wage agricultural income price elasticities. One option is to combine the agricultural income equation with the unit value equations. Writing the agricultural income equation for

cluster c as a stacked vector $\widehat{\mathbf{y}}^2 = \mathbf{1}_C\alpha_2 + \pi\lambda + \mathbf{u}^2$, I find that the covariance between $\widehat{\mathbf{y}}^2$ and $\widehat{\mathbf{y}}_g^1$ is

(39) $\qquad cov(\widehat{\mathbf{y}}^{2\prime}, \widehat{\mathbf{y}}_g^1) = \lambda'\mathbf{\Pi}\psi_g + E[\mathbf{u}^{2\prime}\mathbf{u}_g^1].$

This allows me to build a $G \times 1$ vector $\mathbf{v}_{21}$ with element g given by (39)

(40) $\qquad \mathbf{v}_{21} = \mathbf{\Psi\Pi}\lambda + \omega_{21},$

where ω_{21} is a vector with g element $E[\mathbf{u}^{2\prime}\mathbf{u}_g^1]$. Next, I define a matrix $\mathbf{B}_1 = [\mathbf{v}_{21} - \omega_{21}]' [\mathbf{V}_1 - \mathbf{\Omega}_{11}]^{-1}$, so that

(41) $\qquad \mathbf{B}_1 = \lambda'\mathbf{\Psi}^{-1}.$

These are all the steps needed to close the model. The mechanics of the solution involves using (32), (38) and (41) to solve for the matrices $\mathbf{\Theta}$ and $\mathbf{\Psi}$, and the vector λ. Replacing (38) and (33) in (32), I get

$$\widehat{\mathbf{\Psi}} = [\mathbf{I} - D(\xi)\mathbf{B}' - b_w D(\xi)D(\mathbf{s})\mathbf{1}_G \otimes \mathbf{B}_1 + D(\xi)D(\mathbf{s})]^{-1}.$$

This matrix is a function of the data, and can be estimated after $\mathbf{B}$ and $\mathbf{B}_1$ have been computed from the data. Plugging this into (38) and (41), I get

$$\widehat{\mathbf{\Theta}} = \mathbf{B}'\widehat{\mathbf{\Psi}},$$

$$\widehat{\lambda}' = \mathbf{B}_1\widehat{\mathbf{\Psi}}.$$

This vector $\widehat{\lambda}$ is the vector of agricultural income price-elasticities that are needed to jointly assess, for instance, the effects of trade reforms on income and expenditure. This is discussed in more detail in the empirical application.

3.1 A Special Case

The model described so far is quite general. By allowing for the estimation of a wage agricultural equation, a number of complications arose. Changes in prices bring about changes in demands but also changes in wages. This means that the total expenditure of the household may change when prices change. In consequence, the typical model of demand with exogenous expenditure (Deaton and Muellbauer, 1980a) had to be modified to account for the additional effects of prices on quantities via changes in expenditure. Another important complication was that the agricultural income equation introduced an endogeneity problem in the estimation of the first stage. In some potential applications, these complications are not present, and the estimation of the model can be simplified. A special case that is not subject to these problems is when the interest lies, for example, in the estimation of the effects of price reforms on behavior, such as health, nutrition, education, and labor market participation.[5]

The extension is simple. The budget share and unit values equations remain intact. I replace the agricultural income equation with an "outcome" equation

$$(42) \qquad o_{hc} = \alpha_2 + \gamma_2' \mathbf{m}_{hc} + \sum_{k \epsilon G} \lambda_k \ln \pi_c^k + u_{hc}^2,$$

where o_{hc} is the outcome of interest. In the empirical application (and in the discussion that follows), this outcome is the labor market participation of young males.

The estimation steps are exactly the same as before, except that now there is in principle no need to utilize instruments in the estimation of the first stage for the share and unit value equations. I define $\mathbf{V}_1 = \mathbf{\Psi} \mathbf{\Pi} \mathbf{\Psi}' + \mathbf{\Omega}_{11}$, $\mathbf{V}_{10} = \mathbf{\Psi} \mathbf{\Pi} \mathbf{\Theta}' + \mathbf{\Omega}_{10}$, $\mathbf{B}' \mathbf{\Psi} = \mathbf{\Theta}$, $\mathbf{v}_{21} = \lambda' \mathbf{\Pi} \mathbf{\Psi} + \omega_{21}$, and $\mathbf{B}_1 = \lambda' \mathbf{\Psi}^{-1}$.

The quality model has to be amended because I am back in an scenario with exogenous

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[5]The literature includes many examples of assessments of the impacts of price reforms on household outcomes such as health, nutrition, education, and child labor. The papers by Edmonds and Pavnick (2003) and (2004) are excellent examples.

expenditure. The formulas are easily simplified to

$$(43) \qquad \mathbf{\Psi} = \mathbf{I} + D(\xi)\mathbf{\Theta} - D(\xi)D(\mathbf{s})\mathbf{\Psi},$$

as in Deaton's original formulations.

The solution delivers

$$\widehat{\mathbf{\Psi}} = \left[\mathbf{I} - D(\xi)\mathbf{B}' + D(\xi)D(\mathbf{s})\right]^{-1},$$

$$\widehat{\mathbf{\Theta}} = \mathbf{B}'\widehat{\mathbf{\Psi}},$$

$$\widehat{\lambda}' = \mathbf{B}_1\widehat{\mathbf{\Psi}}.$$

The vector $\widehat{\lambda}$ contains the elasticities of the outcomes (young adults labor market participation) with respect to the prices of the agricultural goods g.

4   Empirical Results

I implement the empirical method to study the impacts of agricultural prices on the agricultural wage income of the household, and on the labor market participation of young adults in rural Mexico.

4.1   Agricultural Income

Discussions about the poverty impacts of trade reforms often make the argument that supply responses are critical for the poor. Specifically, WTO reforms on agricultural trade are expected to boost production opportunities in rural areas in developing countries. Behind these arguments, there lies the notion that agricultural trade liberalization will bring about increases in international prices of agricultural goods, such as corn. Faced with higher permanent corn prices, households may choose to devote more resources to agricultural production and firms will increase their labor demand in agricultural. This higher demand may involve higher employment in rural farms (for planting, weeding, or harvesting); or it

may imply higher labor demand in agricultural services, such as sales of fertilizers and tools, farm maintenance, etc.

I use the model described in section 3 to estimate the impacts of agricultural prices on agricultural wage income. This is defined as wage income in agricultural activities and self employment income earned in agricultural. The ENIGH surveys collect detailed information on these sources of income. As mentioned before, the ENIGH gathers data on unit values for many different food items, too. In what follows, I focus on the most relevant agricultural prices, namely corn, wheat, dairy, oils & fats, meat, and fruits & vegetables.

Results are reported in Table 2.[6] In each specification and for each of these six price regressors, I report two elasticities, one for the model with exogenous expenditure in the share and unit value equations, and another for the model that uses instrumental variables in these equations. Since I am more interested in wage price-elasticities rather than in demand and expenditure elasticities, I focus here on the estimates of the vector λ. Discussion of own- and cross-price elasticities is left for Appendix 2.

I begin by discussing the model with instrumental variables (column 2). The prices of corn and fruits & vegetables are positively and significantly associated with household agricultural wage income. The elasticity of corn is 0.53, and that of fruits & vegetables, 0.90. There is no statistically significant effect of the prices of wheat, oils & fats, and meat. In contrast, the price of dairy is negatively associated with agricultural income, with an elasticity of -0.79.

In column 3 of Table 2, I report the OLS estimates (assuming exogeneity of expenditure in the first stage estimation of the share and unit value equations). It is found that higher corn prices are associated with higher agricultural wage income, whereas higher prices of dairy products negatively affect agricultural income. No statistically significant effect is found in the rest of the cases, including fruits & vegetables.

The comparison of the results in Table 2 with those estimated in the simple model that uses average cluster unit values as a proxy for prices (Table 1) reveals the following conclusions. The price of corn seems to be systematically related with agricultural wage

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[6]The first column of the Table reports the results of the simplified model of section 2.

Table 2
Applying the Methodology

	Simplified Model (1)	IV (2)	OLS (3)	Alternative 1 IV (4)	OLS (5)	Alternative 2 IV (6)	OLS (7)
Corn	0.95	0.53	0.88	0.63	0.99	0.51	0.88
	(0.14)	(0.14)	(0.16)	(0.16)	(0.16)	(0.14)	(0.16)
Wheat		−0.09	−0.11	−0.08	−0.12	−0.07	−0.11
		(0.13)	(0.13)	(0.14)	(0.14)	(0.12)	(0.12)
Dairy		−0.79	−0.35	−0.61	−0.31	−0.69	−0.31
		(0.14)	(0.11)	(0.12)	(0.10)	(0.14)	(0.10)
Oils & Fats		−0.26	−0.12	−0.16	−0.05	−0.17	−0.05
		(0.52)	(0.39)	(0.42)	(0.38)	(0.46)	(0.37)
Meat		−0.37	0.11	−0.38	0.14	−0.31	0.13
		(0.24)	(0.25)	(0.26)	(0.26)	(0.20)	(0.24)
Fruits & Vegetables		0.90	0.02	0.78	−0.04	0.77	−0.04
		(0.35)	(0.06)	(0.33)	(0.29)	(0.33)	(0.29)

(1) Simplified model with only corn prices (section 2)
(2) Full Model using instrumental variables
(3) Full Model using OLS
(4) and (5) Alternative 1: $\widehat{\boldsymbol{\Psi}} = \mathbf{I}$
(6) and (7) Alternative 2: $\tilde{\boldsymbol{\Psi}} = D(\text{vecdiag}(\widehat{\boldsymbol{\Psi}}))$

income, the relationship being positive. The elasticity ranges from 0.53 (IV case) to 0.88 (OLS case), which are similar to the elasticity of 0.58 reported in Table 1. The use of average unit values as regressors may be incorrect, however, since dairy and fruits & vegetables are shown to have impacts on household wage agricultural income. In addition, the price of meat, which was found to be positively related with a_{hc} in Table 1, it is no longer significant in Table 2. Since the method of section 3 is robust to possible inconsistencies that may arise by using unit values as proxies for prices, I argue that it is important to correct unit values to make them more accurate measures of prices. In one case, namely corn, the models seem to deliver comparable elasticities; but in three out of the remaining five cases, results are significantly different. It appears that using unit values as measures of prices can be inappropriate, and that the correction proposed here improves the estimates.

There might be concerns about the complexity of the joint estimator discussed in this paper. Specifically, the full model requires the estimation of a complete system of demand

and agricultural wage income. This may imply a lot of hard work, mainly in setting up the data and in computing the matrices developed in section 3. It seems important to inquire if slightly modified versions of the model can help simplify the formulas. In addition, since the model can only estimate linear regression functions for household outcomes, it may not be used in cases where the outcome involves discrete choices (such as labor supply decisions, see below). Thus, it is also important to investigate whether more flexible ways to implement the model are feasible. These alternatives are discussed next.

One option is simply to assume that unit values are only affected by own prices, so that the cross-price effects in equation (21) are zero. Further, it may be argued that the coefficients ψ_{gg} are unity, so that unit values respond one to one with own prices. This would be consistent with a model with negligible quality shading effects caused by prices. However, it is still possible to purge the average cluster unit values to take care of the expenditure quality and demographic effects.

In practice, these assumptions imply that the matrix $\mathbf{\Psi}$ is the identity matrix. This may not be a strong assumption, since the full model delivers, in the end, estimates of the off-diagonal elements of $\mathbf{\Psi}$ that are very close to zero. Estimation of the model is thus much easier. Indeed, I could either replace $\mathbf{\Psi} = \mathbf{I}$ in the formulas, or I could estimate the first stage, purge unit values, and use average "purged" unit values as regressors in the agricultural wage equation. The estimated coefficients are in columns 4 (using instrumental variables in the share and unit value equations) and 5 (using OLS) of Table 2. This simple model is an improvement over the simple OLS estimation with average unit values of Table 1; the results are also close to the the estimation of the full model (in columns 2 and 3). Corn and fruits & vegetables are positively associated with agricultural rural income, dairy is negatively associated, and the remaining prices have no significant effects.

Another option, which lies in between the full model of section 3 and the model with $\mathbf{\Psi} = \mathbf{I}$, is to estimate the diagonal elements ψ_{gg} but assume that all the $\psi_{gk} = 0$, for $k \neq g$. This would be a model that assumes that unit values are affected by quality choice, so that they are not the same as prices, but that they are a function of own-prices only. Estimation can be carried out as in section 3, but replacing $\widehat{\mathbf{\Psi}}$ with $\widetilde{\mathbf{\Psi}}$, a diagonal matrix with the

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elements $\widehat{\psi}_{gg}$ in the diagonal, and zero off-diagonal elements. Results are in columns 6 and 7 of Table 2. As expected, this version of the model improves the OLS estimation of Table 1 and delivers estimates that are even closer to those in the full model. This result is not too surprising since, as argued, the estimates $\widehat{\psi}_{gk}$ are not, in general, significantly different from zero. This model seems to be a good compromise between the full model, which may be quite complicated to estimate and not be flexible enough in some applications (see Balat and Porto, 2004).

4.2   Labor Market Participation of Young Adults

In theory, higher corn prices (brought about, for example, by the WTO reforms in agricultural trade) may affect labor market decisions of different household members. There is an income and a substitution effect. Since higher corn prices lead to higher wage agricultural income, there is an incentive to work more. In contrast, parents in rural household with higher agricultural income may force children and young adults to attend further schooling. In this section, I briefly study the effects of corn prices on labor markets participation of male young adults in rural Mexico. The model is estimated with the formulas developed for the special case developed in section 3.1.

Results are in Table 3. The first two rows report the coefficients of a linear probability model and a probit model using average cluster unit values as measures of prices. Both models deliver similar elasticities, 0.044 and 0.047 respectively; notice, however, that these elasticities are not statistically significant.

The estimation of the full model is performed under the assumption that there is no correlation in the error of the outcome equation and the unit value or share equations. In row (3) of Table 3, the coefficient is 0.039 and statistically significant. This elasticity of the labor choice with respect to the price of corn is quite similar to the crude estimates of the first two rows. Notice that the elasticity is now statistically significant.

Since I am estimating a discrete choice model, the linear specification of the full model may not be appropriate. Unfortunately, the full model cannot be modified to deal with nonlinear models. Instead, this type of models can be handled with the alternatives discussed

Table 3
Labor Market Participation
Males aged 14-18

	marginal effect	standard error	R^2
	(1)	(2)	(3)
OLS	0.044	(0.034)	0.09
Probit	0.047	(0.037)	0.07
Full Model			
No correlation	0.039	(0.018)	
Alternative 1			
OLS	0.056	(0.035)	0.09
Probit	0.061	(0.038)	0.07
Alternative 2			
OLS	0.046	(0.029)	0.09
Probit	0.050	(0.032)	0.07

Note: OLS and Probit in the first two rows refer to the estimation of the
model using average unit values as proxies for prices
The Full Model corresponds to the model in section 3.1
Alternative 1: $\widehat{\boldsymbol{\Psi}} = \mathbf{I}$
Alternative 2: $\widetilde{\boldsymbol{\Psi}} = D(\text{vecdiag}(\widehat{\boldsymbol{\Psi}}))$

at the end of the previous section. In the first alternative, I assume that $\boldsymbol{\Psi} = \mathbf{I}$; in the second alternative, I may assume that $\boldsymbol{\Psi} = \widetilde{\boldsymbol{\Psi}}$. In both cases, the model can be estimated as follows. After estimating the first stage of the model, unit values are purged from the expenditure and demographic effects. The average of these purged unit values are measures of $\ln \pi_c^g$ (if $\boldsymbol{\Psi} = \mathbf{I}$) or of $\widehat{\psi}_{gg} \ln \pi_c^g$ (if $\boldsymbol{\Psi} = \widetilde{\boldsymbol{\Psi}}$). The outcome equation is then estimated using purged unit values as regressors.

Rows (4) and (5) of Table 3 reports the results when $\boldsymbol{\Psi} = \mathbf{I}$. In the linear model, the elasticity is 0.056; in the probit, it is 0.061. In both cases, the elasticity is not statistically significant. Rows (6) and (7) display the estimates from the model with $\boldsymbol{\Psi} = \widetilde{\boldsymbol{\Psi}}$. The elasticities are slightly lower (0.046 and 0.050 in the linear and probit models respectively), but not quite significant.

In general, my findings do not support the notion that the labor market decisions of

young males are affected by the prices of corn in rural Mexico, except in the complete model with fully corrected unit values. It may be that the income effects and the substitution effects almost cancel out, or it may be that the decision to work involves a different model that cannot be studied with the available data. In any case, the exercise shows that in this case the correction of unit values does not make much difference in the point estimates but increases their precision.

5   Conclusions

This paper has introduced an empirical model designed to be used in the evaluation of price reforms. These reforms bring about price changes, which affect households both as consumers and as producers or income earners. Studying consumption effects is relatively straightforward. Budget shares can be used to approximate first order effects. Deaton's methods (Deaton, 1987, 1988, and 1990) can be used to estimate demand elasticities and second order effects.

The estimation of the impacts on the income side is harder since, in general, there is not enough price variation at the household level. One obvious option is to use unit values as a proxy for prices. Although such a model would generate sufficient variability in the regressors, there are problems of endogeneity of unit values, biases due to proxy variables, and measurement error. In this paper, I have proposed a method that uses unit values as measures of prices, but that would be free from these problems. The method combines Deaton model of demand with an equation that describes a household behavior or outcome. By estimating the demand model together with the quality shading model, I was able to extract the right price signal from unit value data. These data can then be plugged in the outcome equation to identify elasticities that would show how household behavior is affected by prices.

The method was first applied to the estimation of the response of agricultural wage income to agricultural prices in rural Mexico. I found a positive effect of corn prices on household wage agricultural income. It was found that the corrections suggested in this paper can make

a difference and should be preferred to a simpler model that uses average cluster unit values as regressors. Failing to control for endogeneity, biases, and measurement errors may lead to inconsistent estimates of the price elasticities and to an incorrect or misleading evaluation of policy changes.

The second application of the method pursued in the paper investigated the response of the labor market choice of young adults in rural areas. My findings suggested that the price of corn impacts positively but not significantly on the decision to enter the workforce at a young age. The unit value correction seems to be less important in this case.

Since the model proposed here is quite intensive in data, and some of the formulas of the general model can be difficult to code, I have explored intermediate models that would restrict the model a little bit while still preserving the correction of unit values. It was found that a model that purges unit values from quality choices, but that restricts own price to affect unit values (rather than own and cross price effects) performs quite well and is relatively simple to estimate.

Appendix 1: The Mexican Data

This Appendix briefly describes the data used to implement the empirical method discussed in section 3. The method can in principle be applied to any household survey with information on expenditures and quantities. I have chosen to implement the model using the Mexican data for a number of reasons. First, agriculture, and particularly corn, is a key activity in rural Mexico. Second, since Mexico is a major trading partner of the US, it will be very much affected by WTO Doha round negotiations in agriculture. Third, there are actually several surveys in the 1990s that can be used to improve the estimation.

Table A1.1 reports sample sizes and other summary statistics.

Appendix 2: Demand Elasticities

This appendix describes the own- and cross-price demand elasticities estimated with the different models developed in the paper. Since demand elasticities are not the focus of my investigation, I describe the estimates of the own price elasticities, cross-price elasticities being just briefly described for one of the cases.

In Table A2.1, I report own-price elasticities obtained from the different models discussed in the text. The first two columns report the estimation of the full model, with fully corrected unit values, using IV and OLS, respectively. Alternative 1 simplifies the model by assuming that $\Psi = I$, while alternative 2 assumes that $\Psi = \widetilde{\Psi}$. All the Hicksian own-price elasticities

are negative and highly significant, as expected. There are no major differences across specifications.

Table A2.1
Own-price Elasticities
Agricultural Income Full Model

	IV	OLS	Alternative 1		Alternative 2	
			IV	OLS	IV	OLS
	(1)	(2)	(3)	(4)	(5)	(6)
Corn	−0.9995	−1.2151	−1.2872	−1.4035	−1.0197	−1.25
	(0.0541)	(0.0709)	(0.1)	(0.0955)	(0.0542)	(0.0702)
Wheat	−1.3121	−1.4331	−1.5742	−1.5807	−1.3287	−1.4166
	(0.0643)	(0.0737)	(0.0904)	(0.0902)	(0.0664)	(0.0734)
Dairy	−1.8857	−1.5384	−1.546	−1.5022	−1.767	−1.4995
	(0.1175)	(0.0823)	(0.0857)	(0.0829)	(0.1113)	(0.0826)
Oils & Fats	−1.124	−1.1382	−1.0099	−0.9922	−1.0901	−0.9727
	(0.3232)	(0.2422)	(0.2769)	(0.256)	(0.3277)	(0.246)
Meat	−1.1785	−1.3769	−1.4696	−1.5044	−1.195	−1.366
	(0.1347)	(0.1713)	(0.1944)	(0.2013)	(0.134)	(0.168)
Fruits & Vegetables	−0.9472	−1.0438	−0.9597	−1.02	−0.9468	−1.0132
	(0.1134)	(0.1121)	(0.1182)	(0.1154)	(0.1139)	(0.1142)

(1) Full Model using instrumental variables
(2) Full Model using OLS
(3) and (4) Alternative 1: $\widehat{\boldsymbol{\Psi}} = \mathbf{I}$
(5) and (6) Alternative 2: $\tilde{\boldsymbol{\Psi}} = D(\text{vecdiag}(\widehat{\boldsymbol{\Psi}}))$

In Table A2.2, I report the own-price elasticities estimated with the special case of section 3.1. Essentially the same results are obtained. Notice that the first column reports the results that would be obtained using Deaton (1990) method.

Finally, I report in Table A2.3 the cross-price elasticities for the full model estimated with instrumental variables.

Table A2.2
Own-price Elasticities
Young Adults Labor Model

	Deaton	Alternative 1	Alternative 2
	(1)	(2)	(3)
Corn	−1.1329	−1.4035	−1.1642
	(0.0662)	(0.0955)	(0.0656)
Wheat	−1.4354	−1.5807	−1.4296
	(0.0735)	(0.0902)	(0.0734)
Dairy	−1.5205	−1.5022	−1.4998
	(0.0828)	(0.0829)	(0.0826)
Oils & Fats	−1.1398	−0.9922	−0.9739
	(0.2437)	(0.2560)	(0.2468)
Meat	−1.3683	−1.5044	−1.3603
	(0.1651)	(0.2013)	(0.1632)
Fruits & Vegetables	−1.0428	−1.0200	−1.0134
	(0.1117)	(0.1154)	(0.1140)

(1) Estimation using Deaton's (1990) formulas
(2) Alternative 1: $\widehat{\boldsymbol{\Psi}} = \mathbf{I}$
(3) Alternative 2: $\tilde{\boldsymbol{\Psi}} = D(\text{vecdiag}(\widehat{\boldsymbol{\Psi}}))$

Table A2.3
Cross-price Elasticities
Full Model with Instrumental Variables

	Corn	Wheat	Dairy	Oils & Fats	Meat	Fruits & Vegetables
Corn	-0.9995	0.0192	-0.0768	-0.2667	-0.1276	0.2066
	(0.0541)	(0.0603)	(0.1442)	(0.0858)	(0.0615)	(0.0482)
Wheat	0.1376	-1.3121	0.1154	0.3258	0.1061	-0.0875
	(0.0695)	(0.0643)	(0.1268)	(0.1050)	(0.0670)	(0.0611)
Dairy	0.4665	0.1304	-1.8857	-0.4092	0.4292	0.4311
	(0.0672)	(0.0592)	(0.1175)	(0.0901)	(0.0678)	(0.0462)
Oils & Fats	0.0676	-0.7266	-0.1182	-1.1240	0.0114	0.5746
	(0.2370)	(0.2216)	(0.5054)	(0.3232)	(0.3293)	(0.1719)
Meat	-0.1803	0.1386	0.0579	-0.1858	-1.1785	0.3661
	(0.1007)	(0.0929)	(0.2011)	(0.1435)	(0.1347)	(0.0733)
Fruits & Vegetables	-0.0868	-0.0273	-0.0470	0.0425	0.1709	-0.9472
	(0.1413)	(0.1407)	(0.3074)	(0.2185)	(0.1613)	(0.1134)

Note: Full model with instrumental variables

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