



*The World's Largest Open Access Agricultural & Applied Economics Digital Library*

**This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.**

**Help ensure our sustainability.**

Give to AgEcon Search

AgEcon Search

<http://ageconsearch.umn.edu>

[aesearch@umn.edu](mailto:aesearch@umn.edu)

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

*No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.*

**Department of Agricultural and Resource Economics  
University of California, Davis**

# **Subsistence Response to Market Shocks**

by

George A. Dyer, Steve Boucher and J. Edward Taylor

Working Paper No. 05-004

July 2005



---

Copyright © 2005 by George A. Dyer, Steve Boucher and J. Edward Taylor

All Rights Reserved. Readers May Make Verbatim Copies Of This Document For Non-Commercial  
Purposes by Any Means, Provided That This Copyright Notice Appears On All Such Copies.

---

**Giannini Foundation for Agricultural Economics**

## **Subsistence Response to Market Shocks**

George A. Dyer, Steve Boucher and J. Edward Taylor<sup>\*</sup>

### **Abstract**

Micro-economic models posit that transaction costs isolate subsistence producers from output market shocks. We integrate microeconomic models of many heterogeneous households into a general-equilibrium model and show that supply on subsistence farms may respond, in apparently perverse ways, to changes in output market prices. Price shocks in markets for staple goods are transmitted to subsistence producers through interactions in factor markets. In the case presented, a decrease in the market price of maize reduces wages and land rents, stimulating maize production by subsistence households; however, real income of subsistence households falls.

JEL classification: O12; Q11; R13

Key words: Agricultural households, general equilibrium models, transaction costs, agricultural supply, village economies, immiserized growth, Mexico.

## Subsistence Response to Market Shocks

*"No [one] is an island, entire of itself..."  
-John Donne*

It is received wisdom that subsistence producers are isolated from output markets in which they do not participate; that is, their supply response is inelastic with respect to price shocks in those markets. Stiglitz (1989) notes the pervasiveness of market failures in developing economies. De Janvry, Fafchamps and Sadoulet (1991) argue that selective market failures "severely constrain peasants' abilities to respond to price incentives and other external shocks" (page 1401). Omamo (1998a,b) and Kurosaki (1995) highlight the effects of market failures on diversification on farms. Access to markets is not uniform across rural households, because some households face lower transaction costs than others (de Janvry, Sadoulet and Gordillo de Anda (1995); Key, Sadoulet and de Janvry (2000); Omamo 1998b; Kurosaki (1995)). The result is a heterogeneous rural economy in which commercial producers may coexist with subsistence farmers who are shielded from selected markets by high transaction costs. Production of subsistence goods is guided not by exogenous market prices, but rather, by shadow prices endogenous to the household.

The premise of this paper is that even subsistence producers are likely to adjust their supply—possibly in perverse ways—to changes in output market prices. While subsistence households are not affected directly by price shocks in markets in which they do not participate, the shadow prices that guide their behavior are affected by the market. Market prices affect shadow prices through *other* markets--in particular those for factors of production--in which subsistence households and commercial producers interact. As a result, a change in the market price of staples produced by commercial farms may

indirectly alter the shadow price of staples in subsistence households as it is transmitted via general equilibrium effects in land and labor markets. The sign as well as magnitude of the market-price effect on subsistence-household shadow prices depends upon the nature of the other markets. In some cases the indirect relationship between market and shadow prices may dampen or even reverse the aggregate supply response.

We illustrate this argument with a simple analytical model that shows how a price shock in an output market in which a single class of actors participates can be transmitted to other actors via a labor market, resulting in the seemingly paradoxical combination of production gain and welfare loss. The simple model highlights the importance of capturing heterogeneity among rural households when estimating production and welfare effects of market shocks. We then propose an empirical methodology designed to capture multiple factor-market linkages across heterogeneous households in a rural economy. The empirical model incorporates the highest degree of heterogeneity possible by integrating a series of individual agricultural household models into a general-equilibrium model of a village economy. It is estimated with data from surveys carried out in a Mexican village.

Mexico is an ideal site to test our hypothesis that subsistence households are not isolated from the market. Heterogeneity among producers is a trademark of Mexican agriculture, where a majority of land-poor, subsistence households coexist in more or less isolated markets with a small number of land-rich commercial (*i.e.*, surplus) growers (Hewitt (1976); Esteva (1982); Appendini (1993)). The extent of their interaction is such that social scientists often explain each group's actions in relation to those of the other group (see Bartra (1982); Fox (1992); Wilk (1997)). In recent years, Mexico has been

the site of major agricultural policy and market reforms that significantly increased maize imports and reduced prices but, contrary to predictions of economic models, not aggregate output or cultivated area on rain-fed farms.<sup>1</sup> Despite this, the Mexican government has faced pressure from farmer and peasant organizations who argue that increasing maize imports have adversely affected small-farmer incomes.<sup>2</sup>

We show that the presence of even a small number of commercial producers is sufficient to generate a supply response by subsistence households to a change in the market price of a staple. Under plausible market assumptions, when the market price falls, subsistence production increases and welfare decreases. This significantly dampens the aggregate supply response to the market price shock.

The combination of increased staple output and welfare loss is reminiscent of the predictions of models of “immiserized” growth, i.e., the negative correlation between production and welfare in small-farm economies. Barrett (1998) presents a model in which agricultural liberalization policies that increase both the mean and variance of food prices exacerbate food insecurity, reducing welfare while stimulating farm effort and output in net-buyer households. In our model, a decrease rather than an increase in the market price triggers a positive output response on subsistence farms. The market-price shock increases labor effort on subsistence farms via factor-market linkages, which transmit the influence of the shock from commercial to subsistence producers.

Shively (forthcoming) proposes a model in which labor-market and environmental linkages may lead to immiserized growth. In Shively’s model, upland farm households engage in crop production that creates negative externalities for lowland farms. They also supply labor to lowland farms. If the externalities reduce productivity

and the wage, a downward spiral can result, in which highland households reduce their labor supply to lowland farms and intensify production on their own farms. This, in turn, increases the externality and further lowers lowland farm productivity and the wage. The result is an increase in production accompanied by a decrease in welfare of upland households. An endogenous feedback between upland production and lowland production creates the possibility of mutually reinforcing declines in income and environmental quality. This is similar to our model, in that a shock perceived by one group or class of producers is transmitted to the other group via factor markets. Both studies attempt to explain puzzling production and welfare outcomes in the presence of a market imperfection; however, the nature of the imperfection is different. In Shively's model, it is an endogenous environmental externality, whereas in our model it is an exogenous market failure that buffers subsistence households from market shocks.

### **A Simple Analytical Model of Subsistence Supply Response**

De Janvry, Fafchamps and Sadoulet (1991), building upon Singh, Squire and Strauss (1986), argue that many producers are isolated from changes in the market prices of goods they produce. Production and consumption decisions on subsistence farms are shaped by unobservable "shadow prices," which are household specific. Because of this, they are unresponsive to the market price.<sup>3</sup>

This is not the case, however, when subsistence and commercial households interact in local economies. In theory, the presence of a single commercial household is sufficient to transmit a market-price shock in a village comprised primarily of subsistence households. To illustrate this, consider a simple model in which there are two types of

agents, a single commercial farmer and  $n$  subsistence households. The profit maximizing commercial farm produces a staple,  $Q_c$ , using Cobb-Douglas production technology with variable inputs of labor,  $L_c$ , and fixed land,  $\bar{T}_c$  (where the subscript “ $c$ ” denotes “commercial”):

$$(1) \quad Q_c = A\bar{T}_c^{1-\gamma} L_c^\gamma = \lambda_c L_c^\gamma$$

For simplicity, assume that all labor utilized on the commercial farm is supplied by subsistence households. For a given wage,  $w$ , and output price,  $p$ , profit maximization yields the following labor demand by the commercial farm:

$$(2) \quad L_c^D(w) = \left[ \frac{p\gamma\lambda_c}{w} \right]^{\frac{1}{1-\gamma}}.$$

Subsistence households maximize utility from consuming the home-produced staple,  $Q_s$ , and market goods,  $M_s$ , according to a simple linear utility function:

$$(3) \quad U(Q, M) = \alpha Q + \beta M,$$

subject to the same staple-production technology but with a smaller fixed land input  $\bar{T}_s < \bar{T}_c$ :

$$(4) \quad Q_s = A\bar{T}_s^{1-\gamma} L_s^\gamma = \lambda_s L_s^\gamma$$

and a cash-income and time constraint (assuming each subsistence household has a labor endowment equal to 1):

$$(5) \quad \begin{aligned} M &= wL^S \\ L + L^S &= 1 \end{aligned}$$

$L^S$  is the labor supplied by a subsistence household to the commercial farm. The solution of the constrained utility maximization model yields the following labor supply rule for each subsistence household:



$$(6) \quad L^S(w) = 1 - \left[ \frac{\alpha w}{\beta \gamma \lambda_s} \right]^{\frac{1}{\gamma-1}},$$

and an aggregate labor supply equal to  $nL^S(w)$ . Setting aggregate labor supply equal to labor demand yields the equilibrium wage:

$$(7) \quad w^*(p, \underline{Z}) = \left( \frac{\phi(p, \underline{Z})}{n} \right)^{1-\gamma},$$

where  $\underline{Z} = [\gamma, \lambda_c, \lambda_s, \alpha, \beta, n]$  is a vector of technology and preference parameters, and

$$(8) \quad \phi(p, \underline{Z}) = (p\gamma\lambda_c)^{\frac{1}{1-\gamma}} + n \left( \frac{\beta\gamma\lambda_s}{\alpha} \right)^{\frac{1}{1-\gamma}}.$$

Since  $\partial\phi/\partial p > 0$ , an increase in the staple price will lead to an increase in the village wage. Substituting  $w^*(p, \underline{Z})$  into (6) yields the reduced-form labor supply:

$$(9) \quad L^S(p, \underline{Z}) = 1 - \alpha \left( \frac{n}{\phi(p, \underline{Z})} \right) \left( \beta\gamma\lambda_s \right)^{\frac{1}{1-\gamma}},$$

which is an increasing function of the staple market price. Finally, substituting (9) into (4), it is evident that subsistence production is a decreasing function of the staple price:

$$(10) \quad Q_s(p, \underline{Z}) = \lambda_s \left[ \left( \frac{n}{\phi(p, \underline{Z})} \right) \left( \frac{\beta\gamma\lambda_s}{\alpha} \right)^{\frac{1}{1-\gamma}} \right]^\gamma, \quad \frac{dQ_s(p, \underline{Z})}{dp} < 0$$

While the model is simplistic, it highlights a basic insight that can easily be overlooked in partial equilibrium analyses of market imperfections: subsistence households are indirectly connected to commodity markets via factor market linkages with commercial producers. In our stylized model, the supply of labor to subsistence production, and thus subsistence production itself, are functions of the market price of the

staple good as well as household-specific production and consumption parameters. Subsistence households do not participate in the staple market, yet subsistence production increases when the market price falls, due to the labor market linkage. The same argument holds, *ceteris paribus*, for other factors (i.e., rented land).

### **Empirical Modeling of Subsistence-Commercial Interactions**

In our empirical model, as in real life, subsistence producers are heterogeneous and may interact with commercial producers in more than one factor market.<sup>4</sup> An analytical model quickly becomes intractable under these conditions. Our empirical model integrates many individual agricultural households into a regional general-equilibrium model, calibrated with survey data and solved using GAMS. Thus, in our model, households share the same general form of preferences and technologies, but the parameters in the utility and production functions may vary across households. This sets it apart from conventional village Social Accounting Matrix (SAM) and Computable General Equilibrium (CGE) models (Taylor and Adelman (1996); Lewis and Thorbecke (1992); Subramanian and Sadoulet (1990); Adelman, Taylor and Vogel (1988)), in which households are aggregated into groups and all households share the same prices, preferences and technologies.

Our objective is to trace out the impact of a shock to the market price of a staple good—maize—on household resource allocation and welfare. We hypothesize that market price shocks are transmitted via interactions across households in factor markets; thus, we explore the sensitivity of the results to different assumptions regarding the integration of the village into regional labor markets and the functioning of local land

markets. We examine four scenarios based on combinations of two polar assumptions regarding factor markets. On the labor market side, we assume that either the village wage is exogenously determined, institutionally or in markets outside the village, or that high transaction costs prevent labor contracting across villages so that the local wage is instead determined endogenously within the village. On the land side, we assume that either a perfect land rental market exists within the village or that land transactions are illegal or associated with high transaction costs for other reasons, so that no land market exists. This provides us with the following four scenarios: A) Endogenous wage with local land market; B) Exogenous wage with local land market; C) Endogenous wage without land market; and D) Exogenous wage without land market.

The optimization problem facing a given household depends upon whether or not the household is a subsistence or a commercial maize producer and on the existence (or not) of a local land market. Consider first the problem facing household  $h$  in scenarios A and B (i.e., with a local land market):

$$\underset{M, X, \underline{c}, \underline{L}, \underline{T}}{\text{Max}} \quad U(M, X, \underline{c}; \underline{\beta}^h)$$

Subject to :

$$(C1) \quad \sum_{i=1}^I p_i c_i = p_M (Q_M - M) - w L_M - r T_M + \sum_{i=1}^v p_i Q_i - w \left[ \sum_{i=1}^v L_i - F^h \right] - r \left[ \sum_{i=1}^v T_i - \bar{T}^h \right] + I$$

$$(C2) \quad Q_M = Q_M(L_M, T_M; \bar{k}_M^h, \gamma_M^h); \quad Q_i = Q_i(L_i, T_i; \bar{k}_i^h, \gamma_i^h) \quad i = 1, \dots, v$$

$$(C2) \quad X + F = \bar{L}$$

$$(C4) \quad M \leq Q_M$$

In the above optimization program,  $U$  is a standard, quasi-concave utility function,  $M$  is consumption of home-produced maize,  $X$  is leisure, and  $\underline{c} = (c_1, c_2, \dots, c_I)$  is a vector of consumption of other goods which may be produced by the household or purchased in the local market.  $\underline{L}_i$  and  $\underline{T}_i$  are the amount of labor and land used in the

production of each good.  $\underline{\rho}^h$  is a vector of household specific preference parameters and  $I$  is exogenous transfer income from remittances and government programs. Equation C1 is the household's cash-income constraint in which goods are ordered such that the first  $v$  goods are produced by the household,  $Q_i$  is the output of the  $i$ 'th good produced by the household,  $w$  is the local wage rate,  $F$  is the household's total labor supply (to both own farm and off-farm),  $r$  is the rental rate of land and  $\bar{T}^h$  is the household's land endowment. Equation C2 gives the household's technology constraints, where output of each good is assumed to exhibit constant returns in labor, land, and capital,  $\bar{k}_i$ , which is assumed fixed. C3 is the time constraint, with  $\bar{L}^h$  the household's time endowment. Finally, C4 is the subsistence constraint which restricts consumption of home produced maize to the household's production.

Commercial households are defined by a non-binding subsistence constraint. Equivalently, as characterized by de Janvry, Fafchamps, and Sadoulet (1991), the home produced staple is a tradable good for these households. Thus the optimization problem is recursive and commercial households will allocate resources to maximize profit. Profit maximization, in turn, implies factor demands in the production of maize— $L_M^h$  and  $T_M^h$ —and in the production of other goods— $L_i^h$  and  $T_i^h$ —that are functions only of exogenous (to the household) prices of goods and factors, the household's capital endowment, and household specific technology parameters:

$$\begin{aligned}
 L_M^h &= L_M^h(p_M, w, r, \bar{k}_M^h, \gamma_M^h); \\
 T_M^h &= T_M^h(p_M, w, r, \bar{k}_M^h, \gamma_M^h); \\
 L_i^h &= L_i^h(p_i, w, r, \bar{k}_i^h, \gamma_i^h) \quad i = 1, \dots, v; \\
 T_i^h &= T_i^h(p_i, w, r, \bar{k}_i^h, \gamma_i^h) \quad i = 1, \dots, v.
 \end{aligned}
 \tag{11}$$

The household's full income  $Y^h$  includes profit plus the value of household endowments. Utility maximization subject to the full income constraint yields commercial households' demand for consumption goods and leisure:

$$(12) \quad \begin{aligned} M^h &= M^h(p_M, \underline{p}, w, Y^h, \underline{\beta}^h); \\ \underline{c}_i^h &= \underline{c}_i^h(p_M, \underline{p}, w, r, Y^h, \underline{\beta}^h); \\ X^h &= X^h(p_M, \underline{p}, w, r, Y^h, \underline{\beta}^h). \end{aligned}$$

In scenarios C and D, where land markets are absent, the final term on the right hand side of the cash income constraint (net rental payments) is dropped and a household land constraint is added. In these two scenarios, commercial households are again profit maximizers with land being treated as a fixed factor. In addition, as households must allocate a fixed land area across alternative uses, factor demands in production of good  $i$  will be a function of the prices of good  $i$  as well as the price of all other goods produced by the household.

For subsistence households, home produced maize is a non-tradable good. Subsistence households face a binding subsistence constraint and therefore must strike an internal equilibrium of supply and demand for home grown maize. The relevant maize price for subsistence households is not the exogenous market price—as it is for commercial households—but instead the household's endogenous shadow price of maize,  $\rho^h = \mu / \lambda$ , where  $\mu$  is the shadow value of the subsistence constraint (C4) and  $\lambda$  is the marginal utility of income (De Janvry, Fafchamps and Sadoulet, 1991). To explicitly acknowledge the dependence of this shadow price on household preferences, we write  $\rho^h = \rho^h(\beta^h)$ . Given the missing market for maize, the optimization problem for subsistence households is not recursive. Under the assumption of non-joint production

and some fixity of capital, subsistence households will behave as profit maximizers with respect to goods other than maize that they produce. Thus their factor demands in the production of these goods have the same form as those of commercial households, as given by equation (11). Factor demands in the production of maize as well as the demand for consumption goods will be functions of household preferences:

$$\begin{aligned}
 L_M^h &= L_M^h(\rho(\beta^h), \underline{p}, w, r, \bar{k}_M^h, \gamma_M^h, \beta^h); \\
 L_i^h &= L_i^h(\rho(\beta^h), \underline{p}, w, r, \bar{k}_i^h, \gamma_i^h, \beta^h) \quad i = 1, \dots, v; \\
 T_M^h &= T_M^h(\rho(\beta^h), \underline{p}, w, r, \bar{k}_M^h, \gamma_M^h, \beta^h); \\
 T_i^h &= T_i^h(\rho(\beta^h), \underline{p}, w, r, \bar{k}_i^h, \gamma_i^h, \beta^h) \quad i = 1, \dots, v; \\
 M^h &= M^h(\rho(\beta^h), \underline{p}, w, r, Y^h, \beta^h); \\
 c_i^h &= c_i^h(\rho(\beta^h), \underline{p}, w, r, Y^h, \beta^h) \quad i = 1, \dots, I; \\
 X^h &= X^h(\rho(\beta^h), \underline{p}, w, r, Y^h, \beta^h).
 \end{aligned}
 \tag{13}$$

To operationalize our model, a household version of a social accounting matrix (SAM) (Stone 1986; Pyatt and Round, 1979) was constructed from survey data for each household in the sample (the data are described in the next section). Data in the household SAMs were used to calibrate the individual household models. Each household model is in effect a CGE for a very small economy. The precise form of the factor and consumption demands in (11), (12), and (13) depend on technology and preferences. On the technology side, we assume Cobb-Douglas production functions for each good. Exponents in the household-specific production functions were set equal to measured factor shares in value added, as implied by profit maximization. Thus, for example, the exponent on labor in the maize production function for a subsistence household was set equal to the local wage times total labor used (including the household's own labor) divided by the value of output which, in turn, equals the

household's shadow value of maize times the quantity of output.<sup>5</sup> This parameter for a commercial household was computed in the same way, except that output was valued at the market price. Consumption demands were modeled using a linear expenditure system (LES) with no minimum required quantities (Deaton and Muellbauer (1980)). This LES specification implies that preferences are described by a Cobb-Douglas utility function. The parameters in the demand equations were set equal to measured budget shares for each household and each good.<sup>6</sup> These simple specifications are sufficient to demonstrate the transmission of market prices into subsistence economies.<sup>7</sup>

The individual household models were then linked together into a village computable general equilibrium model. The general equilibrium closure equations depend upon which goods are tradable versus non-tradable at the village level as well as the nature of factor markets. As discussed above, we examine four different scenarios with respect to factor markets.

In the textbook model (Singh, Squire and Strauss, 1986), land is treated as a fixed input and thus implicitly has a shadow price that varies across households. This may be a reasonable assumption when policies or customs impede the functioning of local land markets (e.g., the Mexican *ejido* or reform-sector lands prior to liberalization of land markets in 1992). However, it is not reasonable when there is significant activity in local land rental markets which work towards equalizing the marginal value product of land across farms. This is increasingly the case in post-reform Mexico (World Bank, 2001).

With regard to wages, it might be argued that there is an active labor market in rural Mexico that is linked to internal and international migration. However, there is a striking geographic variation in the agricultural wage.<sup>8</sup> This suggests the existence of

market imperfections generating local wages or at least wage rigidities. If all households had access to a migrant labor market, one might expect rural wages to tend towards equalizing. However, access to migrant labor markets is not uniform; it is geographically concentrated and shaped by networks of family contacts at migrant destinations and other local and household-specific variables (Munshi, 2003; Taylor, 1987).<sup>9</sup>

We believe that the endogenous-wage and land rent specification (Scenario A) is realistic, but alternative market specifications are not likely to change the basic argument of this paper. The existence of *any* good or service whose price is determined in the local economy, in theory, can transmit changes in market prices to shadow prices in subsistence households. As discussed above, Scenarios B – D are added to explore the sensitivity of our empirical findings to the endogenous-wage assumption as well as to the existence of land rental markets.

Endogenous village factor prices are incorporated into the model through general-equilibrium constraints equating total village demand for land and labor to total village endowments of these factors.

Comparative statics in the village model are complex because of the large number of agricultural households, each with its own production technology and consumption demands, interacting in multiple markets. They involve direct effects (e.g., Slutsky effects of exogenous price changes on household demands) as well as indirect effects (household-farm profit effects and influences acting through endogenous village prices and household-specific shadow prices). Signing as well as quantifying the total impacts of policy shocks requires a programming approach.



Technology and preference specifications as well as the general equilibrium closure equations are summarized in Table 1. The GAMS program including the model and data is available from the authors on request.

### **Study Site and Data**

Mexican maize agriculture is marked by a panoply of market imperfections. Transaction costs have been described in relation to maize markets (de Janvry, Sadoulet and Gordillo, 1995; Key, Sadoulet and de Janvry, 2000), and a diversity of crops and services associated with maize are typically non-tradable (Clawson, 1985; Martínez *et al.*, 1995; Evangelista, 1998).<sup>10</sup> However, enormous geographical heterogeneity suggests that the particular combination of market imperfections affecting this sector varies widely.

Our village model was calibrated using data from a survey of households in Zoatecpán, an indigenous community in the rugged Sierra Norte region in the state of Puebla, Mexico. Household income and expenditure data were gathered over the 1999/2000 crop cycle by surveying a random sample of 48 households representing slightly more than 10 percent of the village household population. To increase reliability, each household in the sample was interviewed four times (three months apart), and data were collected on the previous month's consumption. Income and production data were gathered for the entire quarter during each visit. The four seasonal observations were combined to produce a single annual observation per household.

Maize is overwhelmingly the main agricultural output in this village. Most (94%) of the households in the village are subsistence maize growers; only two households in

the sample can be considered commercial growers of maize (*i.e.*, households that grow maize for the market). Nearly all households own land, but endowments vary widely: 2% of households own 50% of the land, and the average land holding is 0.4 hectares. There is an active land rental market in which nearly half of all households participated at the time of the survey. Forty six percent of households rented in land (all to produce maize), and 5% of households rented out land. (No land was rented to individuals outside the village.) The few households that rented out land are the largest landholders in the village, a pattern widespread in this region. The rental market fosters a more egalitarian distribution of arable land among local households. No household in this village had a migrant in the United States, while just under half (47%) had a migrant at an internal destination. Agricultural wages averaged 450 pesos – just under \$5 US – per day, putting this village at the bottom end of the distribution of agricultural wages in Mexico. No farmers in the sample had credit to grow maize, and there was no evidence of interlocking factor markets (e.g., credit interlinked with labor and output markets), which have been found to be important in other countries (Bardhan, 1980).

### **Empirical Findings**

Results of the market-price simulations are reported in Tables 2 and 3. Table 2 presents impacts of a 10-percent decrease in the market price of staples, both on village aggregates and separately for commercial and subsistence households. Table 3 summarizes welfare effects of the price change.

### ***Local Land and Labor Markets (Scenario A)***

In this first scenario, we allow for a village land rental market and assume that transaction costs of transacting in extra-village labor markets are sufficiently high that the wage is determined locally. Commercial production of maize contracts sharply (by 28.5%) in response to the decrease in output price. This implies a higher supply elasticity than most estimates from agricultural household models. For example, staple output price elasticities in models reviewed by Singh, Squire and Strauss (1986) ranged from 0.11 (in Sierra Leone) to 1.56 (in the Republic of Korea). They are also higher than in most village models, where general-equilibrium effects influence response elasticities (Taylor and Adelman, 1996). In all of the above-mentioned studies, land was assumed to be a fixed input in production. In our highly disaggregated model, commercial staple producers respond to the price decrease by sharply curtailing production and renting land to other (subsistence) households in the village. The impact of a local land market can be seen by comparing column A to column C and column B to column D. Under each wage scenario, the commercial supply response is considerably lower when there is assumed to be no local land market (i.e., -28.52 versus -14.57 and -47.65 versus -31.14). Aggregate supply elasticities for the village, in which total land area is fixed, are lower, and they are similar to those found in other village models.<sup>11</sup>

In scenario A, the market-price shock is transmitted to subsistence households via adjustments in the equilibrium prices of land and labor. The exogenous decline in the market price of maize causes a contraction of demand by commercial farmers for both factors, resulting in a decrease in the local land rent and wage rate of 14% and 9.6%, respectively (Table 2, Column A). Lower rents and wages reduce the incomes of

households supplying these factors, causing an inward shift in the demand for normal goods, including maize. However, because land and labor are inputs into subsistence production, the lower factor prices also cause an outward shift in the maize supply curves of subsistence households. Total maize produced by subsistence households increases by 4.8%, while the largest increase on an individual subsistence farm is 12.5%. That is, in spite of income losses in subsistence households, output increases. As land cultivation shifts from commercial to subsistence farmers, the less efficient use of inputs by the latter results in a 4.9% decrease in the village's total (commercial plus subsistence) maize output.

Impacts of lower maize prices are transmitted to other sectors of the village economy, producing secondary income effects. The consumption demand for non-maize goods and services decreases. Lower village demand provokes a contraction in activities that supply local demand but that do not make intensive use of land or labor, such as non-agricultural activities and, in some households, livestock.<sup>12</sup> The price of village non-tradables drops, counteracting the drop in demand, but demand for fixed-priced imports decreases even more sharply, spurring the decline of the formal-commerce sector. As a result, the village's GDP decreases by 7.3%.

### ***Impacts under Alternative Village Market Scenarios (B-D)***

Outcomes are sensitive to factor market assumptions. A missing land market (Column C) forces commercial farmers to cultivate land which they otherwise would rent out. This cushions the negative impact of the price shock on commercial production, wages and subsistence-household incomes, and it dampens adverse demand effects on other sectors

in the village. Paradoxically, perhaps, income falls less sharply when the land market is constrained; indirect income effects on the local economy diminish. When households are deprived of the ability to enter into rental contracts, the shadow price of land is lower for surplus growers but higher for subsistence households. Subsistence output increases by less than in the perfect land-market scenario.

If wages are fixed (Columns B and D), production does not benefit from the general equilibrium wage feedback when the price of maize falls. The staple sector's overall contraction is larger than before, and subsistence production no longer expands. Nevertheless, fixed wages and fixed land cushion subsistence-household incomes from the collapse in commercial production (Column D). This partially mitigates the contraction of non-agricultural activities and commerce. The livestock sector grows, stimulated by lower feed costs. Other (commercial) agriculture is completely unaffected, inasmuch as its output price and labor costs are unchanged.

### ***Welfare***

In each of the four scenarios, every household experiences a decrease in nominal income. Changes in real income range from a 2.7% increase to a 12.4% decrease; 7 out of 10 households experience a real-income loss.

Table 3 summarizes distributional and poverty outcomes of the 10% decrease in staple price. These are calculated from household-level impacts, which are not obtainable from village or aggregate general equilibrium models that do not model households individually. As household real income falls, income is redistributed, but only in a marginally progressive fashion: in each scenario, the Gini coefficient for income

drops from 0.36 to 0.35.<sup>13</sup> The redistribution of operated land is progressive in the two scenarios with local rental markets: the Gini coefficient for operated land decreases from 0.56 to 0.51 in Scenario A ( 0.52 in Scenario B). Nearly 15% of households rent in land previously cultivated by commercial growers.

Concerns about welfare changes in rural economies are concentrated largely on the lower tail of the income distribution. To explore the poverty impacts of the staple-price change, we compare poverty estimates under each of the four factor-market scenarios to the base poverty level, using the Foster-Greer-Thorbecke poverty index:

$$P(y; z) = \frac{I}{nz^\alpha} \sum_{i=1}^q (z - y_i)^\alpha$$

where  $n$  is the total number of adult equivalents in the village and  $y$  is a vector of per-capita incomes,  $q = q(y; z)$  is the number of adult equivalents living in poor households,  $z - y_i$  is the income shortfall (the gap between the individual's income and the poverty line) of the  $i$ th (poor) individual, and  $\alpha$  is a parameter. The poverty line we use is the per-capita income required to purchase a basic basket of food items in rural areas, estimated by the Mexican government at 15.4 pesos (approximately US\$1.50) per day in 2000.<sup>14</sup> Impoverished individuals are those who were living in households in which the per-capita income per day was less than 15.4 pesos. Using this poverty line, 90% of households in the village were poor. Because of this, sensitivity of the poverty index to the depth and severity of poverty is critical when measuring poverty impacts of market shocks.

As  $\alpha$  increases, greater weight is placed on the poorest households. Using a simple headcount poverty measure ( $\alpha=0$ ), there is no change in poverty under any of the

market scenarios (Table 3). Using the poverty gap measure ( $\alpha=1$ ), poverty increases. The poverty impact of the staple-price shock is far and away greatest using the squared poverty gap measure. This indicates that the price shock increases inequality among the poor, adversely affecting the poorest households in the village. Factor-market linkages shape poverty outcomes. Under both the poverty gap and squared poverty gap measures, poverty increases most when land markets exist and wages are endogenous. It increases least when wages do not adjust to the price shock and land inputs are fixed, so farmers cannot use the land market to adjust to the price shock.

These findings indicate the vulnerability of very poor households, who rely primarily on their endowment of labor, to the general equilibrium effects of market price shocks. The poorest households receive a large share of their income from local wage work, and they suffer disproportionately via general-equilibrium effects operating through labor markets. Households engaged in formal commerce experience the greatest percentage decreases in income, even greater than those of commercial maize growers. However, they are not poor. Poor households whose chief income source is public or private transfers experience increases in real income. They benefit as consumers from the lower staple prices, without being adversely affected by the decrease in wages. However, they are not among the poorest in the village.

## **Conclusions**

The presence of a single commercial producer theoretically is sufficient to transmit the impacts of price and other policy shocks throughout a largely subsistence economy, with potentially surprising results. Commercial producers transmit shocks from national and

international commodity markets through their interactions with subsistence producers in local factor markets. As a result, no one is truly isolated from market shocks; “shadow prices” in subsistence households ultimately are linked with outside market prices.

Our analytical and empirical findings suggest a previously unrecognized explanation for immiserized growth, or a negative association between output and welfare changes, in small-farm economies. General equilibrium linkages, via local factor markets, can result in conflicting welfare and output effects of market price shocks in subsistence households. Our results also suggest a local explanation for the sluggish (and apparently perverse) response of production on rain-fed lands to changes in market prices of maize in the wake of Mexico’s agricultural reforms. Most farmers in Mexico are subsistence producers on rainfed lands.<sup>15</sup> Like consumers in a Becker (1965) household model, they combine land, labor and other inputs to produce a utility-generating output. As structural adjustments lower the opportunity cost of land and labor, production of home-grown maize expands. The result, ironically, may be a movement towards a more inward looking, subsistence economy in the wake of market liberalization. Development of land markets may exacerbate this apparently perverse supply response by encouraging land rental. While the existence of local land markets increases the supply elasticity on commercial farms, our experiments show that it also can reinforce a positive supply elasticity on subsistence farms. Integration with outside labor markets, via migration or expansion of rural nonfarm employment, may dampen the subsistence response (while exacerbating the commercial response) by limiting local wage adjustment.

Findings using data from a single village cannot be generalized; the mix of commercial and subsistence households in one village do not reflect the overall rural



economy. Nevertheless, they are sufficient to demonstrate that interactions in local markets can transmit changes in market prices to shadow prices in subsistence households, affecting supply response in surprising ways. The outcomes of our experiments would almost certainly be different in villages that are more closely integrated with outside markets, particularly for labor, and in regions with commercial alternatives to staple production. Commercial farmers in Puebla did not benefit from input subsidies that supported Mexico's commercial production of maize in the wake of falling output prices.<sup>16</sup>

A basic tenet of our modeling approach is that heterogeneous local conditions can generate a variety of policy and market outcomes. Disaggregated models that allow for heterogeneous micro responses as well as interactions among actors in a general-equilibrium context can help explain unexpected micro responses and aggregate effects of policy and market shocks. Micro agricultural household models, with or without missing markets, are special cases of general-equilibrium models, because they rule out the transmission of influences among households. This limitation is likely to be increasingly serious as market liberalization enables diverse agents to respond to policy changes in new ways.

## References

- Adelman, I., J.E. Taylor, and S. Vogel. 1988. "Life in a Mexican Village: A SAM Perspective." *Journal of Development Studies* 25:5-24.
- Appendini, K. 1993. *De la milpa a los tortibonos: La restructuración de la política alimentaria en México*. Mexico: El Colegio de México, Instituto de Investigaciones de las Naciones Unidas para el Desarrollo Social.
- Bardhan, P. 1980. "Interlocking Factor Markets and Agrarian Development: A Review of Issues." *Oxford Economic Papers* 32(1):82-98.
- Barrett, C. B. 1998. "Immiserized Growth in Liberalized Agriculture." *World Development* 26(5):743-753.
- Bartra, R. 1982. *Campesinado y poder político en México*. Mexico: Ediciones Era.
- Becker, G.S. 1965. "A Theory of the Allocation of Time." *The Economic Journal* 75:493-517.
- Clawson, D.L. 1985. "Harvest Security and Intraspecific Diversity in Traditional Tropical Agriculture." *Economic Botany* 39(1):56-67.
- De Janvry, A., M. Fafchamps, and E. Sadoulet. 1991. "Peasant Household Behavior with Missing Markets: Some Paradoxes Explained." *The Economic Journal* 101:1400-1417.
- De Janvry, A., E. Sadoulet, and G. Gordillo de Anda. 1995. "NAFTA and Mexico's Maize Producers." *World Development* 23(8):1349-1362.
- Deaton, A. 1997. *The Analysis of Household Surveys: A Microeconometric Approach to Development Policy*. Washington, D.C.: The World Bank; Baltimore: John Hopkins Univ. Press.

- Deaton, A., and J. Muellbauer. 1980. *Economics and Consumer Behavior*. Cambridge: Cambridge University Press.
- de Ita, A. 2003. “Los Impactos Socioeconómicos y Ambientales de la Liberación Comercial de los Granos Básicos en el Contexto del TLCAN: El Caso de Sinaloa.” Paper presented at the *Second North American Symposium Assessing the Environmental Effects of Trade*, Mexico City, March 25-26.
- Esteva, G. 1982. *La Batalla en el México Rural*. México: Siglo XXI.
- Evangelista O.V. 1998. “Influencia de Dos Cultivos Comerciales en el Cultivo de Maíz en la Comunidad de Naupan, Puebla.” MS thesis, Universidad Nacional Autónoma de México.
- Fox, J. 1992. *The Politics of Food in Mexico: State Power and Social Mobilization*. Ithaca, N.Y.: Cornell University Press.
- Hewitt de Alcantara, C. 1976. *Modernizing Mexican Agriculture: Socioeconomic Implications of Technological Change 1940-1970*. Geneva: United Nations Research Institute for Social Research.
- INEGI. 1998. *Anuario Estadístico del Estado de Puebla*. INEGI, Gobierno del Estado de Puebla, Mexico.
- . 2003. Online database [www.inegi.gob.mx](http://www.inegi.gob.mx).
- Key, N., E. Sadoulet, and A. de Janvry. 2000. “Transaction Costs and Agricultural Household Supply Response.” *American Journal of Agricultural Economics* 82:245-259.
- Kurosaki, T. 1995. “Risk and Insurance in a Household Economy: Role of Livestock in Mixed Farming in Pakistan.” *Developing Economies* 33(4):464-485.

- Levy, S., and S. van Wijnbergen. 1994. "Labor Markets, Migration and Welfare: Agriculture in the North-American Free Trade Agreement." *Journal of Development Economics* 43:263-278.
- Lewis, B.D. and Thorbecke, E. 1992. "District-level Economic Linkages in Kenya: Evidence Based on a Small Regional Social Accounting Matrix." *World Development*, 20(6): 881-897.
- Lewis, W. A. 1954. "Economic Development with Unlimited Supplies of Labour." *Manchester School of Economic and Social Studies* 22:139-191.
- Martínez, M.A., V. Evangelista, M. Mendoza, G. Morales, G. Toledo, and A. Wong. 1995. *Catálogo de plantas útiles de la Sierra Norte de Puebla, México*. Cuadernos 27, Mexico: Instituto de Biología, UNAM.
- Munshi, K. 2003. "Mexican Migrants in the U.S. Labor Market." *Quarterly Journal of Economics* 118(2):549-599.
- Omamo, S.W. 1998a. "Transport Costs and Smallholder Cropping Choices: An Application to Siaya District, Kenya." *American Journal of Agricultural Economics* 80(1):116-123.
- \_\_\_\_\_. 1998b. "Farm-to-Market Transaction Costs and Specialization in Small-Scale Agriculture: Explorations with a Non-separable Household Model." *Journal of Development Studies* 35(2):152-163.
- Pyatt, G. and J.I. Round. 1979. "Accounting and Fixed-Price Multipliers in a Social Accounting Matrix Framework." *The Economic Journal* 89:850-73.
- Robinson, S., M.E. Burfisher, R. Hinojosa-Ojeda, and K.E. Thierfelder. 1993. "Agricultural policies and Migration in a US.-Mexico Free Trade Area: A

- Computable General Equilibrium Analysis.” *Journal of Policy Modeling* 15(5&6):673-701.
- Shively, G.E. Forthcoming. “Externalities and Labor Market Linkages in a Dynamic Two-Sector Model of Tropical Agriculture.” *Environment and Development Economics*, in press.
- Singh, I., L. Squire, and J. Strauss. 1986. “The Basic Model: Theory, Empirical Results, and Policy Conclusions.” In I. Singh, L. Squire, and J. Strauss (eds.) *Agricultural Household Models: Extensions, Applications, and Policy*. Washington, D.C.: The World Bank; Baltimore: John Hopkins University Press, pp. 17-47.
- Stiglitz, J.E. 1989. “Markets, Market Failures, and Development.” *American Economic Review* 79(2):197-203.
- Stone, R. 1986. “Nobel Memorial Lecture 1984: The Accounts of Society.” *Journal of Applied Econometrics* 1(1):5-28.
- Subramanian, S. and E. Sadoulet. 1990. “The Transmission of Production Fluctuations and Technical Change in a Village Economy: a Social Accounting Matrix Approach.” *Economic Development and Cultural Change*, 39(1): 131-173.
- Taylor, J. E. 1987. “Undocumented Mexico-U.S. Migration and the Returns to Households in Rural Mexico.” *American Journal of Agricultural Economics* 69(3):626-38.
- Wilk, R.R. 1997. *Household Ecology: Economic Change and Domestic Life Among the Kekchi Maya in Belice*. DeKalb: Northern Illinois University Press.
- World Bank. 2001. *Mexico Land Policy – A Decade After the Ejido Reform*. Report No. 22187-ME. Washington D.C.: The World Bank.

**Table 1. Technology, Preferences and General Equilibrium Conditions**

Production Technology			
Goods Produced by Household $h$ :	$Q_i^h = a_i^h \left(L_i^h\right)^{\gamma_{L,i}^h} \left(T_i^h\right)^{\gamma_{T,i}^h} \left(\bar{k}_i^h\right)^{1-\gamma_{L,i}^h-\gamma_{T,i}^h}; \quad i=1,...,v$		
Goods Not Produced by Household $h$ :	$Q_i^h = 0; \quad i = v+1,...,I$		
Budget Constraint	$Y^H = \sum_i (p_i Q_i^h - w L_i^h - r T_i^h) + w \bar{L}^h + r \bar{T}^h + I^h = \sum_i p_i c_{hi}$		
Factor Demands:	Non-Maize	Maize-Commercial	Maize-Subsistence
Labor	$L_i^h = \frac{\gamma_{L,i}^h \cdot p_i \cdot Q_i^h}{w}$	$L_M^h = \frac{\gamma_{L,M}^h \cdot p_M \cdot Q_M^h}{w}$	$L_M^h = \frac{\gamma_{L,M}^h \cdot \rho^h(\beta^h) \cdot Q_M^h}{w}$
Land (Scenarios A & B)	$T_i^h = \frac{\gamma_{T,i}^h \cdot p_i \cdot Q_i^h}{r}$	$T_i^h = \frac{\gamma_{T,M}^h \cdot p_M \cdot Q_M^h}{r}$	$T_M^h = \frac{\gamma_{T,M}^h \cdot \rho^h(\beta^h) \cdot Q_M^h}{r}$
Consumption Demands (Based on LES)	$c_i^h = \frac{\beta_i^h Y^h}{p_i}$	$c_M^h = \frac{\beta_M^h Y^h}{p_M}$	$c_M^h = \frac{\beta_M^h Y^h}{\rho^h(\beta^h)}$
General-Equilibrium Conditions for Factors			
Labor market clearing (Scenarios A and C)	$\sum_h \sum_i (\bar{L}_i^h - L_i^h) = 0$		
Land market clearing (Scenarios A and B)	$\sum_h \sum_i (\bar{T}_i^h - T_i^h) = 0$		
No Land market (Scenarios C and D; implicit household-specific rental rates)	$r_h = p_i \frac{\partial Q_i^h(L_i^h; \bar{k}_i^h, \bar{T}_i^h)}{\partial T} \quad , \quad \bar{T}^h - \sum_i T_i^h = 0 \quad \forall i$		
General-Equilibrium Conditions for Commodities			
Village Tradables (possibility of nonzero village marketed surplus, $MS_i$ )	$\sum_h (Q_i^h - c_i^h) = MS_i$		
Village Non-Tradables	$\sum_h (Q_i^h - c_i^h) = 0$		

**Table 2. Percentage Effects of a 10% Decrease in the Market Price of Maize,  
Zoatecpan Village, Mexico**

	Scenario <sup>*</sup>			
	(A)	(B)	(C)	(D)
Production Activities				
Maize: Aggregate	-4.89	-14.22	-2.52	-10.12
Commercial Hhs	-28.52	-47.65	-14.57	-31.15
Subsistence Hhs	4.77	-0.56	2.40	-1.53
Other Agriculture	4.45	0.00	2.89	0.00
Livestock	-0.64	0.64	0.32	1.01
Non-Ag Activities	-18.98	-9.49	-12.50	-7.11
Commerce	-36.19	-18.45	-23.82	-13.81
Wage	-9.60	—	-6.46	—
Rental Rate	-14.05	-14.25	—	—
Village GDP	-7.26	-3.77	-4.78	-2.82
Household Real Income	-1.69	-0.87	-0.77	-0.45
Commercial Hhs	-3.97	-3.04	-1.30	0.39
Subsistence Hhs	-1.57	-0.75	-0.74	-0.50

\* The scenarios are as follows: A) Local land market (endogenous rental rate)/local labor market (endogenous wage); B) Local land market/open labor market (exogenous wage); C) No land market/local labor market; D) No land market/open labor market.

**Table 3. Welfare effects of a 10% decrease in the market price of maize**

Indicator	Scenario				
	Base	A	B	C	D
Gini Coefficient					
Real Income	0.36	0.35	0.35	0.35	0.35
Cultivated Land	0.56	0.52	0.51	0.56	0.56
Percentage change in poverty					
Poverty Gap ( $\alpha=1$ )		0.90%	0.47%	0.14%	0.06%
Squared Poverty Gap ( $\alpha=2$ )		1.70%	0.67%	0.48%	0.24%

\* The scenarios are as follows: A) Local land market (endogenous rental rate)/local labor market (endogenous wage); B) Local land market/open labor market (exogenous wage); C) No land market/local labor market; D) No land market/open labor market.



## Footnotes

---

\* The authors are, respectively, UC-CONACYT post-doctoral fellow in the Center of Economic Studies at El Colegio de Mexico and Professor and Assistant Professor of Agricultural and Resource Economics at the University of California, Davis. Boucher and Taylor are members of the Giannini Foundation of Agricultural Economics. We are grateful to an editor and three referees of this journal and to participants in the UC Davis Development Workshop for their valuable comments. Critical financial support was provided at various stages of this research by the William and Flora Hewlett Foundation, the University of California Institute on Mexico (UC Mexus), and the McKnight Foundation. Corresponding author: J. Edward Taylor, Department of Agricultural and Resource Economics, One Shields Ave., University of California, Davis, CA. 95616. email: jetaylor@ucdavis.edu ph: (530) 752-0213 fax: (530)752-5614.

1 E.g., see Levy and van Wijnbergen (1994). According to the FAO and Mexican Ministry of Agriculture (SAGAR and SIACON data bases and "Anuario estadístico de la producción agrícola 1999-2002"), average annual maize production on rain-fed lands was 40% higher in 2001-03 than in 1983-90, despite lower maize prices. This change was due to an increase in planted area and, to a lesser extent, in yields.

2 The National Accord for the Countryside (ANC), signed in April 2003, increases subsidies (PROCAMPO payments) to producers with fewer than five hectares and expands several programs benefiting the poorest sectors of the rural society.

3 The exception is when the market-price change is of sufficient magnitude to nudge the household out of the “price band” that is created by transaction costs; see Key, Sadoulet, and de Janvry (2000).

---

4 This paper's focus is on interactions between subsistence and commercial households in local markets. We therefore assume throughout that subsistence households exist. Our treatment of subsistence production is analogous to Becker's (1965) treatment of "Z goods," produced by households for home consumption using purchased and family inputs. These goods implicitly have endogenous, shadow prices.

5 To provide an idea of the distribution of a given parameter across sample households, the exponent on land in the production function for maize ranged from .04 to .67 with a median value of .12. The budget share of maize ranged from 0 to .5 with a median of .18.

6 The budget and factor shares for the subsistence good were obtained by valuing this good at a shadow price equal to its observed per-unit cost of production; see Becker (1965).

7 We have found the results of policy experiments using similar models to be robust to the specification of functional forms, including more complex production and expenditure functions with assumed elasticities. This is not surprising, inasmuch as the model is always estimated at the same point given by the survey data, and policy experiments involve marginal changes in exogenous variables. Simple functional forms permit estimation of a separate model for each agricultural household in the sample and lend transparency to results. Despite linearity of individual household responses, aggregate outcomes of market shocks are highly nonlinear, shaped by specific households' production and demand parameters and the endogenous prices of nontradables.

---

8 According to data from the 2003 Mexico National Rural Household Survey (Encuesta a Hogares Rurales de Mexico—ENHRUM), daily agricultural wages in Mexico ranged from 50 to 300 pesos in summer 2003 (estimates by authors).

9 Among the 80 villages surveyed in the ENHRUM, the percentage of village populations working as international migrants in 2002 ranged from zero to 49.7%, with a mean of 14.0%. The percentage working as internal migrants ranged from 0.0% to 53.0%, with a mean of 15.2%.

10 Non market benefits of maize cited include economic, social and ritual services; e.g., food security, income diversification and social standing.

11 Taylor and Adelman (1996) estimate staple-price elasticities of 0.38 to 1.4 in village models for Senegal, India, Mexico, Kenya and Java.

12 These activities are geared entirely to satisfy local demands; they are not connected with outside markets. Thus, they are treated as village nontradables with endogenous local prices.

13 See Deaton (1997) for the formula to estimate the Gini coefficient.

14 See [http://www.sedesol.gob.mx/subsecretarias/prospectiva/medicion\\_pobreza](http://www.sedesol.gob.mx/subsecretarias/prospectiva/medicion_pobreza)

15 De Janvry, Sadoulet, Gordillo de Anda (1995).

16 ASERCA marketing supports to commercial producers of basic crops reached 6,406 million pesos (US\$613 million) in 2003. Around 30% of ASERCA payments are to commercial producers of corn; however, they are concentrated in the northwestern regions, primarily the state of Sinaloa (de Ita, 2003).