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Linking Trade and Productivity: New Research Directions

James R. Tybout

It is a mistake to think of productivity growth as an orderly shift in the production function of the representative plant. Gradual processes of technological diffusion or the displacement of inefficient plants with efficient ones are what matter. Trade orientation may affect these processes through many channels. Exposure to increased foreign competition is found to be associated with improvements in the average level of technical efficiency, reductions in the cross-plant dispersion in technical efficiency, and reductions in plant size. However, preliminary work suggests no clear link between trade policies and patterns of entry and exit.

This article brings together diverse literatures on the measurement of productivity and its relation to trade regime, focusing on recently developed techniques and their application. Section I briefly reviews the theoretical arguments linking trade policy and productivity. Empirical work at the sector and macro level is discussed in section II, and plant level empirical work is discussed in section III. Applications of the different approaches are reported for a sample of semi-industrial countries that have recently been analyzed in the World Bank research project "Industrial Competition, Productivity, and Their Relation to Trade Regimes," hereafter the ICPT project.

I. The Theory of Productivity Growth and Its Link to Trade

In trade models that presume perfect competition, "opening up" generally improves the allocation of factors across sectors and thereby induces a one-time increase in the value of domestic production. However, liberalization does not reduce the volume of inputs needed to produce a given bundle of outputs. Thus, although many economists believe that there are important links between trade

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regimes and factor productivity, they have had to look elsewhere for formal models that support their priors.

Linking Trade Regimes and Productivity Levels

To development economists, perhaps the best-known argument linking trade regimes and productivity is that the returns to entrepreneurial effort increase with exposure to foreign competition (Corden 1974; Martin and Page 1983).1 Unfortunately, formal representations of this argument reveal its fragility. To hold, the entrepreneurial labor supply curve must be upward sloping in the relevant range, and changes in work incentives must go in the same direction for both export-oriented and import-substituting producers (Corden 1974; Rodrik 1988).

Arguments based on increasing returns are also common in the development literature. Nishimizu and Page (1991, p. 253) summarize the logic as it has often appeared: “The existence of economies of scale . . . implies that a widening of the market through trade should lead to reductions in real production costs. In the context of an output-oriented development strategy, this argument is usually cast in terms of the benefits of increased demand through export expansion . . . .” As with entrepreneurial effort arguments, however, analytical scrutiny has shown that scale economies can cut both ways (Krugman 1986; Rodrik 1992; Roberts and Tybout 1991). When domestic firms enjoy market power, extra competition from foreign producers can force producers to expand or exit. But the net effect of liberalization on productivity depends upon the specifics of the demand shifts that accompany liberalization, ease of entry or exit, and the nature of competition.

Finally, trade reforms affect the tightness of the link between domestic and world markets and generate speculation about their own sustainability. These uncertainty effects can influence productivity. For example, when the incentive structure changes frequently and unpredictably, managers are reluctant to repeatedly incur the sunk costs of retooling (Dixit 1989a, 1989b; Baldwin and Krugman 1989; Baldwin 1989). Similarly, when substitution possibilities exist, managers may react to uncertainty by choosing labor-intensive technologies, even though more capital-intensive technologies would be less costly to operate if market conditions were stable (Lambson 1989). Rapid and efficient adjustments in productive capacity are likely only when trade reforms establish a credible, stable regime.

Diffusion and Innovation in Partial Equilibrium

Trade regimes have also been directly linked to rates of diffusion and innovation. For example, Rodrik (1992) shows that a firm’s market share can affect the payoff it reaps from adopting new technologies. Trade reforms may therefore

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1. Hart (1983) uses a principal-agent model to arrive at a similar result. His arguments are more subtle than those in the development literature, but equally fragile, as Scharfstein (1988) shows.
reduce the rate of catch-up to international productivity levels in import-competing sectors and accelerate it among exportables. Rodrik (1992) also observes that domestic producers compete through choice of technique (among other things), so they may tacitly collude when protected from foreign competition by failing to modernize their plants. He is quick to note that both arguments hinge critically upon some fairly arbitrary assumptions.

A more venerable strand of the literature focuses on plant heterogeneity. It begins with the premise that new processes diffuse through an industry as managers learn about them and older vintage machines depreciate. This means that there is no single production function, and it is a mistake to think of productivity growth as an orderly shift in technology. Rather, the processes of learning, innovation, investment, entry, and exit are what matter. Trade orientation affects these processes through many channels, often by influencing entrepreneurial ability to monitor new technological developments or by changing the expected returns from innovation. Stewart and Ghani (1992) provide a useful review of the conceptual and empirical studies relevant to developing countries.

**The New Literature on Endogenous Growth**

Other strands of the literature provide general equilibrium representations of the links among trade, innovation, and growth. Unlike the treatments reviewed above, these models rely critically on the interaction among sectors. Examples are Krugman (1985) and Lucas (1988), which use learning-by-doing externalities at the sector level to create a link between trade policy and sectoral growth patterns. Any policy-induced shift in the composition of output changes patterns of sectoral learning rates and productivity growth; in turn these changes determine trade patterns.

Grossman and Helpman (1989, 1990) and Helpman (1990) explore another, related mechanism. In their models productivity growth is driven by private sector research and development, which results in new intermediate goods that enhance final good productivity and also contributes to public knowledge. Entrepreneurs in the research and development sector sell blueprints for income, and the rate of increase in the stock of blueprints determines the rate of productivity growth.

Trade policy matters in this framework for several reasons. First, when deciding whether to develop new products, entrepreneurs consider the variety of substitute products already available, which depends in turn upon their exposure to international competition and the ease with which knowledge crosses international boundaries. Second, in larger markets there is more demand for

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3. In Grossman and Helpman (1989) the industrial countries develop new products, and developing countries invest in "de-engineering" them. This variant of the basic structure allows for product cycle effects.
any particular new product variety, so, other things being equal, market size encourages innovation. These two effects can work against one another, making the net impact of integrating with world markets ambiguous. Finally, research and development requires labor and capital inputs, which are also used to produce traded goods. So a change in trade regime that affects relative output prices also affects the returns to new product development (through Stolper-Samuelson linkages) and thereby influences the rate of productivity growth.

II. SECTORAL AND INDUSTRY-LEVEL APPROACHES TO MEASURING PRODUCTIVITY

As the discussion above makes clear, there are many potential links between trade and productivity. It is not at all obvious which ones are empirically relevant, much less what their net effect will be in a particular liberalization episode. Accordingly, considerable attention has focused on empirical research.

Traditional Residual-Based Calculations

The most common approach to productivity measurement begins by assuming a neoclassical production function at the sectoral or industry level:

\[ Y = f(v,t). \]

Here total output \( Y \) is a concave function of the vector of inputs \( (v_k \times 1) \) and a time index \( (t) \) that allows the function to shift with technological innovations or improvements in the efficiency of existing technologies. The elasticity of output with respect to time, \( \epsilon_{Y,t} = \frac{\partial f/\partial t}{Y} \), is hereafter referred to as total factor productivity (TFP) growth.

The role of TFP growth is typically isolated by expressing equation 1 in growth terms and rearranging:

\[ \epsilon_{Y,t} = \frac{\dot{Y}}{Y} - \sum_{j=1}^{k} \theta_j \frac{\dot{v}_j}{v_j}. \]

Here a dot over a variable denotes its total derivative with respect to time, and \( \theta_j = \frac{\partial f/\partial v_j}{Y} \) is the elasticity of output with respect to the \( j \)th factor input. Then, making the critical assumption that each factor is paid the value of its marginal product, one may replace output elasticities with factor shares \( (s_j) \) and estimate TFP growth using a Divisia index:

\[ \hat{\epsilon}_{Y,t} = \frac{\dot{Y}}{Y} - \sum_{j=1}^{k} s_j \frac{\dot{v}_j}{v_j}. \]

The carat on \( \epsilon_{Y,t} \) indicates that this is an estimator, and implementation requires that instantaneous time derivatives be replaced with discrete changes. The shares become averages of current and previous period shares, and the resultant measure of TFP growth is known as a Tornqvist index. In more involved applica-
tions diverse types of labor, capital, and intermediates are aggregated using Tornqvist indexes, and changes in the quality of each factor are analyzed (for example, Jorgenson and others 1987).

Given the possible trade-productivity links reviewed in section I, it has often been asked whether estimated TFP figures \( (\hat{\varepsilon}_y, t) \) correlate with exposure to foreign competition. Much of this literature is surveyed elsewhere (Chenery and others 1986; Pack 1988; Havyryshyn 1990), so a few summary remarks suffice here. First, many cross-country studies find that rapid output growth is associated with rapid export growth or high export to output ratios. It is less common to find that rapid TFP growth correlates positively with openness. Pack (1988) writes that “comparisons of total factor productivity growth among countries pursuing different international trade orientations do not reveal systematic differences in productivity growth in manufacturing...” However, Chenery and others (1986), Balassa (1985), and Edwards (1989) have found a positive association between TFP growth and openness. Second, after reviewing studies based on within-country temporal correlations, Pack (1988) and Havyryshyn (1990) both conclude that there is no strong evidence linking productivity and openness. Nonetheless some studies do find a positive association between export growth and productivity (for example, Krueger and Tuncer 1982; Nishimizu and Robinson 1984; Nishimizu and Page 1991). Third, in their multicountry study of industry-level TFP indexes, Nishimizu and Page (1991) find that other dimensions of policy—notably the degree of government intervention—significantly influence the relation between trade and productivity.

As a first step in researching the trade-productivity link, each author preparing a country study for the ICPT project was asked to regress annual industry-specific estimated TFP series on components of a demand-side sources of growth decomposition (domestic market growth, import substitution, and export expansion), a Herfindahl index of concentration, and an interaction term that allows the coefficient on import penetration to vary with market concentration. The index of concentration and interaction term allow for market structure effects like those discussed in Rodrik (1992)—they were a novelty of the ICPT specification. Industry dummies and annual time dummies were included in all regressions. Thus all explanatory variables were at the sector level.

The strongest result was a familiar one: output expansion and TFP growth covary. This positive association between the components of output growth and measured productivity, known as Verdoorn’s Law, is sometimes taken to reflect scale economies or the embodiment of new technologies during periods of rapid investment (Chenery and others 1986; Nishimizu and Page 1991). Alternatively, it may simply reflect spurious correlation due to the identity \( X_1 + X_2 + X_3 = \hat{\varepsilon}_y + \sum s_{ij}(v_i/v_j) \), where \( X_1, X_2 \), and \( X_3 \) decompose output growth into domestic market growth, import substitution, and export expansion, respectively. That is, if total output is measured with error, this error will show up on both sides of
the regression equation. Finally, as will be discussed shortly, violations of the assumptions behind equation 3 can induce spurious correlation.

The ICPT results also indicated that it matters whether demand expands because of domestic market growth, export growth, or import substitution, but the pattern was country specific. In Chile and Morocco import substitution had a significantly smaller effect on productivity growth in concentrated industries. But in Colombia import substitution was associated with especially high productivity growth in concentrated industries. Taken together, the results suggest that market structure does affect the nature of the link between trade patterns and productivity, but the relationship is not a stable one. Methodological problems no doubt account for some of the instability; for example, measurement error may occur in different components of output growth in different countries. But it is difficult to explain why these problems should cause the pattern to vary so strikingly across countries, or how they might cause market concentration to condition the relation between import substitution and growth.

A Refinement of Residual-Based Productivity Measures

Even when data are observed without error, for calculations based on equation 3 to reflect productivity growth, the following assumptions are necessary: there are constant returns to scale, all factors are freely adjusted to maximize profits, markets are competitive, and all plants employ identical technologies. None of these assumptions is innocuous. An extended version of this article provides details on problems that result when these assumptions are violated and reviews various corrections that have been attempted (Tybout 1991). Herein we limit discussion to recent studies that attempt to control for nonconstant returns to scale, adjustment costs, and noncompetitive product markets (Hall 1986, 1988a, 1988b; Domowitz and others 1988; Shapiro 1987; Caballero and Lyons 1989a, 1989b, 1990).

Suppose that all plants are identical, and output price at the representative plant is given by the downward-sloping demand function, \( P = p(Y) \) (with plant subscripts suppressed). Then the first-order conditions for profit maximization equate factor prices to marginal revenue products:

\[
\phi_j = P[1 + \mu] \partial P/\partial y_j, \quad j = 1, \ldots, k
\]

where \( \mu < 0 \) is the inverse of the elasticity of demand perceived by the representative plant, and \( 1/[1 + \mu] \) is its markup of price over marginal cost. Given that \( \mu \) is negative, factor shares underestimate the true marginal product of the associated factors, so TFP calculations based on equation 2 yield:

\[
\dot{e}_{Y,t} = \dot{Y}/Y - (1+\mu) \sum_{j=1}^{k} \theta_j (\dot{y}_j / y_j) = \epsilon_{Y,t} - \mu \sum_{j=1}^{k} \theta_j (\dot{y}_j / y_j).
\]

Accordingly, the extent of the upward bias depends directly upon the rate of growth in factor stocks, and measured productivity growth is procyclical. Hall (1986, 1988a, 1988b) suggests that this problem can be corrected with-
out knowing $\mu$ by regressing output growth on the share-weighted sum of input growth rates. Defining $v_1, v_2,$ and $v_3$ as labor, materials, and capital, respectively, this amounts to fitting the regression:

$$\frac{\dot{Y}}{Y} = \beta_0 + \beta_1 \sum_{j=1}^{3} s_j \left( \frac{\dot{v}_j}{v_j} \right) + u. \tag{6}$$

By equation 4, $s_j = \theta_i (1 + \mu)$, so equation 6 is a restatement of equation 2 with $\beta_1 = 1/(1 + \mu)$ and $\beta_0 = \epsilon_x - u$. This means that $\beta_0$ is the average rate of productivity growth, and $\beta_1$ is the markup over marginal cost.

The Hall methodology is appealing, but for several reasons its validity hinges critically on the availability of good instrumental variables. First, although markups are treated as parametric in equation 4, they are likely to be procyclical (Domowitz and others 1986), so ordinary least squares (OLS) estimates of $\beta_1$ are likely to be biased upward. Similar biases will result whenever the transitory TFP growth ($u$) is correlated with factor stock growth. Hall recognizes the potential correlation of factor stocks with the disturbance term, and uses growth of gross national product as an instrument in a two-factor version of equation 6. But critics of the Hall methodology argue that the problem remains, given that this growth is itself likely to be correlated with $u$ and $\epsilon$ (Abbott and others 1989).

Each country study author in the ICPT project was asked to estimate a three-factor version of equation 6, generalized to the case of quasifixed capital stocks and nonconstant returns to scale. The most straightforward variant used was

$$\frac{\dot{Y}}{Y} - \frac{\dot{v}_3}{v_3} = \beta_0 + \beta_1 \sum_{j=1}^{2} s_j \left( \frac{\dot{v}_j}{v_j} - \frac{\dot{v}_3}{v_3} \right) + \beta_2 \frac{\dot{v}_3}{v_3} + u. \tag{7}$$

Here $\beta_2 = 1 - \sum \theta_i$ is positive (negative) if firms exhibit increasing (decreasing) returns to scale. Most authors fit a version of this equation twice—one with OLS and once using instruments. Also, for two of the countries (Turkey and Côte d'Ivoire) the authors investigated whether trade reforms were associated with a change in either the corrected TFP growth rate or the price-cost markup. They did this by allowing $\beta_0$ and $\beta_1$ to shift in sample years when the economy was under a liberal trade regime.

All country authors performed regressions pooling time series on each three-digit industry (industry dummies were included). These typically yielded believable TFP growth figures ($\beta_0$) between 7 and -7 percent. They also yielded sensible markup coefficients ($\beta_1$), on average, ranging from 1.03 to 1.08 for OLS and 1.24 to 1.67 for instrumental variable estimators. But returns to scale ($\beta_2$) were not accurately identified, and the markup coefficients were especially sensitive to the instrument set used.

In separate ICPT studies Harrison (1990) and Levinsohn (1991) applied Hall's methodology at the plant level, where they could control for a number of complicating factors. They both concluded that certain protected sectors had significant markups and that these markups fell with trade liberalization or exchange rate appreciation. Harrison also found that, although TFP series based on equa-
tion 3 correlate strongly with trade regimes, the corrected TFP series based on equation 7 (that is, $\hat{\beta}_0$) do not.

Overall the Hall methodology appears to hold some promise, although it has several potentially serious shortcomings. First, it attributes all deviations of factor shares from marginal productivities to product market distortions. Second, it is disturbingly sensitive to the choice of instruments. Finally, it fails to deal with several of the same problems that limit the usefulness of Tornqvist indexes. Particularly when applied at the industry level, it involves heroic assumptions about the uniformity of technologies and behavior across plants as well as the homogeneity of factor inputs, both across plants and through time.

III. Micro Approaches to Measuring Productivity

The empirical methodologies discussed above all presume that a well-defined production technology describes all plants within the industry, sector, or country of analysis. If technological innovation takes place through a gradual process of efficient plants displacing inefficient ones or through the diffusion of new knowledge, the approaches to measuring productivity based on the behavior of a representative plant are at best misleading. At worst they fail to capture what is important about productivity growth altogether (Nelson 1981).

Heterogeneity and Productivity Growth

One of the most obvious features of industrial censuses is the tremendous amount of cross-plant heterogeneity. Even within narrowly defined industries, one observes wide ranges of output levels, capital-labor ratios, capital stock vintage, and profitability (Berry 1992; Tybout and others 1991). Accordingly, if changes in productivity are systematically induced by changes in the cross-plant distribution of these features, the productivity growth process will not be revealed by sectoral or macro analysis. An important question, about which we know very little, is whether such changes in the distribution of plants account for a significant portion of observed changes in sectoral output per unit of input (see, however, Gomulka 1976).

A complete analysis of this issue would require extensive engineering studies and is well beyond the scope of this article.4 To provide a modest start, some simple statistics can be constructed to summarize the roles of plant turnover, scale, and heterogeneity in shaping productivity growth. Specifically, for a given industrial sector let $F = h(v)$ be a scalar index of factor input use. (For example, $F$ might simply be number of workers, or it might be a share-weighted aggregation over capital, labor, and intermediates.) Then total industrial output ($Y$) can

---

4. Pack (1992) surveys the literature on engineering studies of certain groups of plants. He finds that "the emphasis in the recent technical change studies on the firm rather than the industry makes it difficult to evaluate the significance of the reported innovative activity. . . . [A]lmost all of the technical change studies examine the history of only one or two firms."
be expressed as output per unit of factor input \((y = Y/F)\) times number of plants \((N)\), times factor input per plant \((f = F/N)\). In discrete growth terms:

\[
\Delta Y / Y_{t-1} = (\Delta y / y_{t-1})(\omega_1) + (\Delta f / f_{t-1})(\omega_2) + (\Delta N / N_{t-1})(\omega_3)
\]

The first term on the right side of equation 8 reflects productivity growth, the second term reflects changes in the average scale of operations (measured by factor use), and the third term reflects net entry. The weights \(\omega_1\), \(\omega_2\), and \(\omega_3\) are averages of all possible variants of the identity and reflect the fact that the equation is in discrete terms; each weight will be close to one. The identity represented by equation 8 reveals not only whether output expansion has come mainly from productivity growth, but also whether productivity changes have been accompanied by changes in scale or net entry.

Annual data on all plants with at least 10 workers were available for three of the countries in the ICPT project: Chile 1979–85, Colombia 1977–87, and Morocco 1984–87. Using plant identification codes, it was possible to identify plants entering and exiting each of these data bases and to thereby implement equation 8. (Ideally entry and exit would reflect the births and deaths of plants, respectively, but in practice they also reflect crossings of the 10-worker threshold.)

Letting \(F\) be number of workers so that \(G_1\) measures growth in labor productivity, implementation of equation 8 resulted in the figures reported in table 1. We did not observe capital stock figures for all plants in all countries, so it was not possible to construct broader indexes of factor use. Broader productivity measures have yielded similar results. For example, Liu (1991) finds evidence in the Chile data that labor productivity and multifactor productivity measures are closely related.

In table 1 values are given for all plants in the manufacturing sector and for three broad subgroups: exportable producers, importable producers, and nontradable producers. A firm is classified as producing an exportable product if its three-digit industry exports more than 25 percent of its output, on average. A firm is classified as producing an importable product if its three-digit industry exports less than 25 percent of its output, but at least 25 percent of the domestic market for this industry’s good is supplied by imports. All other firms are classified as nontradable producers. Year-to-year fluctuations in our decomposition probably largely reflect capacity utilization effects. Hence, to get an overview of the long-run significance of each effect, we begin with an intertemporal average of each component value for each country.

There are two striking features of table 1. The first is that entry and exit (reflected by changes in the number of plants) are quite significant, which implies that there are high returns to improving our understanding of turnover processes. The second is that output expansion appears to occur through very different mechanisms in the different economies, even though the reported statistics are averages spanning at least four years. In Chile and Morocco adjust-
Table 1. Decomposition of Output Growth in the Manufacturing Sector in Chile, Colombia, and Morocco
(average annual growth rate)

<table>
<thead>
<tr>
<th>Country, period, and plant category</th>
<th>Output productivity (G)</th>
<th>Scale productivity (G_2)</th>
<th>Number of plants (G_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chile (1979–85)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All plants</td>
<td>0.014</td>
<td>0.044</td>
<td>0.018</td>
</tr>
<tr>
<td>Exportables</td>
<td>0.085</td>
<td>0.093</td>
<td>0.034</td>
</tr>
<tr>
<td>Importables</td>
<td>0.001</td>
<td>0.036</td>
<td>0.014</td>
</tr>
<tr>
<td>Nontraded</td>
<td>-0.018</td>
<td>0.013</td>
<td>0.016</td>
</tr>
<tr>
<td><strong>Colombia (1977–87)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All plants</td>
<td>0.043</td>
<td>0.046</td>
<td>0.006</td>
</tr>
<tr>
<td>Exportables</td>
<td>0.033</td>
<td>0.034</td>
<td>0.009</td>
</tr>
<tr>
<td>Importables</td>
<td>0.056</td>
<td>0.058</td>
<td>0.005</td>
</tr>
<tr>
<td>Nontraded</td>
<td>0.038</td>
<td>0.041</td>
<td>0.007</td>
</tr>
<tr>
<td><strong>Morocco (1984–87)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All plants</td>
<td>0.046</td>
<td>-0.038</td>
<td>0.009</td>
</tr>
<tr>
<td>Exportables</td>
<td>0.026</td>
<td>-0.105</td>
<td>0.042</td>
</tr>
<tr>
<td>Importables</td>
<td>0.083</td>
<td>-0.001</td>
<td>0.013</td>
</tr>
<tr>
<td>Nontraded</td>
<td>0.049</td>
<td>0.018</td>
<td>-0.038</td>
</tr>
</tbody>
</table>

Source: Author's calculations based on World Bank data.

Table 1 obscures the fact that entering, exiting, and incumbent plants probably differ systematically in size and productivity. Documenting these differences should help us to understand the influence of plant heterogeneity on measured TFP. To this end one may further decompose each element on the right side of equation 8. First, the productivity growth index, G_1, reflects three influences:

\[ \frac{\Delta y}{y} = \Delta y_c \frac{\bar{y}_c}{y} + \Delta \alpha_c \frac{\bar{y}_c - 1/2(\bar{y}_d + \bar{y}_b)}{y} + \Delta y_b - \Delta y_d (1 - \bar{\alpha}_c)/y \]

Here \( \alpha_c \) is the proportion of total factor use accounted for by plants that were in the industry both last period and this period (hereafter "continuing" or "incumbent" plants), and \( \bar{y}_c \) is average productivity among these plants. (A bar above a variable indicates an average of last period's and this period's value.) Similarly, \( \bar{y}_b \) is productivity among plants that have entered the industry this period, and \( \bar{y}_d \) is productivity among plants that were in the industry last period, but exited this period. Hence the first term \( (G_{11}) \) indicates what portion of productivity comes largely from entry and exit, while in Colombia adjustments in the productivity of incumbent plants appear more important. Sector-specific differences in the nature of adjustment are also apparent: tradables appear to accomplish more adjustment through entry and exit than nontradables in Colombia and Morocco. These results suggest that behavioral models emphasizing sunk costs and uncertainty hold promise.

**Decomposition of Growth Factors**

Table 1 obscures the fact that entering, exiting, and incumbent plants probably differ systematically in size and productivity. Documenting these differences should help us to understand the influence of plant heterogeneity on measured TFP. To this end one may further decompose each element on the right side of equation 8. First, the productivity growth index, G_1, reflects three influences:

\[ \frac{\Delta y}{y} = \Delta y_c \frac{\bar{y}_c}{y} + \Delta \alpha_c \frac{\bar{y}_c - 1/2(\bar{y}_d + \bar{y}_b)}{y} + \Delta y_b - \Delta y_d (1 - \bar{\alpha}_c)/y \]

Here \( \alpha_c \) is the proportion of total factor use accounted for by plants that were in the industry both last period and this period (hereafter "continuing" or "incumbent" plants), and \( \bar{y}_c \) is average productivity among these plants. (A bar above a variable indicates an average of last period's and this period's value.) Similarly, \( \bar{y}_b \) is productivity among plants that have entered the industry this period, and \( \bar{y}_d \) is productivity among plants that were in the industry last period, but exited this period. Hence the first term \( (G_{11}) \) indicates what portion of productivity...
growth is due to productivity improvements among incumbents, the second term \((G_{12})\) indicates how changes in the market share of incumbent plants influence productivity (hereafter, the “net entry effect”), and the last term \((G_{13})\) reflects any improvement in productivity from replacing exiting plants with entering plants (hereafter the “turnover effect”).

If entering plants are more productive than exiting plants, \(G_{13}\) will be positive, reflecting desirable turnover effects. However, increases in the net entry rate cause the share of employment among incumbent plants to fall \((\Delta \alpha_c < 0)\), so, if productivity is higher among incumbents than the average productivity among entering and exiting plants, overall productivity growth may be dampened by increases in entry.

Growth in scale, \(G_2\) in equation 8, can be similarly decomposed. Defining \(\lambda_c = N_c/N\) as the number of incumbent plants divided by the total number of plants, then

\[
\begin{align*}
\Delta f/f &= \Delta f/\lambda_c + \Delta \lambda_c [\bar{f}_e - 1/2(\bar{f}_d + \bar{f}_b)] f + (b_c - f_c)(1 - \lambda_c)/f \\
G_2/\omega_2 &= G_{21}/\omega_2 + G_{22}/\omega_2 + G_{23}/\omega_2.
\end{align*}
\]

Here \(G_{21}\) reflects expansion in plant size (that is, factor use) among incumbents, weighted by incumbents’ market share. Size differences among incumbents, entrants, and exiting plants are reflected by \(G_{22}\) and \(G_{23}\). The former, the net entry effect, is the gap between incumbent size and the average size among entering and dying plants, all weighted by the change in incumbent share. The latter, the turnover effect, is the difference in average size between entering and dying plants, weighted by the share of nonincumbents.

The last term in equation 8 \((G_3)\) represents the effect of net entry on expansion. It can be decomposed into the difference between entry and exit rates:

\[
\begin{align*}
\Delta N/N &= N^e/N - N^d/N \\
G_3/\omega_3 &= G_{31}/\omega_3 - G_{32}/\omega_3.
\end{align*}
\]

**Aggregate effects of turnover on growth.** Values of elements on the right side of equations 9, 10, and 11 are presented in table 2. Again, to approximate long-run values, these are averages over annual growth rates. Plant turnover plays a significant role in determining growth rates. If there were no entry and exit, growth would simply reflect productivity increases and expansion among incumbents \((G_{11} + G_{21})\). But this figure is typically very different from realized total growth figures \((G, \text{in table 1})\). For example, output grew by an annual average of 1.4 percent in the Chilean manufacturing sector; with zero net exit this figure would have been 2.4 percent \((0.030 - 0.006 = 0.024)\). Similarly, net entry accounts for 2 percent of Morocco’s 4.6 percent average annual output growth.

**Decomposition of growth in labor productivity.** The figures in tables 1 and 2 also suggest productivity differences among incumbent, entering, and exiting plants. In Chile and Morocco the net entry \((G_{12})\) and turnover \((G_{13})\) compo-
Table 2. Detailed Growth Decomposition for the Manufacturing Sector in Chile, Colombia, and Morocco  
(average annual growth rates)

<table>
<thead>
<tr>
<th>Country, period, and plant category</th>
<th>Labor productivity</th>
<th>Scale</th>
<th>Number of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incumbents ($G_{11}$)</td>
<td>Net entry ($G_{12}$)</td>
<td>Turnover ($G_{13}$)</td>
</tr>
<tr>
<td><strong>Chile (1979–85)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All plants</td>
<td>0.030</td>
<td>0.012</td>
<td>0.002</td>
</tr>
<tr>
<td>Exportables</td>
<td>0.078</td>
<td>-0.002</td>
<td>0.016</td>
</tr>
<tr>
<td>Importables</td>
<td>0.030</td>
<td>0.001</td>
<td>0.006</td>
</tr>
<tr>
<td>Nontraded</td>
<td>-0.001</td>
<td>0.011</td>
<td>0.002</td>
</tr>
<tr>
<td><strong>Colombia (1977–87)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All plants</td>
<td>0.037</td>
<td>0.004</td>
<td>0.006</td>
</tr>
<tr>
<td>Exportables</td>
<td>0.032</td>
<td>-0.002</td>
<td>0.005</td>
</tr>
<tr>
<td>Importables</td>
<td>0.039</td>
<td>0.008</td>
<td>0.012</td>
</tr>
<tr>
<td>Nontraded</td>
<td>0.037</td>
<td>0.003</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Morocco (1984–87)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All plants</td>
<td>-0.021</td>
<td>-0.017</td>
<td>0.001</td>
</tr>
<tr>
<td>Exportables</td>
<td>-0.072</td>
<td>-0.031</td>
<td>-0.001</td>
</tr>
<tr>
<td>Importables</td>
<td>-0.010</td>
<td>-0.006</td>
<td>0.015</td>
</tr>
<tr>
<td>Nontraded</td>
<td>0.028</td>
<td>-0.013</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Source: Author's calculations based on World Bank data.
nents of labor productivity are both generally non-zero. In particular Chile's net exit increases the market share of incumbents, and this improves productivity. Indeed, among Chilean importables and nontradables, this is the main component of productivity change (compare $G_{12}$ and $G_1$). Net entry does the opposite in Morocco.

Differences in productivity between entering and exiting plants ($G_{13}$) generally account for changes in sectoral aggregates that are significant, but these changes are smaller than those resulting from productivity gaps between incumbents and others. Exiting plants tend to be less productive than the entering plants that displace them. Part of the productivity difference between incumbent plants and others results from the fact that the former are relatively large and more capital intensive, but the result is robust to multifactor productivity measures (Liu 1991; Backinezos 1991).

**Decomposition of growth in scale.** It appears that scale heterogeneity is also significant. Incumbents are much larger than either entering or exiting plants (Roberts 1989; Tybout 1989), so the net exit that takes place in Chile significantly increases average plant size ($G_{22}$), even though incumbent plants are shrinking ($G_{21} < 0$). The same logic works in reverse for Morocco, when rapid net entry takes place. Thus, to the extent that scale economies matter, the procyclical tendencies of factor productivity are likely to be dampened by turnover. However, Liu (1991) finds that learning-by-doing is relatively rapid among entrants that survive.

**Comparison with U.S. patterns.** It is surprising that the gross entry and exit rates of all three countries match or exceed those found in the United States. Hence the popular view that institutional barriers to entry and exit are relatively important in developing countries is not borne out. This is not immediately apparent from table 2; it can be inferred by comparing the five-year entry/exit patterns reported in Dunne and others (1988) with cohort survival figures reported in Roberts (1989), Tybout (1989), and Haddad and others (1990). Moreover plants that enter and exit in these countries are as large relative to the industrywide average plant size as they are in the United States.

**Trade, Entry, and Exit**

All of the above points in the direction of productivity analysis based on changing populations of heterogeneous plants. An emerging analytical literature provides some theoretical underpinnings (Jovanovic 1982; Pakes and Ericson 1987; Jovanovic and Lach 1989; Lambson 1989), but most of the models are too abstract to lend themselves to empirical implementation (see, however, Olley and Pakes 1990, Ericson and Pakes 1987, and Dunne and others 1989). This literature does suggest that we might improve our understanding of growth processes by devoting more empirical attention to the entry, exit, and growth processes; cohort-specific cost or production functions; and learning curves.
Evidence on the first issue will help us understand the composition of an industry at each point in time, whereas evidence on the latter two issues will help us map alternative compositions into associated sectorwide productivity levels. The functions representing entry, exit, growth, and production or cost should be time-dependent and potentially sensitive to regime changes.

Several stylized facts concerning growth, entry, and exit are well established. Specifically, as new plants mature, their probability of failure drops, and their size increases toward industry norms. For recent studies of the United States see Dunne and others (1989) and Evans (1987); for ICPT project countries see Haddad and others (1990), Roberts (1989), and Tybout (1989). However, there is relatively little in the literature documenting the effects of trade policy on these processes. To provide some preliminary results, regressions linking entry and exit with industrial output growth and import penetration rates were attempted for several of the ICPT project countries (Tybout 1989; Roberts 1989). These regressions were done using annual data on three-digit industries, controlling for fixed industry effects and time effects with dummies. Hence the coefficients on import penetration rates were identified with temporal fluctuations, not cross-industry contrasts.

Several findings emerged. First, output growth is positively correlated with entry but does not correlate significantly with exit. The latter depends heavily on time dummies, thus suggesting that macro phenomena like high interest rates are more important than product market fluctuations in causing failures. Second, controlling for fixed industry effects, macro conditions, and output growth, fluctuations in import penetration do not correlate significantly with entry and exit patterns. This could mean that our regression model fails to capture the relevant dynamics, or it could mean that all significant effects of import penetration are picked up through industrywide fixed effects and output fluctuations. Third, industry dummies are generally significant, so to the extent that liberalization changes patterns of specialization, it is likely to change economywide rates of turnover. Finally, many coefficients are sensitive to the sample period chosen, thus possibly reflecting changing levels of uncertainty.

Pursuing the issue further, Backinezos (1991) used the Colombian data panel to fit industry-specific cost functions jointly with a probit function that controlled for selectivity due to exit. She found that in most sectors temporal variations in the import penetration rate were not associated with the probability of failure. Among those sectors where significant correlations were found, there were roughly as many positive correlations as negative ones. In short, although much remains to be done in exploring the dynamics of plant turnover, we have not yet uncovered systematic relations between entry and exit patterns and exposure to international competition.

The Size Distribution of Plants

Although contemporaneous correlations reveal no strong association between import penetration and entry and exit patterns, foreign competition might still
affect the size distribution of plants by inducing size adjustments among incumbents or by inspiring entry or exit with a lag. In turn, given the presence of scale economies, these shifts in size distributions may affect industrial productivity. With these links in mind, we next turn to empirical evidence on the relation between trade regimes and the size distribution of plants.

As Berry (1992) notes, earlier studies have found that larger plants are more likely to be exporters. Similarly, it is sometimes conjectured that imports compete more directly with large plants, given the nature of their product lines. But it is difficult to find studies that correlate trade policy with the size distribution of plants in developing countries. Econometric studies of this issue are also rare for developed countries; Baldwin and Gorecki (1983) is the only example I am aware of. The ICPT project provides three exceptions.

Roberts and Tybout (1991) compare the plant size distributions in Chile and Colombia, industry by industry, and relate contrasts to associated differences in trade regime. To summarize the distribution of plant sizes for industry $i$, country $j$, and year $t$, they rank plants by ascending employment level and find the employment levels of plants at the 10th, 25th, 50th, 75th, and 90th percentiles. This generates five size measures: $\ln(\text{EMP}_k^{ij}) = \text{logarithm of the } k\text{th percentile of the employment size distribution (}k = 10, 25, 50, 75, 90\text{).}$

Each of these measures is regressed on proxies for various types of demand determinants. This can be done by exploiting either temporal variation, cross-country variation, or both. Given that the former requires modelling of the dynamics of adjustment and that the latter accounts for most of the variation in the data, we summarize the cross-country results here. These are based on industry- and country-specific averages of annual values for each variable, and should approximate long-run relations. Letting bars above variables denote temporal averages, the estimated regressions are:

\begin{equation}
\text{EMP}_k^{ij} = \beta_1 \ln Y^{ij} + \beta_2 \text{ERP}^{ij} + \beta_3 \text{TUR}^{ij} + \beta_4 \text{TUR}^{ij} \text{ERP}^{ij} + \beta_5 \text{TUR}^{ij} \ln Y^{ij} \\
+ \lambda_i + \mu_j + \epsilon_{ij}
\end{equation}

where $\ln Y^{ij}$ is the log of real industry output, $\text{ERP}^{ij}$ is the effective rate of protection, and $\text{TUR}^{ij}$ is the turnover rate. The turnover rate is the sum of the industry's entry and exit rates (that is, $G_{i1}/\omega_3 + G_{i2}/\omega_3$). These rates are averaged across all years for each industry in each country to get a long-run value that is specific to each industry in each country. Here the log of real industry output proxies total demand for the industry's output, the effective rate of protection proxies protection from international markets, and the turnover rate proxies the ease of entry and exit. As suggested by many models of trade with imperfect competition, the sensitivity of size distributions to demand shifts should depend upon the ease of entry and exit. The turnover variable is therefore interacted with the log of real industry output and the effective rate of protection. Finally, to control for industry-specific technology effects and country-specific conditions, represented by $\lambda$ and $\mu$, respectively, industry and country dummies are included.
The results indicate that higher effective protection rates are associated with larger plant sizes, especially at the low end of the size distribution. This suggests that demand contraction, factor market effects, and other forces associated with increased import competition dominate any expansionary forces coming from higher demand elasticities in open economies; Baldwin and Gorecki (1983) found similar effects in Canadian data. Also the negative correlation of size and trade exposure is more substantial in low-turnover industries. This is consistent with the theoretical result that more size adjustment occurs when exit is not easy (Rodrik 1988; Buffie and Spiller 1986). Alternatively, the results may simply mean that the discipline of foreign competition matters more in industries where the discipline of potential entry is less important. All of these results hold up if size is measured with output instead of employment. They also hold up if the effective rate of protection is replaced with import penetration rates and export ratios—in fact this strengthens them. In regressions based on time series (rather than cross-country) variation in the data, however, no clear pattern emerges. This probably reflects the inability of the model to capture the dynamics of adjustment.

In a related study Tybout and others (1991) compare the 1967 and 1979 Chilean industrial censuses and ask whether sectors that underwent relatively large reductions in effective protection between the census years showed distinctive shifts in their size distribution. They look at the cross-industry Spearman rank correlation between changes in an effective protection measure and changes in the various size percentiles. This exercise is very similar to the Roberts and Tybout (1991) regressions, except here variation is examined across time rather than across countries.

When they measure size with employment, Tybout and others (1991) weakly confirm Roberts and Tybout's finding that higher levels of protection are associated with larger plant sizes, controlling for industry-specific effects and the state of the macroeconomy. However, when size is measured with output or value-added, Tybout and others find a negative weakly significant association between protection and size for the lower percentiles and a positive insignificant association for the higher percentiles. This implies that labor productivity among small plants tends to improve most in those industries undergoing the most dramatic reductions in effective protection.

Tracking Moroccan plants through time, Dutz (1991) also finds that import expansion caused by the relaxation of quotas was associated with contractions in plant size. But unlike the studies summarized above, he finds that small firms contracted proportionately more than large firms. So it is possible that efficiency improved with liberalization because of scale economy exploitation in Morocco. Much remains to be done in determining whether the findings of these three studies generalize to other countries and liberalization episodes, but they do cast doubt on the popular conjecture that opening an economy leads to efficiency gains through the exploitation of plant-level scale economies.
Scale Economies

To link changes in the size distribution of plants with productive efficiency, it is necessary to have some sense of the importance of plant-level scale economies. After reviewing various problems associated with econometric estimates of the returns to scale—due especially to measurement error and unobservable management effects—Tybout and Westbrook (1991) settle on a “method of moments” estimator that predicts changes in output with changes in input vectors over long periods, using instruments to reduce the measurement error in capital stock growth rates. They find econometric evidence that their estimator works better than more naive variants but also that very few Chilean industries show returns to scale significantly different from unity. Similar findings emerged from other project output that focused less on methodological issues (Tybout and others 1991). Hence, although external scale economies resulting from infrastructure and learning spillovers may be important, project participants could find little empirical support for promoting “bigness” at the plant level.

Plant-Specific Technologies

In the preceding analysis we have been looking for links between trade policy and productivity that are based on plant heterogeneity. Thus far we have been unable to establish a strong link between trade patterns and turnover. We have also seen that, if anything, increases in trade exposure appear to contract plants in terms of employment. So if we are to muster evidence that trade liberalization improves productive efficiency through heterogeneity effects, it must come from a change in the technical efficiency of incumbent plants or from changes in the types of plants that enter and exit. This section argues that there is some evidence of the former, but as yet the latter has not been researched.

Perhaps the most popular approach to documenting plant-specific technologies is based on efficiency frontiers. The notion is that if the frontier production technology \( Y = f(v,t) \) represents the maximum output achievable with the input vector \( v \) at time \( t \), then production observed at the \( i \)th plant will fall short of the frontier by some amount \( e_i = f(v_i,t) - Y_i \). If the technology \( f(\cdot) \) can be estimated, then one can obtain not only a measure of returns to scale, but also a set of plant-level inefficiency indexes, \( e_i \). A variety of approaches to estimating \( f(\cdot) \) exist; partial surveys may be found in Schmidt (1985), van den Broek and others (1980), and Forsund and others (1980).

Pack (1988) notes that among studies of countries pursuing import substitution, large intra-industry differences in productivity are common, as are low average productivity levels relative to the frontier technology (Handoussa and others 1986; Page 1984; Pack 1987). Pack (p. 363) speculates that similar work “in export-oriented countries would reveal considerably smaller intra-industry variation in TFP as well as a better average level of TFP” but stresses that all evidence points in the direction of one-time improvements in the level of TFP.
with trade liberalization, rather than improvements in the long-run rate of TFP growth. Studies by Chen and Tang (1987) and Handoussa and others (1986) are consistent with this conjecture. Havyrylshyn (1990) is less cautious in his assessment. After reviewing several studies applying efficiency frontiers to developing countries (Pitt and Lee 1981; Nishimizu and Page 1991; Page 1984), he concludes that the studies generally "found strong empirical evidence of a positive effect of trade policy liberalization" (p. 16).

Further support for the conjecture that trade liberalization improves technical efficiency may be found in Tybout and others (1991), which compares Chilean industrial census data from an import-substituting period (1967) and an outward-oriented period (1979). Tests for the effects of liberalization are based on the following observation: if exposure to foreign competition improves average efficiency and causes plants below minimum efficient scale to exit, then the estimated production technology should show an increase in its intercept, a reduction in estimated returns to scale, and a reduction in residual variation. Rather than use frontier production functions to look for these patterns, econometric attention is devoted to correcting for measurement error in capital stocks and missing data (Tybout 1992). It is found that, although no more than half of the three-digit industries registered overall productivity gains, the ones that showed the most improvement tended to be those that underwent the largest reductions in effective protection.

IV. CONCLUDING REMARKS

In the past decade there has been a growing realization that traditional Tornqvist indexes of productivity growth actually pick up much more than innovation, scale economies, and movement to the efficient frontier. One conclusion that emerges with force from recent work is that we should approach the reported figures with skepticism. Problems of measurement error, disequilibria, and aggregation bias can easily create the illusion of trends and correlations that have no basis in the economic processes we hope to capture.

These observations are dispiriting, but they have helped to inspire new ways of thinking about productivity growth and new approaches to looking for it. This article has reviewed two new directions. The first is an attempt to salvage traditional residual-based calculations by correcting for scale economies, adjustment costs, or noncompetitive pricing. Although the methodology still suffers from significant measurement problems and aggregation bias, it gives some sense for the robustness of productivity growth series to violations of the litany of assumptions. It also has the obvious advantage of being based on easily accessible data.

The second new direction discussed herein concerns the role of plant heterogeneity in shaping sectoral productivity growth. Except for work on frontier production functions, this strand of the literature is in its infancy, so many of the techniques are still quite rudimentary. Nonetheless they give a crude sense for
the importance of entry, exit, and heterogeneity in shaping productivity growth patterns, as well as some specifics on the nature of aggregation bias in industry-level studies.

Throughout the discussion of new approaches to productivity measurement, performance measures have been examined for correlation with crude indexes of trade regime. In view of the diverse, ambiguous theoretical literature on the link between trade and productivity, it is not surprising that stable, predictable correlations have not emerged. Nonetheless in some countries and during some subperiods there is some association between trade flow patterns and indexes of productivity growth at the industry level, even after correcting for several measurement problems. Also we may tentatively conclude that the effects of trade regimes on productivity growth are interrelated with market concentration, although the nature of this association is itself unstable.

The lack of stable correlations in sectoral and industry-level data is matched by a surprising diversity in the processes of entry, exit, and scale adjustment. In some economies a good deal of output fluctuation appears to come from the creation and death of plants, whereas in others the incumbent plants are what matter. (Cross-country differences in institutions and the degree of uncertainty are possible explanations.) Given that there is considerable variation in size and labor productivity across these plant types, this is one reason the sectoral and industry-level analyses differ. The ICPT project has focused on linking entry, exit, and adjustments in scale and technical efficiency with exposure to trade regime. Thus far it appears that exposure to increased foreign competition is not closely linked with entry patterns, tends to induce reductions in plant size, and may cause some improvements in technical efficiency.

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Transportation Policy and Panterritorial Pricing in Africa

Mark Gersovitz

Many African countries interfere with the spatial pattern of agricultural prices and often mandate a spatially constant (panterritorial) price. Such policies are conceptually identical to the pricing of transport services. The pricing and transportation policies of the Ivorian cotton parastatal provide a case study. The loss in producer surplus from raising current revenues by panterritorial pricing is compared with an optimal policy that minimizes producer loss. For current revenues, a switch to the optimal policy would provide only small gains. At higher revenue levels, however, the gains would increase. These policies are also contrasted with another suboptimal policy—full-cost pricing of transport with an export tax. By dispersing production, panterritorial pricing inflates the gains from transport projects. Transport investment and pricing reform are therefore assessed simultaneously. The number and location of the purchasing depots are also discussed.

Governments influence the price and quality of transport services, both through their investments in transport infrastructure and through a range of regulations. In rural areas these decisions affect the spatial pattern of agricultural production, with consequences for the efficiency of agriculture, the well-being of agriculturalists, and the revenues obtained from the agricultural sector by the government.

In many African countries decisions on the pricing of transport services are made implicitly as a consequence of government interventions in the marketing of agricultural produce. Often these governments establish public or semipublic agencies (parastatals) with monopsony control over the marketing of export crops. The ways in which these parastatals pay farmers at different locations for their crops are equivalent to a set of regulations on the pricing and quality of transport services. One commonly adopted component of parastatal policy is panterritorial pricing, in which all farmers are paid the same price regardless of

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where their produce is purchased. This is the practice of the Compagnie Ivoirienne pour le Développement des Textiles (CIDT), the parastatal that is involved with cotton production and marketing in Côte d'Ivoire. The case of the CIDT illustrates some of the policies on rural transport in Africa.

This article sets out some practical diagnostic tests of the efficiency of (implicit) transport policies embodied in state marketing and discusses the implications of the policies for infrastructural investment. These tests are feasible using readily available data for many African countries and crops. Section I presents a conceptual framework for looking at rural transport and state marketing, by building on the work of Walters (1968) on the Ellet model. Gersovitz (1989) applies the Ellet model to some topics in optimal taxation and agricultural marketing. Then these models are used to organize some basic facts about the operations of the CIDT. Section II models the implications of panterritorial pricing for transport policy and applies the model to the activities of the CIDT. Section III gives special attention to choices about the location of purchasing depots used by parastatals and the consequences for the implicit price of transport. In principle there are a wide variety of options here, and the CIDT exemplifies only one possibility. The final section makes some concluding remarks.

I. The Spatial Pattern of Production and Marketing in the Export Sector

To understand the demand for rural transport generated by the production of a crop, one must understand where the crop is produced relative to where it is consumed or exported. The essence of agricultural production is, of course, the importance of land as an input and the consequent spatial dispersion of production. The volume and location of production are determined both by the area where the crop is cultivated (the extensive margin of cultivation) and by the intensity of production on land that is used to produce the crop (the intensive margin of cultivation). The boundaries of the region in which a particular crop is grown in a particular country may be determined in various ways: by the limits of the country's borders, by the limits of the land that is at all physically suitable for cultivation of the crop, or by the limits of the land on which it is economically profitable to grow the crop. The first two factors are exogenous to the transport policies of the government, whereas the last is highly influenced by them.

In practice whether one emphasizes changes in the intensive or extensive margins of cultivation in agricultural response to transport policy depends partially on the degree of aggregation in the information that is available. For individual farms, it may be possible to see changes in the extensive margin, whereas at a more aggregate level the boundaries of the region where production occurs may not change at all. In Africa information on the effect of transport policy on the agricultural response of individual farms is largely unavailable, either because governments do not collect it or because they treat it as confidential.
For practical reasons, therefore, the study of rural transport is largely re-
stricted to data reported at a geographical level just below that of the region in
which production occurs or to special studies of particular road projects. For the
CIDT the data come from the geographical level termed zones productrices.
Information on the CIDT is from Beenhakker and Bruzelius (1985); DCGT (1986,
1988); and CIDT (various years a, b, c).

The cotton sector of Côte d’Ivoire occupies about 188,000 square kilometers,
split into about 56 zones that the CIDT uses for organizational and reporting
purposes (map 1). It is bordered on the east, west, and north by the international
boundaries of the country. To the south it is limited by the replacement of the
savanna, which is agroclimatically suited to cotton, by the forest, which is not.
It does not, therefore, seem that an important part of the response of production
to decreases in transport costs would come from an expansion in the borders of
the cotton region, as would be reflected in an addition of zones. Consequently, I
assume that the number of zones is fixed when calculating the effects of changes
in the (implicit) price of transport on production, on the benefits received by
agricultural producers, and on government revenues.

It is possible, however, that the region of production could contract from its
current boundaries, with zones dropping out of production entirely, if the effect
of a change in policy on farmers is sufficiently adverse. The constant-elasticity-
of-supply function of the simulations implies that a zone does not drop out as
long as its zonal price is positive. If the number of zones were to change with
changes in the parameters of the model, then it would be necessary to keep track
of which zones are in production at any given time and to alter the summation
signs in the following equations correspondingly.

Calculation of the effects of transport policy requires a calculation of the
benefits received by agricultural producers and the revenues received by the
government. The first step is a calculation of the level of production. For the \(i\)th
zone, production \(Q_i\) is given by

\[
Q_i = \frac{\gamma S(p_i)}{S(p^0)}
\]

where \(S(\cdot)\) is a function that depends positively on the price \(p_i\) received by
farmers in the zone for their production and \(p^0\) is the initial (base case) price
received by farmers for their output. When \(p_i = p^0\), \(Q_i = \gamma\), so \(\gamma\) is just the
production of the zone at the initial price. The production response embodied in
\(S(\cdot)\) reflects the intensification of cultivation from adding inputs such as labor
and fertilizer, bringing uncultivated land into cotton cultivation, and switching
resources from the production of other crops.

Government revenues from the production in a particular zone \(R_i\) are
therefore

\[
R_i = [p^* - c^* - a^* t_i] Q_i
\]

where \(p^*\) is the export price of the output in world markets; \(c^*\) is the costs per
ton paid by the parastatal that do not vary with the region of production; \(a^*\) is
the cost of transport per ton per kilometer paid by the parastatal; and \(t_i\) is the
Map 1. The CIDT's Area of Operation in Côte d'Ivoire

NOTE: NUMBERS REFER TO ZONES OF TABLE 1.
* GINNERS
average distance from the zone to the port of export. The benefits to producers in a zone are measured by their producer surplus ($\Pi_i$):

\begin{equation}
\Pi_i = p_i Q_i - \gamma_i \int_0^{S(p_i)} S^{-1}(x) dx / S(p_i).
\end{equation}

The corresponding total values for the sector as a whole are simply

\begin{equation}
R = \sum_{i=1}^{N} R_i
\end{equation}

and

\begin{equation}
\Pi = \sum_{i=1}^{N} \Pi_i
\end{equation}

where $N$ is the number of zones (56 for the CIDT).

The zones are listed in table 1, with values for the variables that vary by zone: zonal deliveries to ginneries, distance from zone to ginnery, distance from ginnery to port, and transport costs. The values of the price variables used to calculate the cost of transport and the producer surplus ratio are from 1982/83 and the quantity values are from 1987/88. To the extent that the relative prices differed between 1982/83 and 1987/88, this procedure introduces inaccuracies into the benchmarking of the model.

All calculations are in terms of ginned cotton fiber. One kilogram of seed cotton is about 0.419 kilogram of ginned cotton fiber. Therefore, because farmers produce seed cotton and sell it to the CIDT for processing at the ginneries, their output is measured in the modeling exercise as $\gamma_i = 0.419$ times their actual deliveries of seed cotton (column 1 of table 1). To adjust for differences in the weight of unginned and ginned cotton and for differences in the cost of transport at different stages, the following steps are used to calculate $t_i$: divide the distance from the zone to the ginnery (column 2) by 0.419, multiply the distance from the ginnery to the port (column 3) by 0.026 and divide by 0.067 to account for the differences in costs per kilometer per ginned cotton equivalent from the depot to the ginnery and from the ginnery to the port (table 2), and add the results from the preceding two steps to get an (adjusted) $t_i$. The value of $a^*$ is then equal to CFAF0.067 per kilogram-kilometer.

One very weak test for efficiency in the transport policy implicit in these prices is that the return to selling cotton on the world market net of unavoidable costs paid by the CIDT, such as ginning (but not including transport costs), is greater than the costs to move cotton from the zone to the port ($p^* - c^* > a^* t_i$). Because it neglects the farmers' costs, the criterion could be met and production could still be socially undesirable. As the data in tables 1 and 2 show, this condition is easily met for all zones. The net return to selling cotton on the world market is CFAF350, while the largest value of the cost of transport from the zone to the port is CFAF76.3. Furthermore, with the government paying CFAF191 to
Table 1. Deliveries, Distances, and Costs of Transporting Cotton in the Côte d’Ivoire, by Zone

<table>
<thead>
<tr>
<th>Zone</th>
<th>Number</th>
<th>Name</th>
<th>Deliveriesb (kilograms of seed cotton)</th>
<th>Kilometers</th>
<th>Total cost of transport(^c) (CFA francs per kilogram of ginned cotton)</th>
<th>Ratio of producer surpluses(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
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<td>Tingrela</td>
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<td>684</td>
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<tr>
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<td>Sanhula</td>
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<td>0.99</td>
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<tr>
<td>5</td>
<td>Gbon</td>
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<td>83</td>
<td>655</td>
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<td>1.01</td>
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<tr>
<td>6</td>
<td>Kassere</td>
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<td>85</td>
<td>669</td>
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<td>1.00</td>
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<td>Boundiali</td>
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<td>86</td>
<td>586</td>
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<td>1.04</td>
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<tr>
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<td>108</td>
<td>555</td>
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<td>1.00</td>
</tr>
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<td>Niofoin</td>
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<td>568</td>
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<td>Sirasso</td>
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<td>568</td>
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<td>1.03</td>
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<td>597</td>
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<td>564</td>
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<td>Worofla</td>
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<td>Foutounou</td>
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<td>1.05</td>
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Table 1. continued

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Deliveriesb (kilograms of seed cotton)</th>
<th>Kilometers</th>
<th>Total cost of transport (cta francs per kilogram of ginned cotton)</th>
<th>Ratio of producer surplusesf</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
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<td>Marandala</td>
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<td>361</td>
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<td>266</td>
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<tr>
<td>52</td>
<td>Yamoussokro Sud</td>
<td>1,555,122</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
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<td>Bouafle</td>
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<td>125</td>
<td>266</td>
<td>26.9</td>
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<td>266</td>
<td>30.6</td>
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<td>Zuenoula</td>
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<td>266</td>
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<td>Vavoua</td>
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<td>Minimum</td>
<td>251,275</td>
<td>20</td>
<td>266</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>13,936,334</td>
<td>385</td>
<td>684</td>
<td>76.3</td>
</tr>
</tbody>
</table>

- Not available.

a. There are 53 zones reporting data. Data for zones 45, 49, and 52 are not reported for 1987/88.

b. Deliveries to gineries are in (unginned) seed cotton 1987/88.

c. Weighted average of the distances to each ginery to which deliveries were made in 1988 from a given zone, weighted by the fraction of total deliveries from the zone going to that ginery.

d. Distance the cotton from a particular zone travels after it has been ginned. In a first step, distance to the port from a particular ginery is a weighted average of the distances from the ginery to the ports of Abidjan and San Pedro, weighted by the share of each port in the shipments of the particular ginery. In the second step, the distance of the zone to the port is then the weighted average of the distances from the gineries to the ports defined in step 1 to which the zone ships, weighted as in the calculations for distance from zone to ginery. The ginery at Dianra was assigned the same port shares as the ginery at Mankono, and the ginery at Seguela was assumed to ship all its cotton to San Pedro.

e. From farmgate to port via the ginery. Calculation is based on one kilogram of seed cotton being equivalent to 0.419 kilogram of ginned cotton. See also the discussion in the text.

f. The ratio of producer surplus under optimal pricing to that under panterritorial pricing for an elasticity of supply of 0.67 and an R as in table 3.

Source: CIDT (various years c) for deliveries; unpublished data provided by the Caisse Centrale in Abidjan for distance from zone to ginery; and Michelin (1989) and OCCT (1986, p. 24) for data to calculate weighted distance from ginery to port. For ratio of producers' surplus calculations from model, as discussed in text.
farmers regardless of the zone, the net return to selling cotton on the world market, taking into account the price received by farmers, is CFAF159; this exceeds the largest value of the cost of transport by CFAF82.7. Thus the government gains revenue from every single zone, although the revenue per kilogram is less from the more remote zones.

II. Panterritorial Pricing and Its Alternatives

Relatively remote places of production have relatively higher costs of transport to the place of ultimate consumption or export. Governments that buy farm output at the same price everywhere charge farmers in remote areas nothing for these higher costs. They may be said to subsidize fully the differential transport cost between remote and near-in farmers. Production is more dispersed than is efficient. Farmers may incur some transport costs in getting their output to the place of purchase, a cost of more or less significance, depending on the location of the government's buying depots, an issue that is given more attention in the next section. In Côte d'Ivoire the CIDT maintains a very dense network of depots, purchasing cotton at every village (DCGT 1988). The costs of transport to the farmer are therefore very small, no more than CFAF5 per kilogram in the mid-1980s (Beenhakker and Bruzelius 1985).

What are the implications of panterritorial pricing for the well-being of farmers and for the revenues of governments? To assess the transport pricing policy embodied in panterritorial pricing requires the simulation of alternative transport policies using equations 1 to 5. This, in turn, requires an assumption about the functional form of the zonal supply function, \( S(p) \). There is no information available on the supply function for cotton in Côte d'Ivoire; indeed panterritorial pricing means there is no regional price variation with which to infer response, thus leaving only rather limited time series information. I therefore adopt the form

\[
S(p) = \beta p^\alpha
\]

which has a constant price elasticity of supply denoted by \( \alpha \), and I present a sensitivity analysis for various values of \( \alpha \).

Table 2. Price Variables in the Cotton Sector in Côte d'Ivoire, 1982/83
(CFA francs per kilogram)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export price (( p^* ))</td>
<td>656</td>
</tr>
<tr>
<td>Price received by farmers (( p_0 ))</td>
<td>191</td>
</tr>
<tr>
<td>Nontransport costs paid by parastatal (( c^* ))</td>
<td>306</td>
</tr>
<tr>
<td>Cost of transport from zone to ginnery per kilogram-kilometer (( a^* ))</td>
<td>0.067</td>
</tr>
<tr>
<td>Cost of transport from ginnery to port per kilogram-kilometer</td>
<td>0.026</td>
</tr>
</tbody>
</table>

Note: The export price is the international price. Nontransport costs are net of all taxes and of the price paid to farmers. All variables refer to one kilogram of ginned cotton. The price received by farmers is constant for all zones because the CIDT pursued panterritorial pricing in 1982/83.

Source: Beenhakker and Bruzelius (1985), especially table 8.
Using the constant-elasticity-of-supply function, the CIDT's implementation of panterritorial pricing ($p_i$, a constant, as given in table 2) is compared with the most desirable pricing scheme (set of $p_i$'s). This latter policy maximizes the well-being of farmers ($\Pi$) subject to the constraint of raising an amount of revenue ($R^0$) for the government equal to that raised under panterritorial pricing. The solution to this transport pricing problem is referred to as the optimal policy. Actually, a tax on land that varies with location is first best, because it does not induce any change in farmers' behavior and therefore dominates even the pricing policy that I term optimal. Such a tax is rarely used, however, and appears to require a degree of administrative capability that is not available.

For any zonal supply function, the optimal policy is found by substituting from equations 1 to 5 into

\[ \mathcal{L} = \Pi + \mu (R - R^0) \]

where $\mu$ is a Lagrange multiplier and then setting the derivatives of equation 7 with respect to the prices received by farmers to zero. The derivatives are:

\[ \frac{d\mathcal{L}}{dp_i} = \gamma_i S(p_i) \left[ 1 - \mu \left( 1 - \frac{\epsilon(p^* - c^* - p_i - a^* t_i)}{p_i} \right) \right] = 0, \]

\[ i = 1, \ldots, N, \]

where the elasticity of supply is

\[ \epsilon = \frac{dS(p_i)}{dp_i} \frac{p_i}{S(p_i)}. \]

Equation 8 holds for each of the $N$ zones, so there are $N$ equations. Along with the revenue constraint that $R = R^0$, these $N$ equations determine the spatial pattern of zonal prices and the Lagrange multiplier or (shadow) cost of having to raise one additional unit of revenue measured in lost producer surplus, $\mu$. The shadow cost is the only variable that is not specific to a particular zone in the equation for that zone.

In the special case of a constant elasticity of supply, the spatial pattern of prices takes a very simple form and has an intuitive interpretation of an (implicit) optimal subsidy to transport. Newbery (1990) makes a similar point for the subsidization of inputs when output is taxed. As indicated by equation 8, when the supply function has a constant elasticity, the optimal policy is defined by a pair of constants, $p_\lambda$ and $a_\lambda$, such that

\[ p_\lambda = \lambda (p^* - c^*) \]

\[ a_\lambda = \lambda a^* \]

\[ p_i = p_\lambda - a_\lambda t_i \]

and

\[ R = R^0. \]
Table 3. Alternative Constant-Revenue Pricing Policies for Côte d'Ivoire

<table>
<thead>
<tr>
<th>Elasticity of supply</th>
<th>Panterritorial pricing (1)</th>
<th>Optimal pricing (2)</th>
<th>Full-cost pricing of transport (3)</th>
<th>Panterritorial pricing (4)</th>
<th>Optimal pricing (5)</th>
<th>Full-cost pricing of transport (6)</th>
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<td>0.067</td>
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Note: Government revenue and producer surplus are in billions of CFA francs; producer price and cost of transport are in CFA francs per kilogram. Calculations are for the 53 CIDT zones in table 1. The zonal prices are given by \( p_i = p - at_i \).

Source: Author's calculations based on data from CIDT (various years), Michelin (1989), DCGT (1986), unpublished data provided by the Caisse Central in Abidjan, and Beenakker and Bruzelius (1985).
Note that $p_\lambda$ and $a_\lambda$ differ from $p^*$ and $a^*$ by the same proportion, $\lambda$, and it is easy to show that raising a positive amount of revenue, $R^0 > 0$, implies that $p_\lambda < p^*$, that is, $\lambda < 1$. Thus $1 - \lambda$ is both the tax rate on the export of the product and the subsidy rate on transport relative to a situation in which farmers receive the full export price but pay the full cost of transport.

Once the government is raising some revenue, therefore, it is no longer optimal to pass the full cost of transport, $a^*$, on to the farmer. If the elasticity of supply is constant, transport should be subsidized to the same degree that the export is taxed. In this particular case, the optimal solution has all farmers paying the same tax, $1 - \lambda$, as a proportion of their pretax farmgate price ($p_i = p^* - a^* t_i$). All farmers reduce their production and producer surplus by the same proportion. Therefore the cost of transport must be subsidized so that the percentage tax on the farmgate price is constant regardless of the farmer's location. The linear equation 9c together with equations 9a and 9b does exactly this.\(^1\)

The values of the variables from tables 1 and 2 and equations 1 to 5 as well as various assumptions about the elasticity of supply, $\alpha$, in equation 6 yield values for revenues, $R$, and producer surplus, $\Pi$, under panterritorial pricing as given in column 1 of table 3. In addition equations 9a to 9d yield the value of the tax rate, $1 - \lambda$, that produces the same revenue as under panterritorial pricing, as given in column 2 of table 3.\(^2\) With such a $\lambda$, the value of the producer surplus can be calculated under optimal pricing. For instance, when the elasticity of supply is 0.67, the value of the producer surplus under optimal pricing is 1.0024 (12.02921/12.00070) times the value of the producer surplus under panterritorial pricing (columns 1 and 2 in table 3). When the elasticity of supply is 1.33, which is probably a high value, the corresponding ratio of producer surpluses is 1.0294. Thus, whether the CIDT pursues an optimal policy or one of panterritorial pricing makes relatively little difference to the value of the aggregate producer surplus. Panterritorial pricing is, however, relatively less desirable the more elastic the supply is, that is, the more producers have scope for changing the volume of their output in response to the deviation between panterritorial pricing and the optimal spatial pattern of prices.

In contrast to these results on overall efficiency, switching from a policy of panterritorial pricing to an optimal one has a big effect on the distribution of

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1. If the supply function does not exhibit a constant elasticity, then the relationship between the optimal $p_i$ and $t_i$ is nonlinear and could even embody an implicit tax, rather than a subsidy, on transport (see Gersovitz 1989 for a detailed, theoretical discussion of this issue). However, the prospects are slim for econometrically detecting a supply function that deviates significantly from constant elasticity with available data, so, in practice, the question is moot.

2. The value of $\lambda$ is found by solving numerically the (nonlinear) equation:

$$\sum \gamma_i [p^* - c^* - a^* t_i] \lambda^i [1 - \lambda] \lambda^i - p^0 R^0 = 0$$

where, for each block of tables 3 and 4, $R^0$ is the value of $R$ in column 1.
Table 4. Revenue-Maximizing Pricing Policies for Côte d'Ivoire

<table>
<thead>
<tr>
<th>Elasticity of supply</th>
<th>Transport cost (a')</th>
<th>CFAF 0.067 per kilogram</th>
<th>CFAF 0.0335 per kilogram</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Panterritorial pricing</td>
<td>Optimal pricing</td>
<td>Panterritorial pricing</td>
</tr>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Elasticity of supply = 0.33</td>
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<td></td>
<td></td>
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<tr>
<td>Government revenue (R)</td>
<td>18.66253</td>
<td>18.66253</td>
<td>18.66253</td>
</tr>
<tr>
<td>Producer surplus (II)</td>
<td>4.66563</td>
<td>4.90670</td>
<td>9.26374</td>
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<tr>
<td>Producer price at port (p)</td>
<td>80.</td>
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<td>133.</td>
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<tr>
<td>Implicit cost of transport to producers (a)</td>
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<tr>
<td>Government revenue (R)</td>
<td>15.25243</td>
<td>15.25242</td>
<td>15.25242</td>
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<tr>
<td>Producer surplus (II)</td>
<td>6.10097</td>
<td>6.49666</td>
<td>11.44762</td>
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<td>Producer price at port (p)</td>
<td>127.</td>
<td>145.</td>
<td>186.</td>
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<tr>
<td>Producer surplus (II)</td>
<td>6.93867</td>
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<tr>
<td>Producer price at port (p)</td>
<td>159.</td>
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<tr>
<td>Implicit cost of transport to producers (a)</td>
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<td>0</td>
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<tr>
<td>Elasticity of supply = 1.33</td>
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</tr>
<tr>
<td>Government revenue (R)</td>
<td>13.37285</td>
<td>13.37284</td>
<td>13.37282</td>
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<tr>
<td>Producer surplus (II)</td>
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<td>Producer price at port (p)</td>
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<td>240.</td>
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<td>Implicit cost of transport to producers (a)</td>
<td>0</td>
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</table>

Note: Government revenue and producer surplus are in billions of CFA francs; producer price and cost of transport are in CFA francs per kilogram. Calculations are for the 53 CIDT zones in table 1. The zonal prices are given by \( p = p - at \).

Source: Author's calculations based on data from CIDT (various years c), Michelin (1989), DCGT (1986), unpublished data provided by the Caisse Central in Abidjan, and Beenhakker and Bruzelius (1985).
producer surplus among zones. Column 5 in table 1 gives the ratio of the producer surplus under optimal pricing to that under panterritorial pricing by zone for an elasticity of supply of 0.67. With optimal pricing, the most remote zone, number 25, receives only 0.78 of the producer surplus it received under panterritorial pricing, whereas the nearest-in zone, number 51, receives 1.11 times as much. The coefficient of variation of the proportional gain is 8.2 percent.

I do not, however, know how these changes in zonal producer surpluses would translate into changes in the distribution of farmers' incomes, which is the important welfare issue. It all depends on who owns what land and how much of it. For instance, if all farmers owned an equal share in land everywhere, a change in the distribution of producer surplus among the zones would not affect the relative well-being of different farmers. In Africa, of course, the expectation is that small farmers depend entirely on agricultural land in one vicinity, so changes in the distribution of producer surplus at the zonal level would affect different farmers differently.

The dependence of farmers on land in one area raises further questions: Do farmers in more remote regions have more or better land—or other sources of income—so they are at least as well off as farmers nearer in? In the CIDT zones it would not be surprising if cotton were important in the incomes of these farmers and if poorer farmers lived in more remote areas. If this is so, the distribution of income could become considerably more dispersed by adopting an optimal pricing policy, while the gains in the aggregate producer surplus would be small. If farmers’ incomes are tied to land within zones rather than widely diversified across zones, considerable redistribution relative to the net gain would have to be engineered among farmers in different zones—and in a nondistorting way. Otherwise the movement from panterritorial pricing to optimal pricing would not be a (pareto) improvement that makes no farmer worse off.

If, by contrast, the CIDT were raising more revenue than it currently does (as estimated in table 3), the situation would be somewhat different with respect to efficiency. For instance the price paid to farmers (p₀) that maximizes the government revenue that can be raised under panterritorial pricing is given by:

\[
p₀^{\text{max}} = \frac{[\Sigma Y_i \alpha (p^* - c^* - a^* t_i)]}{[\Sigma Y_i (1 + \alpha)]}
\]

as can be derived by setting the derivative of aggregate revenues, equation 4, to zero.

Columns 1 and 2 in table 4 give the results of the model when the government maximizes the amount of revenue that it can raise under panterritorial pricing, with transport costs of CFAF0.067 per kilogram-kilometer. For an elasticity of supply of 0.67 the revenue-maximizing value of the panterritorial price is CFAF127 (table 4, column 1) or only 0.36 times the world price net of costs that are independent of zonal location (CFAF350 from table 2). In this case an equal amount of revenue can be raised with an optimal pricing policy that has \( \lambda = 0.418 \) in equations 9a to 9c and a level of producer surplus 1.065
times that obtained with panterritorial pricing—a moderate difference. If the elasticity of supply is 1.33, the ratio of producer surplus under optimal pricing to that under panterritorial pricing is 1.092. Movement from the current situation (table 3, column 1) to revenue maximization (table 4, column 1) brings a small increase in revenue (about CFAF54 million) but a large decrease in producer surplus (about CFAF930 million). There is almost a 10 percent potential gain (about CFAF699 million) in producer surplus in moving from panterritorial pricing to optimal pricing (table 4, columns 1 and 2). In general, as the government raises more revenue, the deadweight loss of panterritorial pricing rises relative to that occurring under the optimal policy. Furthermore it is simply impossible to raise more revenue than that given in column 1 of table 4 if the constraint of panterritorial pricing is maintained, although with an optimal policy it would be possible to raise more if desired.

In Côte d'Ivoire cotton is produced in a geographically compact area with good transport compared with many other export hinterlands in Africa, yet the government's choice of an (implicit) transport pricing policy can affect producer surplus. For it to matter significantly, however, the government would have to be raising more revenue than seems to have been its practice as estimated in table 3. For example, in table 4, columns 1 and 2, more revenue is raised than in table 3, and when $\alpha = 1.33$ distortions are estimated to be moderately large. By contrast, if the hinterland were more dispersed or if transportation per kilometer were more expensive, the costs of panterritorial pricing relative to optimal pricing would be higher. In simulations corresponding to those reported in tables 3 and 4, the cost of transport, $a^*$, was doubled to 0.134. Even for this value, net returns to exporting cotton were greater than the cost of transport for all zones ($p^* - c^* > a^*t_i$). The result, corresponding to table 4, columns 1 and 2, for $\alpha = 1.33$ but for $a^* = 0.134$ was a producer surplus ratio of 1.21 in favor of optimal pricing as opposed to the much lower factor of 1.092 reported in table 4 for $a^* = 0.067$.

Tables 3 and 4 provide information to assess the benefits from investments in transport infrastructure as represented by a decrease in the cost per kilogram-kilometer, $a^*$. Revenue amounts shown in columns 4 and 5 of table 3 are the same as in columns 1 and 2, respectively, but transport costs are only half as much, and the same is true in table 4, when columns 3 and 4 are compared with columns 1 and 2, respectively. The values in table 3 show that the gains in

3. Column 4 of table 3 is derived by finding numerically the $p_1$ that solves the (nonlinear) equation:

$$\sum_{i=1}^{n} [p_i - c^+ - a^+t_i] p_1^i = \sum_{i=1}^{n} R_i p_1^{i+1} - p_0 R^0 = 0$$

where $p_0$ is the value of $p$ in column 1. Column 5 is determined from column 4 in the same way that column 2 is determined from column 1 (see footnote 2). The same procedure is followed to compute columns 3 and 4 of table 4.
producer surplus from a transport improvement under panterritorial pricing are larger than under optimal pricing. Nonetheless the magnitude of the differences is small. For \( \alpha = 1.33 \), the most extreme case in table 3, the gain under panterritorial pricing is CFAF6.12 billion, compared with CFAF5.89 billion under optimal pricing. These results carry over qualitatively to table 4, although raising more revenue accentuates the difference between the gains under the two pricing rules. For an elasticity of 1.33 the gain from halving transport costs under panterritorial pricing is CFAF6.94 billion; it is CFAF6.26 billion under optimal pricing. In this hypothetical example, whether a change in pricing policy is adopted may well determine whether an infrastructural investment is justified.

Investment in transport under panterritorial pricing yields greater benefits than under optimal pricing, because production is more dispersed under panterritorial pricing. Decisions about transport investments and pricing are interdependent. Of course the producer surplus is still highest under optimal pricing for a given level of infrastructure. Panterritorial pricing should not be adopted only to get higher apparent gains from transport investments. Rather, the analysis indicates that a move from panterritorial pricing to optimal pricing, if feasible, is an alternative way to realize some of the gains from a transport investment under panterritorial pricing without the corresponding costs. Thus the change in pricing may obviate the need for investment in transport.

The discussion comparing panterritorial pricing and optimal pricing generalizes easily to any other pricing scheme. For instance an export tax (at rate \( r \)) with private (full-cost) transportation would imply that the price received by farmers is given by

\[
p_i = (1 - \tau) (p^\ast - c^\ast) - a^\ast t_i.
\]

Such a scheme has superficial appeal because it may be thought to embody a user charge for transport, which is desirable in many other situations. From equations 9a to 9d, however, such a scheme is suboptimal if the government is raising some revenue (\( R > 0 \), \( \lambda > 0 \), and \( \tau < 1 \)), as in the case of cotton in Côte d'Ivoire. As noted, the reason is that charging the full cost of transport means that a tax at the port results in higher percentage taxation of the farmgate price as distance rises.

The results of full-cost pricing of transportation are illustrated in columns 3 and 6 of table 3. In terms of producer surplus, full-cost pricing of transport is better than panterritorial pricing, generally making up about 60 percent of the

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4. That is, the difference in \( \Pi \) between columns 1 and 4 is larger than the difference in \( \Pi \) between columns 2 and 5.

5. The effect on the producer surplus associated with a given government revenue can be found by solving for the value of \( \tau \) that produces a revenue equal to \( R^\ast \) from equations 1, 2, and 4 and then substituting the consequent set of \( p \), into equations 3 and 5.
gap between panterritorial pricing and optimal pricing. Moving from pan-
territorial pricing to full-cost pricing causes a larger dispersion of zonal gains and
losses than does moving from panterritorial to optimal pricing. For the parame-
ters of the example given in table 1, column 5, the summary statistics for the
ratio of producer surplus under full-cost pricing to that under panterritorial
pricing are: mean, 0.98; standard deviation, 0.12; minimum, 0.64; and maxi-
mum, 1.18. Finally, because full-cost pricing results in less dispersed produ-
tion, it makes investment in transportation infrastructure less attractive than
does either alternative (compare columns 1 to 3 with columns 4 to 6 of table 3).

III. The Density of Depots and Backhauling

Farm outputs are often gathered at depots before transport to processing
plants or to the point of export. The number and location of these depots can
have significant economic effects. One important attribute of a depot system is
the extent of backhauling that it engenders. Here I bend the conventional defini-
tion of backhauling to mean the movement by farmers of their output away
from the point of processing, export, or ultimate consumption. Backhauling can
increase the transport costs of the sector unnecessarily.

Not all marketing systems engender backhauling. For instance, if depots exist
in every village and the marketing authority adopts panterritorial pricing, then a
farmer gets the same price for output no matter where it is sold. Therefore the
farmer sells the output at the nearest depot, which is very close to where the crop
is harvested, and there is (almost) no backhauling. This situation prevails in
Côte d’Ivoire, where the CIDT operates one depot in each cotton-growing village
in the sector.

Another situation in which there need not be an incentive to backhaul occurs
if the marketing parastatal equates the price at any depot to the price received at
the final point of sale less the full cost of transport to that point. If, in addition,
the private sector has the same (or lower) costs of transport to the depot, it never
pays to send produce away from the destination to which the parastatal wants it
to go. The depots nearer the ultimate destination pay a sufficiently higher price
so that farmers send their output to those depots even if they are farther away
than other depots.

The preceding section of this article, however, establishes that full-cost pricing
of transport is not optimal if the government is raising revenue from the sector.
In particular, when the elasticity of supply is constant, equations 9a to 9d show
that the optimal spatial pattern of prices embodies a subsidy to transport. In this
case it is as if the private sector has more costly transport than the parastatal. It
may become privately profitable to move output to a depot that is nearer to the
farm but farther from the destination to which output is being moved by the
parastatal. Backhauling then occurs. Although depots nearer to the parastatal’s
ultimate destination pay higher prices, they are insufficiently higher to guarantee
that it is never profitable to ship to depots that are farther from the ultimate destination but very much nearer to the farmer.

If there are very many depots, then the amount of backhauling is unimportant, because the depot that is farther from the ultimate destination but nearer to the farmer and the depot that is farther from the farmer but nearer to the ultimate destination are both absolutely very near the farmer. If depots are expensive to set up, however, there will be of necessity few of them, and then backhauling can be a problem. Backhauling increases the deadweight loss from raising a given amount of revenue and lowers the maximum amount of revenue that the government can raise (Gersovitz 1989).

Panterritorial pricing can further worsen the problem of backhauling when there are few depots because, by equalizing all depot prices, it gives no incentive for farmers to sell to depots nearer the ultimate destination instead of the depot that is nearest to the farmer. How serious the backhauling problem is depends not just on the number of depots but on their location, so little of generality can be said. Nonetheless some examples suggest what to look for and what to expect from different schemes that may be met in practice.

If there are few depots all with the same producer price, but all are clustered near the ultimate destination, then backhauling is likely to be a small problem. For example, the government may adopt the principle of paying only one price but, in practice, buy output only at the ultimate destination. Thus the pricing scheme is one of full-cost pricing of transport because, although the parastatal pays only one price, it pays this price at only the ultimate location. In this case a second depot, paying the same price as the first and located (optimally) quite near it, can decrease the deadweight loss despite inducing some backhauling. This occurs because, as noted, full-cost pricing of transport is not optimal. A second depot located near the first and paying the same price mimics the transport subsidy implicit in equations 9a to 9d that minimizes deadweight loss and at the same time engenders little backhauling. The net gain from the extra depot is, however, relatively small.6

By contrast, when the placing of depots is constrained and there are few of them relative to the distance to the ultimate destination, severe losses can occur from backhauling. For instance, if production occurs at one ton per kilometer along a road of length $D$ (as measured from the ultimate destination), then, with only one depot at the ultimate destination, the total ton-kilometers to transport the whole crop to the ultimate destination is proportional to $D^3/2$. By contrast, if a second depot, paying the same price, is located $D$ from the ultimate destination (the absolutely worst place for it along the road), then all output of amount $D/2$ produced along the road from point $D/2$ to $D$ is nearer to the second depot

6. The model of equations 21 and 22 of section VI of Gersovitz (1989) can be used to prove this statement by imposing the additional constraint (in the notation of Gersovitz 1989) that $p_0 = p_1$, and then maximizing with respect only to $x_0$, and the common value of $p_0$ and $p_1$. 

and is brought there \( (D^2/8 \text{ ton-kilometers in total}) \).

This output of amount \( D/2 \) produced from \( D/2 \) to \( D \) then has to be brought back a distance of \( D \) to the ultimate destination \( (D^2/2 \text{ ton-kilometers}) \). Total transport costs are proportional to \( 3D^2/4 \), including the \( (D^2/8) \) ton-kilometers generated by the production between point \( D/2 \) and the ultimate destination at point 0. Transport costs rise by 50 percent compared with purchase at only the ultimate destination. Thus a combination of panterritorial pricing, few depots, and bad locations can induce large excess transport costs. In general, if production is uniformly distributed along a road with many \( (n) \) depots, each collecting output from a radius of \( r \), the amount of backhauling is proportional to \( nr^2 \), providing a rough guide to the extent of backhauling.

IV. Conclusions

This article provides diagnostic tests for analyzing the transport policies that are explicitly or implicitly pursued through state marketing in Africa. A central result of the analysis is the interrelationship among rules for the taxation of exports, the pricing of transport, and investment in transport. The models are fairly general and can be applied to readily available data.

If the government uses an export tax to raise revenue, it may be optimal to subsidize transport to lessen the loss in total producer surplus from raising a specified amount of revenue. In the particular case of a supply function with constant elasticity, transport should be subsidized at the same rate as the export is taxed. This result has direct relevance to the debate on the pricing of diesel fuel and kerosene. The usual presumption is that, while it is desirable to subsidize kerosene because the poor use it as a cooking fuel, such a subsidy would result in unacceptable distortions because kerosene can be substituted for diesel as fuel in the transport sector (Newbery and others 1988). This article suggests that some subsidization of transport may be desirable, thus moderating the conflict between kerosene and diesel pricing policies.

The optimal policy can be contrasted with two suboptimal policies: panterritorial pricing and full-cost pricing of transport with export taxation. For cotton in Côte d'Ivoire, the cost of the current policy of panterritorial pricing does not seem to be large relative to the optimal policy. Full-cost pricing closes a little more than half the gap between panterritorial pricing and optimal pricing. Elsewhere in Africa, however, the agricultural hinterland is much larger, production more dispersed, and the gains from moving to optimal pricing are likely to be correspondingly larger. Furthermore, if the network of depots at which output is bought is badly designed, it can lead to large losses, especially when

7. As in footnote 6, the model of equations 21 and 22 of section VI of Gersovitz (1989) can be used to prove this statement by imposing the additional constraint that \( p_0 = p_1 \) and looking at arbitrary values of \( x_D \) and the common value of \( p_0 \) and \( p_1 \).
panterritorial pricing is adopted. Such is not the case in Côte d'Ivoire, if the current dense network of depots is not costly to operate and maintain. Nevertheless, if the government of Côte d'Ivoire were ever to seek more revenue from the cotton sector, the losses from staying with panterritorial pricing would increase. The conclusions on the harmful effects of panterritorial pricing depend critically on how much revenue the government raises from the agricultural sector.

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The Economics of Farm Fragmentation: Evidence from Ghana and Rwanda

Benoit Blarel, Peter Hazell, Frank Place, and John Quiggin

Farm fragmentation, in which a household operates more than one separate parcel of land, is a common phenomenon in Sub-Saharan Africa. Concerned by the perceived costs of fragmented as opposed to consolidated holdings, several countries have implemented land consolidation programs. But these interventions overlook the benefits that land fragmentation can offer farmers in managing risk, in overcoming seasonal labor bottlenecks, and in better matching soil types with necessary food crops. This article uses household data from Ghana and Rwanda to discuss the incidence and causes of fragmentation. It then formally tests the relation between fragmentation and land productivity and risk reduction. The conclusion is that consolidation programs are unlikely to lead to significant increases in land productivity and may actually make farmers worse off. Policymakers should focus instead on reducing the root causes of fragmentation: inefficiencies in land, labor, credit, and food markets.

The existence of fragmented landholdings is an important feature in less-developed agricultural systems. The costs of fragmentation include increased traveling time between fields (hence lower labor productivity and higher transport costs for inputs and outputs), negative externalities (such as reduced scope for irrigation and soil conserving investments as well as the loss of land for boundaries and access routes), and greater potential for disputes between neighbors. In light of these costs numerous land reform policies have been aimed at enforcing, or at least subsidizing, the consolidation of holdings. These policies are premised on the assumption that fragmentation is necessarily inefficient and that agricultural production and social welfare can be increased through land consolidation.

Such policies have already been tried in some African countries (for example, Kenya and Tanzania) and are now being considered by others (for example, Rwanda). Yet little is really known about the incidence of farm fragmentation in Sub-Saharan Africa by region and farm type and about its origins, causes, and
impact on land productivity. Although there are negative aspects to farm fragmentation, there are also reasons why it may be beneficial to farmers (such as reducing risk, easing seasonal labor bottlenecks, and enhancing household-level food security). In fact some degree of farm fragmentation may be desirable and might best be viewed as a rational response by farmers to the economic and institutional environment in which they live. If so, attempts to consolidate holdings beyond some optimal degree could actually reduce farm productivity, and interventions should be focused instead on those features of the rural economy that create the need for fragmentation in the first place.

This article examines the circumstances under which farm fragmentation may be economic to farmers, especially in Sub-Saharan Africa, and relates these circumstances to prevailing conditions in selected regions in Ghana and Rwanda. Available survey data are then used to test the relations among farm fragmentation, and land productivity and risk management.

I. Explanations of Fragmentation

The explanations of land fragmentation offered in the literature fall into two broad categories (McPherson 1982; Bentley 1987). The first treats fragmentation as an exogenous imposition on farmers and consists of what we shall call “supply-side” explanations. The second views fragmentation as primarily a choice variable for farmers and can therefore be described as “demand-side” explanations. Supply-side explanations invariably conclude that fragmentation has adverse effects on agricultural production. Demand-side explanations presume that farmers will, given free choice, choose levels of fragmentation that are beneficial. Imperfections in factor or commodity markets play a key role in both types of arguments.

Supply-Side Explanations

Several forces have been widely cited as causing or contributing to involuntary fragmentation. The most frequently cited are partible inheritance and population pressure resulting in land scarcity (Anthony and others 1979; Binns 1950; Holmberg and Dobyns 1969; Hyodo 1963; Leibenstein 1957; Thirsk 1964; Wolf 1966; World Bank 1978). Many authors argue that partible inheritance logically leads to fragmentation when farmers desire to provide each of several heirs with land of similar quality. Likewise extreme land scarcity may lead to fragmentation as farmers in quest of additional land will tend to accept any available parcel of land within reasonable distance of their house (Farmer 1960).

These factors explain why a young farmer might begin with a fragmented holding. However, as McCloskey (1975) points out, they do not explain the persistence of fragmentation in the face of economic incentives for consolidation. Such persistence indicates significant imperfections in the land market. Some economists (for example, Bauer and Yamey 1957; Lipton 1968; Sargent 1952) claim that land markets themselves are highly fragmented, with few will-
ing sellers. Dorner (1977) cites multiple interests over parcels as restricting the potential supply of land, because unanimous agreement to sell is difficult to achieve. McKinnon (1973) stresses incomplete credit markets and the resulting inability of many farmers to finance land acquisitions.

Another supply-side factor is the breakdown of common property systems under the pressure of population growth. This breakdown has led to increased fragmentation in, for example, Kenya (King 1977) and eastern Nigeria (Udo 1965). A number of authors have demonstrated that fragmentation in certain areas is a consequence of egalitarian objectives on the part of the communal authority (Dahlman 1980; Georgescu-Roegen 1969; Grigg 1970; Quiggin 1988). State laws that restrict land transactions also limit possibilities for land consolidation. Finally, nature itself may limit the boundaries of arable parcels (for example, waterways and wastelands) so that expansion of farm size requires the acquisition of separate pieces of land.

The supply-side explanations, while plausible, are not sufficient to explain fragmentation in all the areas in which it is found. First, even where land markets afford farmers opportunities for consolidation, fragmentation persists (see section III). Second, fragmentation has developed in the absence of land scarcity (for example, in areas of Kenya, Zambia, and The Gambia [McPherson 1982]). Third, ancestors continue to bestow heirs with scattered holdings, a practice that would seemingly be halted if fragmentation was largely detrimental (Douglass 1969; Leach 1968). The argument that partible inheritance is designed for equity reasons runs into difficulty when it is observed that subdivision and fragmentation levels are eventually "checked" after reaching specific levels (noted in India by Hopper 1965, in Mexico by Downing 1977, and in Sri Lanka by Leach 1968). These examples suggest that other factors may be important in explaining fragmentation.

**Demand-Side Explanations**

Demand-side explanations of farm fragmentation presume that the private benefits of fragmentation exceed its private costs. That fragmentation might benefit farmers follows from the realization that land is not homogenous. Parcels differ with respect to soil type, water retention capability, slope, altitude, and agroclimatic location. Recognizing this, Buck (1964) and Johnson and Barlowe (1954) were among the first to note that by operating parcels in different locations, farmers are able to reduce the variance of total output and hence final consumption. This is partly because the scattering of parcels reduces the risk of total loss from flood, drought, fire, and other perils and also because farmers can more efficiently diversify their cropping mixtures across different growing conditions. Other risk-spreading mechanisms, such as insurance, storage, or credit, also reduce variations in household consumption. Therefore fragmentation for risk reduction should persist only if these alternatives are either not available or are more costly (Carter and Matlon nd; Charlesworth 1983; Fen-oaltea 1976; Hyodo 1963; Ilbery 1984; McCloskey 1976; Thompson 1963).
<table>
<thead>
<tr>
<th>Region</th>
<th>Location</th>
<th>Population density (persons/square kilometer)</th>
<th>Sampled households</th>
<th>Households with non-farm income (percent)</th>
<th>Median farm size (hectares)</th>
<th>Median number of parcels</th>
<th>Mean value of Simpson index</th>
<th>Median household size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ghana</td>
<td>Anloga</td>
<td>384</td>
<td>115</td>
<td>89.6</td>
<td>0.26</td>
<td>5</td>
<td>0.64</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Wassa</td>
<td>30</td>
<td>150</td>
<td>69.3</td>
<td>13.24</td>
<td>5</td>
<td>0.62</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Ejura</td>
<td>20</td>
<td>158</td>
<td>30.4</td>
<td>2.57</td>
<td>1</td>
<td>0.23</td>
<td>6</td>
</tr>
<tr>
<td>Rwanda</td>
<td>Ruhengeri</td>
<td>367</td>
<td>72</td>
<td>47.2</td>
<td>0.70</td>
<td>7</td>
<td>0.69</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Butare</td>
<td>342</td>
<td>80</td>
<td>25.0</td>
<td>0.91</td>
<td>7</td>
<td>0.62</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Gitarama</td>
<td>279</td>
<td>80</td>
<td>25.0</td>
<td>0.83</td>
<td>5</td>
<td>0.54</td>
<td>6</td>
</tr>
</tbody>
</table>

*Source*: Authors' calculations based on World Bank survey data.
Another explanation for fragmentation was developed by Fenoaltea (1976) for medieval England. He argued that because of transaction costs in labor markets, the scattering of parcels enabled farmers to better fulfill their seasonal labor requirements and consequently to obtain higher yields. If the labor market does not work at all, labor supply is fixed by household size, and the need for temporally spreading labor requirements is great. Even if labor markets exist, the costs of supervision may induce farmers to scatter parcels and supervise a small number of workers at a time, rather than watch over a large number of hired workers on a consolidated holding at peak periods. This approach is most effective when different types of land are suitable for different crops (hence, when fragmentation facilitates diversification) or when different parcels of land offer sufficient diversity in climatic conditions that the same crop can be staggered over a wider range of planting dates.

Commodity market failures may also cause fragmentation to have a positive impact on productivity. When such failures occur, a subsistence mode may be adopted in which several products are raised for household consumption, rather than purchased with the proceeds of cash crop sales. If different land types or ecozones are suitable for cultivating different crops, then the required diversity can best be obtained from a fragmented landholding (Netting 1972). Because this argument assumes that all of the products required can be produced by a single household, and hence within a single village, trade within the village must also be more costly than land fragmentation. This seems most likely to happen when there is considerable uncertainty about relative price movements, especially for important foods. Farmers will not want to specialize in less essential foods if there is a real risk that they cannot procure sufficient amounts of essential foods through trade. These price risks can be particularly real in Africa, given that the risk-pooling effects of interregional trade are hindered by poor infrastructure and marketing systems.

Farmers might also want fragmented holdings if, holding farm size constant, there are diseconomies of scale with respect to the size of individual parcels. Where this phenomenon occurs, however, it probably reflects malfunctioning labor markets; farmers are unable to procure adequate labor to meet seasonal peaks in the requirements for large parcels.

II. EVIDENCE OF FRAGMENTATION

Data on fragmentation were obtained from three regions in Ghana and Rwanda as part of a larger study of land rights in Sub-Saharan Africa (Migot-Adholla and others 1991). Nearly 150 households were surveyed in each of the Ghanaian regions and about 80 in each of the Rwandan areas (table 1). The data were collected between 1987 and 1988 and included characteristics of the household (such as age, education, and occupation of all individuals; number of regular workers; nonfarm income; wealth; and use of credit), characteristics of the household head (such as farming experience, place of birth, and local offices
held), characteristics of the farm (such as size and number of parcels), and characteristics of each parcel (such as mode of acquisition, soil fertility, distance from house, topography, size, rights of transfer and use, land improvements made, crops grown, and inputs and output in the past season).

In measuring fragmentation, we primarily use the Simpson index, defined as \(1 - \sum \frac{A_i^2}{A^2}\), where \(A_i\) is the area of the \(i\)th plot and \(A = \sum A_i\) is the total farm area. A value of zero indicates complete land consolidation (one parcel only), while the value of one is approached by holdings of numerous parcels of equal size. However, because the Simpson index is sensitive to dispersion in the size of the parcels as well as to their number, we also use the number of parcels as an alternative fragmentation measure. Values for the Simpson index and number of parcels are for individual farms. To look at farm fragmentation in a region, a frequency distribution is constructed of the percentage of farms at different levels of the indicators.

**Ghana**

The regions in Ghana for which we have data include Anloga, a coastal strip in the southeast; Ejura, a savanna area in the center; and Wassa, a forest region in the southwest. The Anloga region has a very high population density (384 persons per square kilometer), which is unusually high for Ghana. The other two regions are much more land-abundant, with densities of around 25. Subtle differences in topography or altitude within the three regions can have a measurable impact on cropping strategies. For instance the Anloga region has the least ecological diversity, yet location, such as proximity to lagoons, is important because it is related to the risk of flooding. The Anloga area is predominantly a shallot-growing area, with only minor areas devoted to other crops. Cocoa predominates in the Wassa area, even though the land is only marginally suitable for cocoa. In Ejura farmers produce a variety of food crops along with groundnuts, and, unlike all the other study regions, many cultural operations are tractorized.

The evidence reported in table 2 indicates that farm holdings in Anloga are highly fragmented. The median number of parcels is 5.0, and the median value of the Simpson index is 0.7. The parcels are, however, generally located close enough to the house to be readily serviced by the household; the average distance is 1.2 kilometers. Greater fragmentation does not result in greater average distances for farmers; the correlation between the Simpson index and the average distance to a parcel is \(-0.091\) (significant at only the 17 percent confidence level), indicating that, if anything, parcels on more fragmented farms are generally closer to the homestead.

For the Wassa region the median number of parcels per farm is 5.0, and the median value of the Simpson index is 0.66. Farmers must travel 1.8 kilometers on average to reach their parcels. Again the average distance to parcels (across households) is not significantly related to the Simpson index of fragmentation (the correlation of 0.059 is only significant at a level of 0.24). The average
distance to parcels is lower for migrant farmers than for indigenous farmers (1.3 versus 2.3 kilometers, respectively) because migrants typically acquire land before building a dwelling, whereas indigenous farmers are more likely first to become established in an existing dwelling or settlement and then to acquire land. Farms managed by migrants are not significantly different from those managed by indigenous farmers with respect to the number of parcels or the Simpson index.

Fragmentation is not as prevalent in Ejura. Table 2 shows that more than 50 percent of farmers operate only one parcel, while 94.4 percent operate three or fewer parcels. The Simpson index is correspondingly low. For 84 consolidated farms the index value is zero. For multiple-parcel farms the index is below 0.55 in most cases and has a maximum of 0.75. The mean value is 0.23. The distance to parcels is greater in Ejura. More than 20 percent of farmers must travel an average of 4.7 kilometers or more to reach their parcels. This is not a problem specific to fragmented farms; similar distances must be traveled to parcels on consolidated and fragmented holdings. The correlation between average distance and number of parcels is 0.002, implying virtual independence of the two variables.

Table 2. Fragmentation of Operated Land in Three Regions in Ghana, 1987–88
(percentage of households)

<table>
<thead>
<tr>
<th>Measure of dispersion</th>
<th>Anloga</th>
<th>Wassa</th>
<th>Ejura</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simpson index</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–0.5</td>
<td>20.9</td>
<td>20.7</td>
<td>87.3</td>
</tr>
<tr>
<td>0.5–0.7</td>
<td>27.0</td>
<td>43.3</td>
<td>9.5</td>
</tr>
<tr>
<td>0.7–0.8</td>
<td>30.4</td>
<td>28.0</td>
<td>3.2</td>
</tr>
<tr>
<td>Over 0.8</td>
<td>21.7</td>
<td>8.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Mean*</td>
<td>0.64</td>
<td>0.62</td>
<td>0.23</td>
</tr>
<tr>
<td>Median*</td>
<td>0.71</td>
<td>0.66</td>
<td>0.00</td>
</tr>
</tbody>
</table>

| Number of parcels     |        |       |       |
| 1                     | 2.6    | 0.0   | 53.2  |
| 2–3                   | 25.2   | 11.3  | 41.2  |
| 4–5                   | 27.0   | 43.3  | 4.4   |
| 6–7                   | 22.6   | 33.3  | 1.3   |
| 8 or more             | 22.6   | 12.0  | 0.0   |
| Mean*                 | 5.67   | 5.52  | 1.70  |
| Median*               | 5.00   | 5.00  | 1.00  |

| Average distance to parcel (kilometers) |        |       |       |
| 0–0.5                                 | 13.9   | 15.3  | 1.3   |
| 0.5–1                                 | 32.2   | 23.3  | 7.6   |
| 1–1.5                                 | 25.2   | 16.0  | 6.3   |
| 1.5–2                                 | 15.7   | 14.0  | 12.7  |
| Over 2                                | 13.0   | 31.3  | 72.2  |
| Mean*                                 | 1.21   | 1.80  | 3.57  |
| Median*                               | 1.10   | 1.50  | 3.00  |

*Expressed in relevant units, not percentages.

Source: Authors' calculations based on World Bank survey data.
Table 3. **Fragmentation of Operated Land in Three Prefectures in Rwanda, 1987–88**  
(percentage of households)

<table>
<thead>
<tr>
<th>Measure of dispersion</th>
<th>Pooled</th>
<th>Ruhengeri</th>
<th>Butare</th>
<th>Gitarama</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Simpson index</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.0–0.2</td>
<td>7.3</td>
<td>2.8</td>
<td>7.5</td>
<td>11.3</td>
</tr>
<tr>
<td>0.2–0.4</td>
<td>10.3</td>
<td>5.6</td>
<td>10.0</td>
<td>15.0</td>
</tr>
<tr>
<td>0.4–0.6</td>
<td>21.1</td>
<td>12.5</td>
<td>20.0</td>
<td>30.0</td>
</tr>
<tr>
<td>0.6–0.8</td>
<td>35.8</td>
<td>44.4</td>
<td>41.3</td>
<td>22.5</td>
</tr>
<tr>
<td>0.8–1.0</td>
<td>25.4</td>
<td>34.7</td>
<td>21.3</td>
<td>21.3</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.61</td>
<td>0.69</td>
<td>0.62</td>
<td>0.54</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>0.66</td>
<td>0.75</td>
<td>0.66</td>
<td>0.57</td>
</tr>
<tr>
<td><strong>Number of parcels</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1–2</td>
<td>9.5</td>
<td>8.3</td>
<td>2.5</td>
<td>17.5</td>
</tr>
<tr>
<td>3–4</td>
<td>22.4</td>
<td>19.3</td>
<td>18.8</td>
<td>28.8</td>
</tr>
<tr>
<td>5–7</td>
<td>27.6</td>
<td>27.8</td>
<td>30.0</td>
<td>25.0</td>
</tr>
<tr>
<td>8–10</td>
<td>22.4</td>
<td>25.0</td>
<td>27.5</td>
<td>15.0</td>
</tr>
<tr>
<td>Over 10</td>
<td>18.1</td>
<td>19.4</td>
<td>21.3</td>
<td>13.8</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>7.1</td>
<td>7.7</td>
<td>7.9</td>
<td>5.9</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>6.0</td>
<td>7.0</td>
<td>7.0</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Topographical dispersion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zero</td>
<td>25.4</td>
<td>38.9</td>
<td>6.3</td>
<td>32.5</td>
</tr>
<tr>
<td>0.0–0.2</td>
<td>22.4</td>
<td>9.7</td>
<td>37.5</td>
<td>18.8</td>
</tr>
<tr>
<td>0.2–0.3</td>
<td>12.9</td>
<td>8.3</td>
<td>16.3</td>
<td>13.8</td>
</tr>
<tr>
<td>0.3–0.4</td>
<td>11.6</td>
<td>12.5</td>
<td>15.0</td>
<td>7.5</td>
</tr>
<tr>
<td>0.4–0.5</td>
<td>14.6</td>
<td>12.5</td>
<td>12.5</td>
<td>17.5</td>
</tr>
<tr>
<td>Over 0.5</td>
<td>13.4</td>
<td>18.1</td>
<td>12.5</td>
<td>10.0</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>0.24</td>
<td>0.25</td>
<td>0.26</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>0.22</td>
<td>0.23</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Average distance (minutes)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–3</td>
<td>22.4</td>
<td>11.1</td>
<td>16.3</td>
<td>38.8</td>
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<td>3–6</td>
<td>16.8</td>
<td>15.3</td>
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<td>30.6</td>
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<td>7.5</td>
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<tr>
<td>Over 15</td>
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<td>22.2</td>
<td>16.3</td>
<td>20.0</td>
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<tr>
<td><strong>Mean</strong></td>
<td>9.8</td>
<td>10.9</td>
<td>9.6</td>
<td>9.1</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>7.5</td>
<td>10.0</td>
<td>7.9</td>
<td>5.4</td>
</tr>
</tbody>
</table>

*Expressed in relevant units, not percentages.

a. An index similar to the Simpson index is used to measure topographical dispersion. The measure is \(1 - \left[\sum t_i / A^2\right]\), where \(t_i\) is the area of land located in topographical location \(i\), and \(A\) is the total farm area. The index is equal to zero when all land is located in a single topographical location.

b. We use time rather than kilometers because this is a more meaningful measure, given the steep, hilly terrain.

Source: Authors' calculations based on World Bank survey data.
The Simpson index is positively correlated with farm size in Anloga (0.305) but is unrelated to farm size in Wassa and Ejura. In all three regions, a higher level of fragmentation is associated with lower average parcel sizes.

**Rwanda**

Rwanda has one of the highest population densities in Sub-Saharan Africa (445 inhabitants per square kilometer of arable land in 1986), as well as one of the highest population growth rates (3.6 percent a year between 1978 and 1986). The ratio of population to total land is high in each of the three study prefectures: Ruhengeri, Butare, and Gitarama. Pressure on existing farmland is made worse by the lack of new land available for agriculture and the lack of off-farm opportunities. The microecological variation of land across Rwanda is tremendous. It is a country dotted with steep hills, where altitudes and slopes change dramatically within shouting distance. A wide variety of crops is grown in each prefecture as well as on most individual farms. The common crops are coffee, sorghum, beans, bananas, sweet potatoes, groundnuts, maize, and Irish potatoes.

The first block of table 3 shows the distribution of the Simpson index for operated parcels by prefecture. Holdings are most fragmented in Ruhengeri and least in Gitarama. Fragmentation declines with farm size; the correlation is statistically significant at -0.201. Gitarama farms typically have fewer parcels than those in Ruhengeri or Butare. This is easily explained by the higher incidence of paysannat farms (settlement schemes farms), which consist of one parcel. Farms are also less dispersed topographically than spatially in all three prefectures. This indicates that farmers operate separate parcels in similar topographical locations, a practice that is most prevalent in Ruhengeri and Gitarama but relatively rare in Butare. The average distance, measured in minutes, between the house and the operated parcels is lowest in Gitarama and highest in Ruhengeri. For the median farm a household member must travel 5.4 minutes to reach a parcel in Gitarama, as opposed to 7.9 minutes in Butare and 10.0 minutes in Ruhengeri.

**III. Causes of Fragmentation in Ghana and Rwanda**

Based on our review in section I, we would expect fragmentation in areas of low population density to be driven primarily by demand. Demand in these areas, while originating from imperfections in the credit, labor, or food markets, will depend on the extent of soil and agroclimatic diversity within the community and hence on the possibilities for staggering labor tasks and diversifying into different crops. In regions where land is scarce, however, supply-side factors are likely also to come into play, especially where land markets are too limited to permit desired levels of farm consolidation. Other things being equal, we would therefore expect fragmentation to be greater in more highly populated regions.

Our regional data confirm a positive relation between population density and
the Simpson index of farm fragmentation (table 1). Wassa, in Ghana, is the exception: even though it has a low population density similar to that of Ejura, also in Ghana, the level of fragmentation is comparable with regions with more than 10 times its population density. Fragmentation in Wassa, however, is largely determined by the scarcity of good cocoa land. Farmers generally seek level areas to establish cocoa parcels, and these areas tend to be small and separated by numerous hills and waterways.

A positive relation between population density and fragmentation does not in itself prove that fragmentation is predominantly driven by supply. It is also necessary to show that land markets fail. This is difficult to verify, given the available data, but some inferences are possible. Land market transactions account for less than half of all parcel acquisitions in our study regions in Rwanda and less than one-third of those in Ghana. Land purchases are particularly rare—except in Ruhengeri (in Rwanda) and Wassa (in Ghana), where they account for about 18 percent of all parcel acquisitions—and they seem to be unrelated to population density. Conversely, temporary land transfers (renting and borrowing) are more common in the more highly populated regions, although relatively rare in the regions with low population densities. One would expect these temporary transactions to provide considerable scope for farmers to consolidate their operated holdings, even if the possibilities for permanent consolidation of owned land are more limited.

But are temporary land transactions used to consolidate operated holdings, especially in the more densely populated areas? We do not have enough data to explore this question for Ghana. In Rwanda, however, apart from a small percentage of large farms that only lease out (rent or lend) land, all households that lease land actually increase the average fragmentation of their operated holdings and the average distance that they must travel to their plots. This is true even of the 14 percent of farmers who “swap” parcels through simultaneous leasing arrangements. Although one should expect smaller farms to lease any available piece of land in a land-scarce situation, the fact that parcel “swapping” is also used to increase fragmentation suggests there may be significant demand for fragmentation in Rwanda. We cannot therefore conclude that fragmentation is a predominantly supply-driven phenomenon in these highly populated areas.

If farm fragmentation in the highly populated study regions is not purely driven by supply, then we should not necessarily expect it to reduce the average productivity of land. Moreover the effect on productivity will depend on the degree of heterogeneity in soil and agroclimatic conditions, and hence the possibilities for efficient crop diversification or the staggering of labor tasks.

Because Anloga and Wassa, in Ghana, are primarily monocrop regions, the advantages of fragmentation are likely more modest there. Nevertheless in Anloga topographical location, soil fertility, and soil moisture retention vary slightly, and, while in dry periods the depressed areas perform relatively better, in wet periods they are more susceptible to flooding. By operating parcels in areas of low and high flood risk, farmers can reduce the likelihood of a complete
disaster as well as contain the variability in total farm yields. The Wassan region is characterized by rolling hills so that spatial separation of flat parcels may mitigate the risks of severe crop failure caused by pests or disease.

Ejura, however, has a wide range of soil types that facilitate efficient crop diversification. The survey data show that fragmented farms have more diversified cropping patterns than do consolidated farms. Land is also relatively abundant in Ejura, and, with its low population density there is little reason to expect that fragmentation is supply-induced. Given the widespread use of tractors in the region, however, we expect the demand for fragmentation to be muted by likely economies of scale in parcel size.

In Rwanda the extensive soil and agroclimatic diversity suggests that fragmentation would offer considerable scope for diversifying crops and staggering planting dates. These advantages may explain why even those farmers who “swap” land through simultaneous leasing arrangements have farms that become more fragmented. Such arrangements may also significantly cushion any efficiency losses arising from supply-induced fragmentation.

In conclusion, there are a priori grounds for expecting that farm fragmentation is driven by demand as well as supply factors in five of the six study regions. Fragmentation in Ejura, which, as shown in table 2, is not widespread, is likely to be largely a demand-driven phenomenon.

IV. An Econometric Model

The measurement of the effect of fragmentation on land productivity requires the formulation of an appropriate econometric model. There are three types of household decision variables of interest: the level of farm fragmentation, $F$; the parcel-level use of direct inputs, $L_i$; and the current stock of land improvements on each parcel, $I_i$. These variables, together with other shifter variables, determine parcel yield, $Y_i$, in the following structural model:

\[
Y_i = f(L_i, I_i, F, X_1, X_2, X_3) \quad i = 1 \text{ to } n
\]

\[
L_i = f(I_i, F, X_1, X_2, X_3) \quad i = 1 \text{ to } n
\]

\[
I_i = f(F, X_1, X_2, X_3, I_{i,t-1}) \quad i = 1 \text{ to } n
\]

\[
F = f(X_2, X_3)
\]

where $X_1$ is a set of parcel-specific characteristics, such as distance from house, parcel size, soil quality, and land rights; $X_2$ is a set of household-specific characteristics, such as family size, wealth, education, risk aversion, farm size; and fragmentation at inheritance; and $X_3$ is a set of village dummies to capture the effects of prices, the efficiency of local land, labor, credit, and food markets, and the available agroclimatic diversity. Subscript $i$ indicates a particular parcel, and there are $n$ parcels.
The yield of each parcel is determined in equation 1 by the use of direct inputs; the current stock of land improvements; the level of farm fragmentation; and parcel, household, and village dummies. Equations 2 and 3 determine the level of direct inputs used on, and the current stock of land improvements made to, the ith parcel, respectively. Both are determined by the level of farm fragmentation, as well as by relevant parcel, household, and village variables, including land improvements that have previously been made \((I_{i-1})\).

Unlike equations 1 to 3, farm fragmentation is determined in equation 4 at the household rather than the parcel level. In keeping with our earlier discussion, we postulate that farm fragmentation depends on household \((X_2)\) and village \((X_3)\) variables. Because fragmentation is either exogenously determined by "supply-side" factors or is a choice variable that predetermines the selection of specific parcels of land, the level of farm fragmentation enters the model as a predetermined variable (that is, in a recursive manner).

In this model fragmentation has direct and indirect effects on yields. It affects yields indirectly through the choice of input levels and land improvements. It also affects yields directly in equation 1 as might arise, for example, from lost output caused by theft or animal destruction, or from additional output as a result of superior matching of soils and crop types.

Because equation 4 does not include the current values of \(Y_i, L_i,\) or \(I_i\), the model can be written in semi-reduced form. We are specifically interested in the semi-reduced form of the yield equation:

\[
(S) \quad Y_i = f(X_{li}, X_2, X_3, F_i = I_{to_n}).
\]

In this equation the farm fragmentation variable captures both the direct and indirect effects of fragmentation on yields.

Fragmentation is assumed to be predetermined before yields in the model. However, the estimated coefficient on the fragmentation variable in equation 5 will be biased if there are unobserved variables influencing both the level of fragmentation and current yields (for example, farmer skill). In order to overcome this difficulty, the appropriate estimation procedure is to first estimate equation 4 to obtain a fitted value for fragmentation \((\hat{F})\), and then to replace the actual values of farm fragmentation in equation 5 with the fitted values. This will give a consistent and unbiased estimate of both the direct and indirect effects of fragmentation on yield.

To estimate the fitted value for fragmentation, the following household-level model was used:

\[
(6) \quad F_j = b_1 Z_j + b_2 V_k + e_j
\]

where \(F_j\) is either the number of parcels or the Simpson index; \(Z_j\) is a vector of explanatory variables comprising the gender and formal education of the household head, whether the household head is migrant or native, the number of years the household head has farmed, inherited wealth, inherited farm size, and either the number of inherited parcels or the Simpson index measured on inherited
parcels; \( V_k \) is a binary variable indicating the location in the village \( k \); \( b_1 \) and \( b_2 \) are vectors of coefficients to be estimated; and \( e_i \) is an error term. Because the Simpson index is bounded by zero and one, it is necessary to use truncation models to estimate equation 6. This problem does not arise when using the number of parcels as the measure of fragmentation because it is an unbounded variable.

Although these regressions will produce fitted values of fragmentation that are uncorrelated with the error term of equation 5, their usefulness depends on their correlation with the observed values of fragmentation. Fortunately, the correlations between the fitted and actual values of fragmentation were greater than 0.5 in all regions, and the explanatory power of the regressions was high. The following variables are consistently significant in all the regressions: inherited farm size (negatively related to fragmentation), the fragmentation of the inherited holding (positively related to fragmentation), and locational variables (mixed signs). The first two lend some support to supply-side arguments for fragmentation, whereas the latter could reflect supply- or demand-side factors.

The semi-reduced-form yield equation to be estimated was specialized to the following exponential functional form for parcel \( i \) of household \( j \), located in village \( k \):

\[
\log Y_{ij} = \alpha V_k + \beta_1 \log X_{1ij} + \beta_2 \log X_{2ij} + \beta_3 F_j + \mu_j + \epsilon_{ij}
\]

where, in addition to previously defined variables, \( \mu_j \) is a household random effect satisfying \( E(\mu_j) = 0, E(\mu_j^2) = \sigma^2_{\mu} \), and is independent across households, and \( \epsilon_{ij} \) is an error term. A random effects specification is used to allow for unobserved household effects when combining data for several parcels from each household.1

Multiple crops are often produced on a single parcel, and the corresponding areas devoted to each crop are not known. In order to aggregate yields of different crops, median prices are used so that the dependent variable is the value of crop output per hectare. The inclusion of multiple crops presents an additional problem. Some of the independent variables may have different effects on yields, depending on the cropping pattern. One can allow for varying effects in two ways. The first is to make separate regressions for each cropping pattern. Unfortunately, this procedure gives relatively small sample sizes (so that controlling for unobservable household effects is problematic) and, by giving crop-specific coefficients for all the independent variables, makes it difficult to

1. Because fitted values are used for \( F_j \), these values will not be correlated with \( \mu_j \). However, it is possible that \( \mu_j \) might be correlated with other parcel or household-specific variables, in which case the coefficients on some of those variables would be biased. This problem can be mitigated by using a fixed rather than a random effects specification. However, because \( F_j \) would then have to be dropped from the equation (it takes on the same value for all parcels operated by the \( j \)th household), we could not use this approach. This means that caution is required in interpreting coefficients on variables other than \( F \) that might be thought of as choice variables.
Table 4. Selected Results from Parcel Yield Regressions for Three Regions in Ghana, 1987–88

<table>
<thead>
<tr>
<th>Variable</th>
<th>Estimate</th>
<th>t-statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anloga</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>0.056</td>
<td>2.02</td>
</tr>
<tr>
<td>Parcel size</td>
<td>-0.171</td>
<td>-5.48</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.112</td>
<td>0.87</td>
</tr>
<tr>
<td>Simpson index</td>
<td>0.771</td>
<td>1.13</td>
</tr>
<tr>
<td>(Number of parcels)α</td>
<td>(0.043)</td>
<td>(1.18)</td>
</tr>
<tr>
<td>F-value</td>
<td>2123.0***</td>
<td>n.a.</td>
</tr>
<tr>
<td>R²</td>
<td>0.91</td>
<td>n.a.</td>
</tr>
<tr>
<td><strong>Wassa</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance—cocoa</td>
<td>0.103</td>
<td>1.49</td>
</tr>
<tr>
<td>Distance—cocoa and maize</td>
<td>0.243</td>
<td>2.31</td>
</tr>
<tr>
<td>Distance—cocoa and plantain</td>
<td>0.232</td>
<td>1.59</td>
</tr>
<tr>
<td>Distance—cocoa and kola</td>
<td>0.033</td>
<td>0.25</td>
</tr>
<tr>
<td>Parcel size—cocoa</td>
<td>-0.370</td>
<td>-5.43</td>
</tr>
<tr>
<td>Parcel size—cocoa and maize</td>
<td>-0.798</td>
<td>-4.41</td>
</tr>
<tr>
<td>Parcel size—cocoa and plantain</td>
<td>-1.257</td>
<td>-4.35</td>
</tr>
<tr>
<td>Parcel size—cocoa and kola</td>
<td>-0.161</td>
<td>-0.80</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.100</td>
<td>0.52</td>
</tr>
<tr>
<td>Simpson index</td>
<td>1.038</td>
<td>0.74</td>
</tr>
<tr>
<td>(Number of parcels)α</td>
<td>(0.021)</td>
<td>(0.26)</td>
</tr>
<tr>
<td>F-value</td>
<td>365.0***</td>
<td>n.a.</td>
</tr>
<tr>
<td>R²</td>
<td>0.81</td>
<td>n.a.</td>
</tr>
<tr>
<td><strong>Ejura</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance—maize</td>
<td>-0.038</td>
<td>-0.40</td>
</tr>
<tr>
<td>Distance—yam</td>
<td>-0.407</td>
<td>-2.97</td>
</tr>
<tr>
<td>Distance—groundnuts</td>
<td>0.093</td>
<td>0.76</td>
</tr>
<tr>
<td>Parcel size—maize</td>
<td>-0.248</td>
<td>-3.08</td>
</tr>
<tr>
<td>Parcel size—yam</td>
<td>-0.341</td>
<td>-3.38</td>
</tr>
<tr>
<td>Parcel size—groundnuts</td>
<td>-0.371</td>
<td>-3.64</td>
</tr>
<tr>
<td>Farm size</td>
<td>0.202</td>
<td>1.31</td>
</tr>
<tr>
<td>Simpson index</td>
<td>0.271</td>
<td>0.55</td>
</tr>
<tr>
<td>(Number of parcels)α</td>
<td>(0.157)</td>
<td>(1.09)</td>
</tr>
<tr>
<td>F-value</td>
<td>627.0***</td>
<td>n.a.</td>
</tr>
<tr>
<td>R²</td>
<td>0.83</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

*** F-ratio that is significant at the 1 percent level.

n.a. Not applicable.

Note: Other variables included in the regression were characteristics related to parcel (cropping pattern, years since acquired, improvements made before acquisition); household (wealth per hectare, nonfarm income per capita, number of male equivalents per hectare); household head (gender, migrant status, occupation, farming experience, education); and location (village binary variables).

α. The reported coefficients were obtained using the Simpson index as the measure of fragmentation. Separate regressions were run using the number of plots as an alternative measure of fragmentation. Because the results did not change much, we have simply included the coefficients for the number of parcel variables in this row.

Source: Authors' calculations based on World Bank survey data.
summarize results for the fragmentation variables. If certain variables are not crop-specific, then a better method is to stack the separate cropping pattern yields into a single regression. Each crop-specific variable is then multiplied by its respective crop dummy variable. Distance to parcel, parcel size, and soil type are examples of crop-specific variables. Thus, our $X_{ij}$ vector in equation 7 is comprised of crop-specific and non-crop-specific variables. No household or farm variables were considered to be crop-specific.

V. The Results

The econometric model is used in this section to test whether fragmentation has a detrimental effect on land productivity. Specifically, our null hypothesis is that fragmentation is inefficient and reduces yields. Rejection of this hypothesis would not prove that fragmentation is demand-driven, because other factors may explain the lack of a negative relation between fragmentation and yield. But it would add credence to the demand-side explanation.

Ghana

In Anloga yield data are only available for shallot parcels, because other cropping patterns are rare. In Wassa there are enough observations for four cropping patterns: cocoa, cocoa and kola, plantain and cocoa, and maize and cocoa. In Ejura maize, yams, and groundnuts are included. Because each region produces distinct crops, there is no gain from combining them into a single regression; thus regressions are made separately for each region. Table 4 summarizes the key fragmentation results. The $R^2$s and the statistical significance of the regressions are good, yet neither the Simpson index nor the number of parcels (fitted values) has a significant effect on yields. Thus we reject the null hypothesis that fragmentation is inefficient.

The distance to parcel was significantly related to yield in a few cases. In Anloga the distance to parcel had a positive impact on parcel yields. An explanation for this counterintuitive finding is that the more fertile of two primary growing areas, and that which is more prone to flooding, is located farther from the villages. The distance to parcel was also positively related to yields in Wassa, although not all the coefficients are significant. One explanation for the outcome is that the farther parcels represent the more recently developed lands. As such they have not lost as many nutrients from continuous cultivation as have other parcels. In Anloga this explanation does not hold, because all the available arable land was used many years ago.

In Ejura the only significant result was that the distance to parcels monocropped with yams negatively affected yields. Because distances to parcels are quite long in Ejura, it is likely that this finding reflects the inefficient use of labor

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2. A similar lack of relationship was obtained when we used actual rather than fitted values of the Simpson index or the number of parcels.
Table 5. Selected Results from Parcel Yield Regressions for Three Prefectures in Rwanda, 1987–88

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pooled</th>
<th>Ruhengeri</th>
<th>Butare</th>
<th>Gitarama</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distance</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>−0.02</td>
<td>−0.03</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(0.63)</td>
<td>(0.66)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>0.05</td>
<td>—</td>
<td>0.10</td>
<td>−0.04</td>
</tr>
<tr>
<td></td>
<td>(1.74)</td>
<td></td>
<td>(2.05)</td>
<td>(0.94)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.05</td>
<td>—</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td></td>
<td>(1.54)</td>
<td></td>
<td>(1.37)</td>
<td>(1.16)</td>
</tr>
<tr>
<td>Sorghum and maize</td>
<td>−0.03</td>
<td>−</td>
<td>−</td>
<td>−0.06</td>
</tr>
<tr>
<td></td>
<td>(0.58)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sorghum and sweet potato</td>
<td>−0.02</td>
<td>—</td>
<td>0.03</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(0.36)</td>
<td></td>
<td>(0.41)</td>
<td></td>
</tr>
<tr>
<td>Sorghum and other</td>
<td>−0.09</td>
<td>—</td>
<td>−0.16</td>
<td>−0.08</td>
</tr>
<tr>
<td></td>
<td>(1.71)</td>
<td></td>
<td>(1.62)</td>
<td>(1.02)</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>0.04</td>
<td>0.02</td>
<td>0.02</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>(1.73)</td>
<td>(0.42)</td>
<td>(0.41)</td>
<td>(0.88)</td>
</tr>
<tr>
<td><strong>Parcel size</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>−0.40</td>
<td>−0.35</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(4.91)</td>
<td>(3.85)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>−0.30</td>
<td>—</td>
<td>−0.21</td>
<td>−0.40</td>
</tr>
<tr>
<td></td>
<td>(4.35)</td>
<td></td>
<td>(2.04)</td>
<td>(3.97)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>−0.42</td>
<td>—</td>
<td>−0.52</td>
<td>−0.43</td>
</tr>
<tr>
<td></td>
<td>(5.88)</td>
<td></td>
<td>(4.01)</td>
<td>(4.91)</td>
</tr>
<tr>
<td>Sorghum and maize</td>
<td>−0.50</td>
<td>−</td>
<td>−</td>
<td>−0.62</td>
</tr>
<tr>
<td></td>
<td>(4.12)</td>
<td></td>
<td>(4.16)</td>
<td></td>
</tr>
<tr>
<td>Sorghum and sweet potato</td>
<td>−0.31</td>
<td>—</td>
<td>−0.33</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>(2.85)</td>
<td></td>
<td>(2.48)</td>
<td></td>
</tr>
<tr>
<td>Sorghum and other</td>
<td>−0.47</td>
<td>−</td>
<td>−0.53</td>
<td>−0.34</td>
</tr>
<tr>
<td></td>
<td>(4.79)</td>
<td></td>
<td>(3.92)</td>
<td>(2.04)</td>
</tr>
<tr>
<td>Sweet potato</td>
<td>−0.42</td>
<td>−0.29</td>
<td>−0.32</td>
<td>−0.55</td>
</tr>
<tr>
<td></td>
<td>(8.19)</td>
<td>(2.71)</td>
<td>(3.30)</td>
<td>(6.28)</td>
</tr>
<tr>
<td><strong>Farm size</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>−0.03</td>
<td>−0.23</td>
<td>−0.10</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>(0.33)</td>
<td>(0.76)</td>
<td>(0.52)</td>
<td>(0.21)</td>
</tr>
<tr>
<td>Coffee</td>
<td>0.25</td>
<td>0.35</td>
<td>0.33</td>
<td>−0.03</td>
</tr>
<tr>
<td></td>
<td>(0.64)</td>
<td>(0.32)</td>
<td>(0.44)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>0.02</td>
<td>−0.01</td>
<td>0.03</td>
<td>−0.01</td>
</tr>
<tr>
<td></td>
<td>(0.74)</td>
<td>(0.09)</td>
<td>(0.56)</td>
<td>(0.04)</td>
</tr>
<tr>
<td>Simpson index</td>
<td>0.25</td>
<td>0.35</td>
<td>0.33</td>
<td>−0.03</td>
</tr>
<tr>
<td></td>
<td>(0.64)</td>
<td>(0.32)</td>
<td>(0.44)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Number of parcelsa</td>
<td>0.02</td>
<td>−0.01</td>
<td>0.03</td>
<td>−0.01</td>
</tr>
<tr>
<td></td>
<td>(0.74)</td>
<td>(0.09)</td>
<td>(0.56)</td>
<td>(0.04)</td>
</tr>
<tr>
<td><strong>F-value</strong></td>
<td>21.01***</td>
<td>8.26***</td>
<td>8.38***</td>
<td>8.23***</td>
</tr>
<tr>
<td><strong>R²</strong></td>
<td>0.56</td>
<td>0.53</td>
<td>0.60</td>
<td>0.68</td>
</tr>
</tbody>
</table>

— Not included in a particular regression.

*** F-ratio that is significant at the 1 percent level.

Note: Figures in parentheses are the absolute values of the t-statistics. Other variables included in the regression were characteristics related to parcel (cropping pattern, slope, topographical location, years since acquired, improvements made before acquisition); household (wealth per hectare, nonfarm income per capita, number of male equivalents per hectare); household head (gender, occupation, farming experience, education); and location (communal binary variables).

a. The reported coefficients were obtained using the Simpson index as the measure of fragmentation. Separate regressions were run using the number of plots as an alternative measure of fragmentation. Because the results did not change much, we have simply included the coefficients for the number of parcels variable in this row.

Source: Authors' calculations based on World Bank survey data.
and labor-intensive inputs on the more removed parcels. In all cases parcel size is negatively related to yield, again suggesting that problems in the labor market might be an important reason for fragmentation.

Rwanda

The analysis was confined to seven cropping patterns for which a sufficient number of parcel observations on output data were available: monocropped parcels of beans, sweet potatoes, sorghum, and coffee and sorghum multicropped with either maize, sweet potatoes, or other crops.

Table 5 summarizes the key fragmentation results for the pooled and individual prefecture-level regressions (many other variables were included in the regressions, and the full results are available from the authors). The regressions have relatively high $R^2$s and are statistically significant at the 1 percent confidence level. Nevertheless neither the Simpson index nor the number of parcels (fitted values) was significantly related to parcel yields in any of the regressions. Hence we again reject the hypothesis that fragmentation is inefficient.

While possible biases caution against undue reliance on some of the other coefficient estimates, farm size is not significantly related to yield in any of the regressions. The distance to parcel has a positive effect on yields for coffee in Butare and in the pooled sample. This probably indicates certain locational advantages—such as coffee parcels being located higher up the hillsides—rather than refuting the purely negative effect of distance on yields through inefficient use of labor and other inputs. Distance has a negative effect on yields of sorghum intercropped with "other" crops in the pooled regression, but the result is only weakly significant, and yields of other sorghum intercrops are not related to distance.

Parcel size is negatively associated with yield in all the regressions. To the extent that diseconomies in parcel size reflect problems in the labor market, these results add credence to the demand-side explanation for fragmentation.

VI. FRAGMENTATION AS A RISK MANAGEMENT AID

Our econometric results refute the hypothesis that fragmentation is inefficient and suggest, but do not prove, that the private benefits from fragmentation are at least as large as the private costs. Although comprehensive analysis of these costs and benefits would require a much more structural and micro-oriented analysis than the available data permit, we can at least test to see if fragmentation confers benefits by reducing risk through less variable output.

A Model of Farm Fragmentation and Risk Spreading

The risk-reducing benefits of fragmentation can be approximated by the reduction in the variance of farm income obtained from cultivating several diverse parcels. A useful model has variations from mean yield arising from fluctuations at the village level, the farmer level, and the parcel level.
Assume that a single crop is produced at a fixed price, which, for convenience, is normalized to unity. The yield for farmer \( h \) on parcel \( i \) in period \( t \) is given by

\[
Q_{hit} / A_i = (d_0 + \theta_i) + (g_h + \eta_{hit}) + (k_i + \gamma_{it})
\]

where \( Q_{hit} \) is the output of the \( i \)th parcel, \( A_i \) is the area of the \( i \)th parcel, \( d_0 \) is the village mean yield for all parcels, \( \theta_i \) is a random village-level effect, \( g_h \) is a fixed farmer effect, \( \eta_{hit} \) is a random (over time) farmer effect, \( k_i \) is a fixed parcel effect, and \( \gamma_{it} \) is a random (over time) parcel effect.

We assume that \( E(\theta, \eta_{hit}) = 0 \) and \( E(\theta, \gamma_{it}) = 0 \), for all \( i, h, t, t^* \) and that \( E(\eta_{hit}, \eta_{it}) = 0 \) and \( E(\gamma_{it}, \gamma_{it^*}) = 0 \), for all \( h \neq s, i \neq j, t, t^* \). Then, letting farmer \( h \)'s total area be \( A = \sum A_i \), total farm output is

\[
\sum_i Q_{hit} = (g_h + \eta_{hit} + d_0 + \theta_i) A + \sum_i A_i (k_i + \gamma_{it}).
\]

The mean output is

\[
E(\sum_i Q_{hit}) = (g_h + d_0) A + \sum_i A_i k_i
\]

and the variance is

\[
\text{Var}(\sum_i Q_{hit}) = A^2 (\text{var}(\eta_h) + \text{var}(\theta)) + \sum_i A_i^2 \text{var}(\gamma_i).
\]

Or, assuming the \( \gamma_i \) are identically distributed with \( \text{var}(\gamma) \),

\[
\text{Var}[(\sum_i Q_i)/A] = \text{var}(\theta) + \text{var}(\eta_h) + (\sum_i A_i^2 / A^2) \text{var}(\gamma).
\]

The coefficient on \( \text{var}(\gamma) \) is equal to \( 1 - S \), where \( S \) is the Simpson index. Thus in this model risk, as measured by the variance of total farm income per hectare, declines linearly as the Simpson index increases.

**Data and Estimation for Rwanda**

Our risk analysis requires time series data on crop production. Such data are available for Rwanda in the National Agricultural Survey (NAS), collected by the Service des Enquetes et des Statistiques Agricoles of the Ministry of Agriculture. Data were obtained for a representative national sample of 1,015 farms. The data combine the results of a detailed household survey for 1986 with aggregate farm output information for six growing seasons (two a year from the second half of 1985 to the first half of 1988). The 1986 cross-section data include information on land fragmentation as measured by the Simpson index; location by prefecture, commune, and village; and soil fertility classification.

Output information is available for a variety of crops at the farm level, but there is no information on yields or on the allocation of crops between parcels. Estimates of the benefits of diversification of output for individual crops are not feasible without implausible assumptions, such as unchanging land use. For this reason output information for the various crops was aggregated using 1986 price weights to form an index of total output.

Unfortunately, information on the output of coffee, groundnuts, and soybeans is not available. This omission is not very serious for groundnuts and soybeans. Coffee, however, is an important crop in many regions, and its exclu-
sion from the measure of total output has the potential to introduce significant biases. Therefore attention was concentrated on Ruhengeri prefecture, with 105 observations, for which coffee output is known from the land rights survey to be a small proportion of total output (less than 2 percent).

Without parcel-level information, equation 12 can be used as the basis for a linear regression. As with equation 5, this is a semi-reduced-form equation. The dependent variable is the variance of income per hectare, and the independent variable is equal to one minus the Simpson index. The intercept is an estimate of $\text{var}(\theta)$. The slope coefficient is an estimate of $\text{var}(\gamma)$. The error term is an estimate of $\text{var}(\varepsilon)$.

One problem in estimating equation 12 is that the fragmentation index may not have remained constant for all farms over the six growing seasons. Without time series data on fragmentation levels, little could be done to correct for any biases introduced by any changes. Fortunately, although short-term leasing and borrowing arrangements are quite common in Rwanda, the land rights study data do show that most parcels held on short-term arrangements are held by the same tenants for extended periods.

Preliminary analysis showed that variability of output was strongly associated with soil fertility in Ruhengeri. Somewhat surprisingly perhaps, output variability was higher for the more fertile soils. The Simpson index was also higher for farmers on the more fertile soils. As a result of this pattern, the raw correlation between the Simpson index and the degree of income variability is positive. If this correlation were (mis)interpreted as a coefficient estimate for equation 12, it would have the wrong sign.

The simplest way to correct for soil fertility is to include it as a separate regressor. The results are reported in the first row of table 6. The independent variable is the variance of income per hectare. The coefficient on fertility is positive and significant, and the coefficient on the Simpson index is negative but insignificant. It may be that because of possible simultaneity bias, the true effect of the Simpson index on variance is more significantly negative. A simultaneous system may exist because the level of fragmentation is observed during the

| Table 6. Regression Results for Risk Analysis for Ruhengeri Prefecture, Rwanda, 1985–88 |
|---------------------------------|------------------|-------------------|-------------|------------------|
| Adjusted sample                | Intercept        | Simpson index     | Soil fertility | $R^2$            |
| Complete data set              | -5.94            | -6.58             | 2.92          | 0.08             |
|                                | (1.21)           | (3.18)            |               |                  |
| Good fertility level           | 1.27             | -1.38             | n.a.          | 0.10             |
|                                | (2.55)           |                   |               |                  |
| Excellent fertility level      | 22.77            | -21.27            | n.a.          | 0.03             |
|                                | (1.41)           |                   |               |                  |

n.a. Not applicable.

Note: Figures in parentheses are the absolute value of the $t$-statistics.

Source: Authors' calculations based on World Bank survey data.
period in which the variance of yield is calculated. The bias is upward because the farmer's choice of level of fragmentation would be a positive function of the variance (for example, an increase in variance would cause farmers to raise their levels of fragmentation). The proportion of total variation explained by the regression variables is small, but this is only to be expected in a model of this kind.

The equation could be expanded to a more comprehensive treatment of soil fertility by including dummy intercept and slope shifters for the different soil types. It is simpler, however, to adopt the equivalent procedure of estimating the regression in equation 12 separately for the different subsets of the data. Three different fertility levels were represented in the Ruhengeri prefecture. However, there were only 12 farms with the lowest fertility level, so results are reported only for the farms with good or excellent fertility levels. In both cases the Simpson index has the correct sign, but it is statistically significant only for the good soils. The estimated coefficient for the farms with excellent fertility is much higher, but the standard error is also very large.

VII. Conclusions

This article has shown that, although farm fragmentation is a pervasive feature of Ghanaian and Rwandan agriculture, it does not seem to have any adverse impact on the productivity of land. Many of the costs generally attributed to fragmentation (for example, travel time) are positively related to the distance between farmers' residences and their parcels. But most parcels are located within surprisingly short distances of the house, and, although fragmentation is positively (though rarely significantly) associated with increases in the average distance, the amount of travel time required is still only a matter of minutes. At the same time fragmentation increases the diversity of agroclimatic conditions available to the farmer, and this leads to more diversified cropping patterns. This can be beneficial for risk reduction, reducing peaks and troughs in labor demand and enhancing household food security.

The major implication of these findings is that, other things being equal, land consolidation policies are unlikely to increase land productivity significantly. Fragmentation is not as inefficient as widely assumed, and it offers farmers a tool for managing risk, seasonal labor shortages, and food insecurity when other alternatives might be more costly. A prime suspect for the lack of efficient alternatives is the inefficiency of many rural credit, labor, and food markets. While rigorous confirmation of these links would require more structural and micro analysis than the available data permit, policymakers could do worse than to focus their attention on improving the functioning of these markets and to avoid interventions in land markets (for example, restrictions on sales and rentals) that limit the ability of farmers to adjust optimally the extent of fragmentation (or consolidation) of their holdings over time.
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Project Evaluation and Uncertainty in Practice:
A Statistical Analysis of Rate-of-Return Divergences of 1,015 World Bank Projects

Gerhard Pohl and Dubravko Mihaljek

This article analyzes the World Bank's experience with project evaluation for a sample of 1,015 projects by comparing estimated rates of return at appraisal with reestimated rates of return when construction works are completed, usually 5 to 10 years after appraisal. The analysis highlights the high degree of uncertainty in project analysis. A wide range of variables has been introduced to explain the observed divergence in appraisal and reestimated rates of return, but only a relatively small part of the divergence can be explained, even with the benefit of hindsight. Project analysis thus has to cope with a large degree of uncertainty, which the traditional methods of project evaluation and selection have not been able to reduce.

The World Bank's long history of project financing provides a unique opportunity to quantify the level of uncertainty in public sector investment projects in developing countries and to assess the effects of cost-benefit analysis on investment decisions. For projects whose costs and benefits are reasonably amenable to quantification, Bank staff calculate economic rates of return at appraisal and again at project completion (after construction works have been completed and the project begins normal operations). For more than 1,000 projects, economic rate of return estimates now are available for both appraisal and completion. The difference between these two estimates provides an interesting empirical measure of the uncertainty of development projects financed by the World Bank.

Cost-benefit analysis is a standard appraisal tool for selecting development projects at the World Bank and other development finance institutions. Several governments also have adopted these techniques in planning public investment projects. The World Bank broadly follows the Little-Mirrlees (1968, 1974) methodology, which expanded earlier approaches to cost-benefit analysis to take

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account of economic distortions typically prevailing in developing countries. Squire and van der Tak (1975) refined the methodology further to take account of income distribution effects, as did Reutlinger (1970) to take account of uncertainty. More recent generalizations and refinements of the theory of cost-benefit analysis are reviewed, for example, in Drèze and Stern (1987) and Squire (1989).

The theory of cost-benefit analysis provides a rigorous conceptual framework in which to evaluate public expenditure programs and investment projects (Little and Mirrlees 1991). Practical applications, however, depart quite substantially from these ideals because some of the key parameters are difficult to estimate in practice. In theory, for example, net discounted benefits at the accounting rate of interest would be the appropriate criterion to decide whether to carry out a particular project in the Little-Mirrlees framework. In practice it is quite difficult to estimate the accounting rate of interest reasonably accurately. Equating the accounting rate of interest with the (highest) rate that just exhausts available investment funds, as suggested early on by Little and Mirrlees, is conceptually clear and simple, but few, if any, developing countries have a comprehensive ranking of available public investment opportunities. Returns on past public sector investments may be misleading due to poor investment decisions or inappropriate economic policies. Project proposals by sectoral agencies, however, may be padded with optimistic assumptions and imply an exaggerated rate of return.

Since public sector and economywide rate-of-return estimates vary considerably across countries (depending on endowments and, more important, on policies), the Bank uses the internal rate of return calculated at shadow prices or, for short, the economic rate of return as an important, but not exclusive, decision criterion. With few exceptions the World Bank finances only projects that have an estimated economic rate of return of at least 10 percent at appraisal (in constant prices).

Of course projects financed by the World Bank are not necessarily representative of public sector investments in developing countries. Projects submitted by governments for Bank financing may primarily include projects with above-average rates of return and below-average risks. This may be particularly true in large countries (such as India), where Bank-financed projects represent only a very small part of the public investment program.

Although a considerable degree of uncertainty is to be expected in implementing development projects, the extent of revealed uncertainty in World Bank projects is striking. Estimates of economic rates of return at appraisal (\(AERR\)) are relatively poor predictors of reestimated rates of return at completion of construction works (\(RERR\)). Figure 1, in which each point represents rates of return for one project, shows this relation—most of the points in the figure are below the 45 degree line, that is, most projects have economic rates of return lower at completion than at appraisal.

The reestimated rates of return are not true ex-post rates of return because
Figure 1. Relation between Appraisal and Reestimated Rates of Return

Reestimated rate of return

Appraisal rate of return

Note: Projects with appraisal or reestimated economic rates of return greater than 40 percent (about 8 percent of all projects) have been omitted for greater clarity.

Source: Authors' calculations.

they are made at the start-up of normal operations. In view of the long life of most investment projects, ex-post estimates can be made only after 10 or more years. However, when the reestimated rates are calculated, the effect of a number of risks already is known (such as investment costs, construction delays, and initial operating performance), and later costs and benefits are more heavily discounted. Because of the long life of most investment projects, the relation between ex-post rates of return and reestimated rates at completion of construction may be as loose as the relation between appraisal and reestimated rates of return.

This article analyzes the differences between appraisal and reestimated rates of return with statistical techniques and provides some initial interpretation of the results. The statistical analysis can capture only factors that are measurable and are applicable to all types of projects. This approach can provide only an
overview and cannot substitute for project performance audits at the project level. The rate of return of a copper project, for example, will depend strongly on whether actual copper price developments fulfill appraisal expectations. The closest our analysis gets to this is through inclusion of a composite real commodity price index on projects in broad sectors (for example, agriculture).

As discussed in the next two sections, the nature of our data set poses several challenges for statistical analysis. Two most serious ones are the heteroskedasticity of residuals and the censoring of reestimated rates of return. To avoid these problems, we have transformed the dependent and explanatory variables in such a way that the error term is constant, and we have used the maximum likelihood estimation technique within the Tobit regression framework. Tests performed confirm the validity of this approach and therefore give additional weight to our results.

I. The Data

This analysis is based largely on a data base maintained by the Bank's Operations Evaluation Department (OED), an independent unit reporting directly to the Executive Directors. The complete data set includes 2,200 projects for which project completion reports had been issued during 1974-87 by the respective project departments for audit by the OED on a sample basis. For slightly more than half of these projects, economic rates of return have been calculated by the staff at appraisal and project completion (start-up of normal operations). For the remainder of the projects in the data base (such as technical assistance and structural adjustment loans), economic rates of return were not available, primarily because quantification was deemed infeasible or unjustified. A few projects were excluded because other key variables were missing from the data set, or because other supplementary data were not available. The analysis thus was carried out with a final sample of 1,015 projects for which a complete data set was available. The sample selection is fairly objective and does not appear to bias the results. The only systematic omission is financial intermediation projects, which finance numerous small- and medium-scale industrial and agricultural projects. A similar analysis could, in principle, be carried out for financial intermediation projects, but would involve considerable effort to collect data.

The OED data base was augmented by supplementary variables that were believed to be important explanatory factors of project success, including the Bank's internal ranking of economic management performance by country as of 1978, a country-specific index of price distortions for the 1970s (Agarwala 1983), real commodity price movements, per capita income, and adult literacy rates. The price distortion index was available for 31 countries accounting for 612 projects. A separate analysis was undertaken for this smaller sample. Sec- toral and regional dummy variables were introduced as proxies for project characteristics and management performance.
Table 1. Summary Statistics for 1,015 World Bank Projects

<table>
<thead>
<tr>
<th>Economic rate of return (percent)</th>
<th>Mean</th>
<th>Median</th>
<th>Maximum</th>
<th>Minimum</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>At appraisal</td>
<td>22</td>
<td>18</td>
<td>158</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>At project completion</td>
<td>16</td>
<td>14</td>
<td>128</td>
<td>-20</td>
<td>13</td>
</tr>
<tr>
<td>Total project cost (US dollar millions, current prices)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At appraisal</td>
<td>86</td>
<td>34</td>
<td>3,193</td>
<td>1</td>
<td>185</td>
</tr>
<tr>
<td>At project completion</td>
<td>102</td>
<td>40</td>
<td>4,045</td>
<td>1</td>
<td>233</td>
</tr>
<tr>
<td>Nominal cost overrun (percent)</td>
<td>22</td>
<td>10</td>
<td>514</td>
<td>-89</td>
<td>46</td>
</tr>
<tr>
<td>Unexpected inflation (percent)</td>
<td>20</td>
<td>23</td>
<td>38</td>
<td>-2</td>
<td>7</td>
</tr>
<tr>
<td>Real cost overrun (percent)</td>
<td>-6</td>
<td>-11</td>
<td>394</td>
<td>-91</td>
<td>34</td>
</tr>
<tr>
<td>Time overrun (years)</td>
<td>2</td>
<td>2</td>
<td>16</td>
<td>-4</td>
<td>2</td>
</tr>
<tr>
<td>Time overrun (percent)</td>
<td>58</td>
<td>46</td>
<td>405</td>
<td>-68</td>
<td>56</td>
</tr>
</tbody>
</table>

Note: Project completion refers to start-up of normal operations.
Source: Authors' calculations.

Table 1 presents the main descriptive statistics for the data set and shows the wide variety of projects. Economic rates of return are derived, as explained above, as real internal rates of return at economic (shadow) prices. Project costs in the data base are in nominal U.S. dollars and range from about $1 million to more than $4 billion. Forty percent of the projects are in agriculture, 30 percent in transport, 20 percent in energy, and the rest in industry and urban development. The larger part of the Bank's industrial lending is intermediated through financial institutions. Unfortunately, average rates of return on financial intermediation lending are not systematically available.

Except for construction costs, the medians are fairly close to the averages for the data set. Constant-dollar cost data are not recorded in the data base, although they are available in the project files and have been used to calculate the economic rates of return. Rather than sifting through 1,015 voluminous project files, we have estimated implicit real costs from forecast and actual price developments as well as from other implementation data in the data base (see the appendix).

There is considerable variation in the appraisal rates of return, ranging from only 1 percent for a water supply project in Bombay to 158 percent for a seed project in India (which had a reestimated rate of return at project completion of only 11 percent). The wide range of rates of return both at appraisal and project completion (-20 to 128 percent) is perhaps surprising. In the more orderly world of economic theory and model-building, one usually assumes that rates of return converge within a fairly narrow range. Ninety percent of all projects have appraisal rates of return in the range of 10–40 percent, but only about half have reestimated rates of return within this range, which highlights the importance of uncertainty. The average rate of return of World Bank projects has behaved in a
more orderly way, averaging 22 percent at appraisal and 16 percent at project completion, with fairly small differences from year to year.

For about 5 percent of all projects the reestimated (internal) rates of return are negative. For many projects with negative rates of return these are given as −5 percent in the data base, presumably because negative internal rates are highly sensitive to small differences in assumptions and to truncation of the time horizon. The economic interpretation of negative internal rates of return in most cases is a zero rate of return (no increase in output for some large investment). Only if variable costs exceeded benefits (both at shadow prices) would one normally speak of “negative” rates of return, which typically would be due to domestic price distortions (negative value added at international prices).

Although the average reestimated rates of return are satisfactory (16 percent, versus 22 percent at appraisal), there are many projects with low returns (25 percent of all projects have reestimated rates of return below 10 percent, 14 percent have below 5 percent, and 8 percent of all projects have zero or negative rates of return). This suggests that considerable benefits could be obtained if the factors that lead to project failure could be identified. Defining project failure is not a simple matter. Some cutoff point for rates of return has to be adopted to distinguish successful from unsuccessful projects. In the Little-Mirrlees framework, that cutoff point would be relatively high (say 10 percent) due to the choice of the numeraire (“uncommitted public income,” as opposed to consumption in the UNIDO methodology; see Dasgupta, Marglin, and Sen 1972 and Ray 1984).

World Bank projects have, on average, taken considerably more time to implement (six years) than expected at appraisal (four years), and project costs in U.S. dollars were, on average, 22 percent higher than estimated at appraisal, despite ample physical and price contingencies built into project cost estimates. Project cost overruns and implementation delays thus could be important factors in explaining project performance and the loose relationship between rate-of-return estimates at appraisal and project completion.

With the help of the derived real project costs, the reported nominal cost overruns were decomposed into two parts: unexpected changes in the general price level for capital goods and project-specific real cost increases. The latter could be due to an error in project cost estimates, unforeseen difficulties and expenditures, or increases in the scope of projects. Nominal cost overruns mostly are explained by unexpectedly high inflation during the period (primarily the 1970s), with actual prices being 20 percent higher than projected at appraisal. Perhaps surprisingly, the appraisal cost estimates were, on average, too high in real terms. Nominal cost overruns thus are primarily due to unexpectedly high inflation. Real cost variations range from −90 percent (probably largely due to cancellations of project components) to increases of nearly 400 percent (probably reflecting expansion in the scope of projects, rather than faulty cost calculations).
II. STATISTICAL METHODOLOGY

The divergence between the appraisal and reestimated rates of return has been analyzed with two types of linear regression; the results from both types of regression are reported in section III. The first consists of regressing the reestimated rates of return at project completion on the appraisal rates of return and several other factors that are thought to influence project performance. Since both the appraisal and reestimated rates of return depend on the same set of other factors, this approach is best interpreted in terms of a "seemingly unrelated regression" model. (See Zellner [1962] for the original contribution; and Wallace, Duane, and Nawaz [1987] for an application similar to this article.)

One statistical problem with the standard ordinary least squares (OLS) estimation of this linear regression model is that residuals calculated from the above data set do not have uniform variance and zero correlation with one another. In the presence of heteroskedasticity the OLS estimator remains unbiased, but it no longer has minimum variance among all linear unbiased estimators. Also the usual formula for the variance-covariance matrix of OLS estimators is incorrect, and therefore the usual estimator of their variance is biased, implying that interval estimation and hypothesis testing using these estimators no longer can be trusted. Intuitively, one would expect larger time and cost overruns to be associated with larger discrepancies in the rates of return. For a wide range of projects the standard deviation of reestimated rates of return increases only moderately with appraisal rates of return (from 9 percentage points for projects with AERRS of 10-20 percent to 14 percentage points for projects with AERRS of 30-40 percent), but it jumps to 25 percentage points for a small number of projects with higher AERRS.

Several techniques exist to correct the standard errors of estimates (White 1980). We eliminate the problem by transforming the variables in such a way that the error term is constant. Thus in the second type of regression model the dependent variable is the percentage change in the reestimated rate over the appraisal rate of return \([\frac{(RERR - AERR)}{AERR}]\). This transformation eliminates heteroskedasticity, but at the cost of losing interesting information about the relation between the appraisal and reestimated rates of return. A third approach (not undertaken here) would be to eliminate projects with very high appraisal rates of return, because these may have an extraordinarily strong influence over the results. High AERRS often are due to major changes in expectations and usually involve comparatively small investments (for example, energy conservation, resource discoveries, and technological breakthroughs).

Besides heteroskedasticity, the nature of our data set gives rise to another statistical problem: censoring of reestimated rates of return. From table 1 it appears that the range of variation of reestimated rates of return is wide enough to make plausible the assumption of an approximately normal distribution of residuals. However, there is a considerable piling up (about 7 percent of proj-
ects) of RERRS at a cutoff point of $-5\%$ percent. This reflects the established practice in the World Bank whereby a project deemed to be a complete failure usually is assigned a $-5\%$ rate of return at completion.\(^1\)

From an econometric point of view, the presence of the cutoff point implies that we are dealing with a censored sample, as some observations of the RERR that correspond to known values of time and cost overruns are not observable, being instead arbitrarily assigned the RERR of $-5\%$. The difficulty with OLS estimation based on censored data samples is that the least squares estimators of regression parameters are biased and inconsistent, using either the entire sample or the subsample of complete observations. (For analysis of censored data samples see, for example, Maddala [1983] or Judge and others [1985].) These kind of data are best analyzed within the framework of the censored regression model, also known as the Tobit model (Tobin 1958). A number of techniques now exist to estimate Tobit models (see Amemiya 1984). To generate more efficient parameter estimates, we used the maximum likelihood technique, which yields estimators with several desirable asymptotic properties (see, for example, Greene 1990).

The Tobit regression model for our data sample is of the form:

\[
y_i = \begin{cases} x_i'\beta + e_i & \text{if } y_i > k, \\ 0 & \text{otherwise} \end{cases} i = 1, \ldots, T - s
\]

and the corresponding regression function is given by:

\[
E(y_i|x_i, y_i > k) = x_i'\beta + \sigma e_i,
\]

where $y$ is a vector of dependent variables (RERRs or percentage changes thereof over the AERRS), $X$ is a matrix of explanatory variables, $\beta$ is a vector of unknown regression parameters, $\sigma$ is an unknown scale parameter, $e$ and $e$ are vectors of errors assumed to come from the standard normal distribution, $k$ is the cutoff point ($-5\%$ percent for regressions where RERR is the dependent variable and $-1$ for regressions where the dependent variable is $(\text{RERR} - \text{AERR})/\text{AERR}$), and $s$ observations out of $T$ are unobservable.\(^2\)

1. Another such practice is that projects with appraisal rates of return of less than $10\%$ usually are not considered for approval. Theoretically, in the presence of this cutoff point the data set would be truncated: values of time and cost overruns and RERRS would be known only when AERRS at or above $10\%$ were observed, so we could make no inference on the potential performance of projects that were not accepted for financing. However, in the data set there are 46 projects (4.5 percent of the total) that were approved even though they had AERRS of less than $10\%$, so information on normally "unobservable" projects actually is not missing.

2. The log likelihood function for this regression model is given by:

\[
\ln L = -(n_1/2)[\ln(2\pi) + \ln\sigma^2] - (1/2\sigma^2)\Sigma(y_i - \beta' x_i)^2 + \Sigma \ln[1 - \Phi(\beta' x_i/\sigma)]
\]

where $\Phi(\cdot)$ is the standard normal cumulative distribution function. The first two parts of this function correspond to the classical regression for noncensored observations; the last part corresponds to the relevant probabilities for the censored observations (see Amemiya 1973). MLE estimates of this regression model were computed using the LIFEREG procedure of the SAS statistical package, version 6.06.
III. THE MODELS AND ESTIMATION RESULTS

In the simplest model the reestimated economic rate of return is the dependent variable, and the appraisal economic rate of return is the explanatory variable. Additional models are presented with explanatory variables for cost overruns, implementation delays, and unexpected inflation. These explanatory variables are also used in alternative models with a transformed dependent variable. Two of the initial five models are estimated with additional explanatory variables to account for changes in primary commodity prices, economic management factors, and sectoral and geographic differences.

Five Initial Models

The simplest possible model relates only appraisal and reestimated rates of return and assumes that no other factors have been identified. Thus equation 3 represents model 1:

\[ RERR = a + b \cdot AERR + \sigma u. \]

Models 2 and 3 expand on model 1 to include project cost overruns and implementation delays, which are intuitively linked with poor project performance. Model 2 introduces two variables from the database: the nominal cost overrun and the time overrun, both in percent. Model 3 introduces two variables that decompose the nominal cost overrun into two components: unexpected inflation and real cost overruns.

Equation 4 gives the format for regressions with the transformed dependent variable \( (RERR - AERR)/AERR \) and the transformed explanatory variables \( (X_t - X_{t-1})/X_{t-1} \):

\[ (RERR - AERR)/AERR = a + b' \left[ (X_t - X_{t-1})/X_{t-1} \right] + \sigma u \]

where \( t \) denotes the relevant observation at the time of completion (of construction) and \( t - 1 \) the appraisal estimate of that same variable.

Maximum likelihood parameter estimates for models 1 through 5 are given in table 2, with summary statistics obtained from the OLS estimates of the regressions. Normal scale parameter \( \sigma \) does not have an intuitive economic interpretation, so its estimates are not reported. In all regressions where the dependent variable is \( RERR \), the estimates of \( \sigma \) are on the order of about 12 percentage points and are statistically highly significant.

Model 1. The results for model 1 indicate that economic rates of return reestimated at project completion are, on average, considerably lower than appraisal estimates \( (b = 0.44) \). The intercept is quite large \((5.88 \text{ percentage points})\), indicating that reestimated rates of return are somewhat higher, relative to appraisal estimates, for projects with low appraisal rates of return. A project with an appraisal rate of return of 10 percent has a reestimated rate of return approximately equal to its appraisal rate of return \((5.88 + 0.44 \times 10)\), whereas
Table 2. Maximum Likelihood Estimates for the Initial Five Models

<table>
<thead>
<tr>
<th>Explanatory variables and regression statistics</th>
<th>Reestimated economic rate of return</th>
<th>Change in reestimated economic rate of return relative to the appraisal economic rate of return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependent variable</td>
<td>Model 1</td>
<td>Model 2</td>
</tr>
<tr>
<td>Intercept</td>
<td>5.88 (0.76)</td>
<td>5.25 (0.88)</td>
</tr>
<tr>
<td>Appraisal rate of return</td>
<td>0.44 (0.03)</td>
<td>0.44 (0.03)</td>
</tr>
<tr>
<td>Nominal cost overrun</td>
<td>n.a. (0.009)*</td>
<td>0.003 (0.03)</td>
</tr>
<tr>
<td>Time overrun</td>
<td>n.a. (0.007)*</td>
<td>0.012 (0.03)</td>
</tr>
<tr>
<td>Unexpected inflation</td>
<td>n.a. (0.007)*</td>
<td>0.23 (0.06)</td>
</tr>
<tr>
<td>Real cost overrun</td>
<td>n.a. (0.01)*</td>
<td>0.01 (0.06)</td>
</tr>
<tr>
<td>Regression statistics (OLS)</td>
<td>0.19 n.a.</td>
<td>0.19 n.a.</td>
</tr>
<tr>
<td>Adjusted R^2</td>
<td>0.19 n.a.</td>
<td>0.19 n.a.</td>
</tr>
<tr>
<td>F-statistic</td>
<td>240 20</td>
<td>80 20</td>
</tr>
<tr>
<td>Chi-square statistic</td>
<td>13.1b (9.2)</td>
<td>26.8b (21.7)</td>
</tr>
<tr>
<td>(critical value for 1 percent level)</td>
<td>(13.1b (9.2)</td>
<td>(26.8b (21.7)</td>
</tr>
<tr>
<td>F-test of the regression</td>
<td>n.a. 7</td>
<td>5.0c</td>
</tr>
</tbody>
</table>

Note: Sample size is 1,015 for all five models. Values in parentheses are the standard errors.

a. Not significant at the 5 percent level.
b. Presence of heteroskedasticity at the 1 percent level of significance.
c. Regression fit improved with respect to model 1.
d. Regression fit improved with respect to model 4.

Source: Authors' calculations.

A project with an appraisal rate of return of 30 percent has, on average, a reestimated rate of return of 19 percent (5.88 + 0.44 × 30). As indicated by the low values of standard errors of estimates, both the intercept and the parameter estimate for $\text{AERR}$ are statistically highly significant. However, the appraisal rate of return explains only 19 percent of the variance, which indicates a rather loose relation between rate of return estimates at appraisal and completion of construction, already shown in figure 1.

Model 2. In model 2 parameter estimates for nominal cost overrun and time overrun are small and statistically insignificant, thus indicating that nominal cost overruns and implementation delays do not seem to be major factors in explaining divergences in the rates of return.

Model 3. In model 3 the real cost overrun parameter remains low and statistically insignificant, while the unexpected inflation variable is statistically significant. Since unexpected price increases have been expressed as negative numbers
(reduction in the real value of available project resources), the parameter estimate implies that for projects with (the average) unexpected increase in the price level of 20 percent, rates of return have been reduced by 4.6 percentage points. The results seem to suggest that real increases in project cost have had no systematic effect on rates of return of World Bank projects. Unexpected inflationary pressures have adversely affected the performance of Bank projects, perhaps because of relative price changes between capital-good inputs and project outputs.

Regression of model 3 also yields a statistically significant estimate of the time overrun variable, which, surprisingly, has the wrong sign. If, for example, it takes an average project 58 percent more time to be completed than forecasted at appraisal, one can expect that this would improve the \( \text{RERR} \) by about 0.7 percentage points. According to this result, the systematic bias toward underestimating the time needed for project completion may be based on the wrong intuitive assumption that long periods of implementation are bad for project performance. However, the modest positive effect that time overruns have on project performance must be weighted against the much bigger negative cost effects stemming from unexpected inflation.

Only the introduction of the decomposed cost overrun variables in model 3 improves the regression fit compared with model 1, as shown by the F-test for additional regressors. But the adjusted coefficient of determination (\( R^2 \)) improves by only one percentage point (from 19 to 20 percent). The chi-square statistic for the White test (see White 1980) indicates the presence of heteroskedasticity at the 1 percent test level.

Model 4. In model 4, which has the transformed dependent and explanatory variables, the estimated regressions have no heteroskedasticity at the 1 percent test level. However, the nominal cost and time overrun parameters are not statistically significant, and the estimated parameters have the wrong sign.

Model 5. In model 5 the decomposition of nominal cost overruns into unexpected inflation and real cost overruns helps somewhat, because the parameter estimate for the unexpected inflation variable now is statistically significant and has the expected (positive) sign (faster than expected inflation is a negative number). An unexpected price increase of 20 percent (the average for the sample) would thus give rise to a 73 percent discrepancy in the rates of return. However, although model 5 significantly improves the otherwise poor fit of model 4, the total explained variance of only 3 percent remains surprisingly low.

Project-specific real cost overruns thus do not seem to affect ex-post rates of return as adversely as one would expect. This may be due to the possibility that projects with large real cost overruns (up to almost 400 percent) reflect mostly expansions of projects, rather than errors in cost estimates. To the extent that project expansions lead to efficiency gains, one would expect improvements in the rate of return from such mislabeled “real cost overruns.”
### Table 3. Maximum Likelihood Estimates for the Expanded Models

<table>
<thead>
<tr>
<th>Explanatory variables and regression statistics</th>
<th>Reestimated economic rate of return</th>
<th>Change in reestimated economic rate of return relative to the appraisal economic rate of return</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Model 3A</td>
<td>Model 3B</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.96</td>
<td>-11.47</td>
</tr>
<tr>
<td>(2.72)a</td>
<td>(5.77)</td>
<td>(0.001)a</td>
</tr>
<tr>
<td>Appraisal rate of return</td>
<td>0.46</td>
<td>0.46</td>
</tr>
<tr>
<td>(0.03)</td>
<td>(0.04)</td>
<td>(n.a.)</td>
</tr>
<tr>
<td>Time overrun</td>
<td>0.015</td>
<td>0.01</td>
</tr>
<tr>
<td>(0.007)</td>
<td>(0.009)b</td>
<td>(0.009)b</td>
</tr>
<tr>
<td>Unexpected inflation</td>
<td>0.19</td>
<td>0.15</td>
</tr>
<tr>
<td>(0.06)</td>
<td>(0.08)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Real cost overrun</td>
<td>0.006</td>
<td>0.003</td>
</tr>
<tr>
<td>(0.01)a</td>
<td>(0.01)a</td>
<td>(0.01)a</td>
</tr>
<tr>
<td>Unexpected change in commodity prices</td>
<td>8.19</td>
<td>9.49</td>
</tr>
<tr>
<td>(2.35)</td>
<td>(3.04)</td>
<td>(3.0)</td>
</tr>
<tr>
<td>Economic management ratings</td>
<td>n.a.</td>
<td>0.42</td>
</tr>
<tr>
<td>(0.36)a</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Agarwala price distortion index</td>
<td>n.a.</td>
<td>n.a.</td>
</tr>
<tr>
<td>(n.a.)</td>
<td>n.a.</td>
<td>(1.40)</td>
</tr>
<tr>
<td>Log(GNP)</td>
<td>n.a.</td>
<td>1.84</td>
</tr>
<tr>
<td>(0.88)</td>
<td>(0.80)</td>
<td>(n.a.)</td>
</tr>
<tr>
<td>Adult literacy</td>
<td>n.a.</td>
<td>-0.06</td>
</tr>
<tr>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(n.a.)</td>
</tr>
<tr>
<td>Regression statistics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(OLS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted $R^2$</td>
<td>0.214</td>
<td>0.23</td>
</tr>
<tr>
<td>$F$-statistic</td>
<td>34.9</td>
<td>n.a.</td>
</tr>
<tr>
<td>Chi-square statistic</td>
<td>63.7f</td>
<td>n.a.</td>
</tr>
<tr>
<td>(Critical value for 1 percent level)</td>
<td>(37.6)</td>
<td>n.a.</td>
</tr>
<tr>
<td>$F$-test of the regression</td>
<td>6.8f</td>
<td>4.5h</td>
</tr>
<tr>
<td>Sample size</td>
<td>1,015</td>
<td>612</td>
</tr>
</tbody>
</table>

Note: Values in parentheses are the standard errors.

a. Not significant at the 5 percent level.

b. Not significant at the 5 percent level, but significant at the 10 percent level.

c. As of 1978, on a scale of 1 to 10; lowest actual rating is 2.

d. Ranges from 1.14 for Malawi (lowest distortion) to 2.86 for Ghana (highest distortion).

e. Presence of heteroskedasticity at the 1 percent test level.

f. Regression fit improved with respect to model 3.

g. Regression fit improved with respect to model 5.

h. Regression fit improved with respect to model 3A, adjusted for sample size.

i. Regression fit improved with respect to model 5A, adjusted for sample size.

Source: Authors' calculations.
Changes in Primary Commodity Prices

Since about 40 percent of the projects in the sample are agricultural projects, unexpected changes in commodity prices might explain a substantial part of the gap in the rates of return. We have chosen the ratio of the Bank’s real commodity price index for 33 primary commodities (excluding energy) at project completion to the same index at the time of project appraisal as a measure of the extent of unexpected commodity price changes during project implementation. This measure is based on an adaptive expectations model of price expectations at the World Bank (see the appendix). Since the Bank’s real commodity price index is deflated by the index of unit value of manufactured exports (MUV) of industrial countries, collinearity between the unexpected commodity price changes variable and the other price variables has been eliminated.

Table 3 gives the results of regressions of models 3 and 5 with this additional explanatory variable in the columns labeled model 3A and model 5A. The estimate for the unexpected commodity price changes variable is statistically significant, and its inclusion improves the fit of the regression, as measured by the $F$-test, with respect to models 3 and 5. The explained variance ($R^2$) increases by about 1.5 percentage points, which is quite respectable compared to regressions with other variables, but the unexplained variance nevertheless remains very large.

The unexpected commodity price changes are measured as an index number, so no change corresponds to the index value of 1.0, and a 10 percent change corresponds to the index value of 1.1 or 0.9. The parameter estimates imply that an unexpected decline in commodity prices by 10 percent would reduce the rate of return by 0.8 percentage points [$8.19 \times (1.0-0.9)]$ in model 3A, or 12 percent ($118.95 \times 0.1$) in model 5A. In model 5A the high estimated values of the intercept term (−161) and the commodity price parameter (119) actually must be set against each other for the zero expected price change to give, approximately, the intercept term from model 5 (−41). The same would hold true of model 3A if the intercept estimate was statistically significant.

A similar analysis was carried out for agricultural projects, using a real agricultural commodity price index, and the results were analogous. The use of individual commodity price indexes (such as a coffee price index for coffee projects) probably would show the greater sensitivity of some types of projects to specific commodity price changes, but the number of observations is too small to permit much further disaggregation. Also many agricultural projects are multi-purpose projects (for example, irrigation) for which the broad commodity price index may be more useful.

Economic Management Factors

A second set of factors that could help explain some of the divergence in rate-of-return estimates between the appraisal and completion of construction are the country-specific factors, such as the human resource endowment, the type of
economic policies pursued by the government, and the efficiency of public administration. Of course these are complex factors that are not easily measurable. We have to make do with a few quantitative indicators, such as adult literacy, per capita income, an index of price distortions for the 1970s (Agarwala 1983), and the Bank's internal ranking of the quality of government economic policies and management (as of 1978, taken as representative for the 1970s).

These factors should have been taken into account by project evaluators and factored into the appraisal estimate of the rate of return and, more important, into project design (for example, the extent of project management services provided by expatriates, which is one way of ensuring the success of the project). The parameter estimates for these variables thus need to be interpreted as the degree to which project evaluators did not sufficiently take account of these factors. In all cases it can be reasonably assumed that project evaluators were aware of these country-specific factors at the time of appraisal. Only in the case of the Agarwala price-distortion index could one possibly argue that there is some benefit of hindsight at work, because the extent of price distortions and their negative consequences may not have been fully appreciated. But Agarwala's index is based mostly on relatively easily available economic data that (at least in their raw form) were already available at appraisal. Moreover the Bank's internal rating of economic management performance is fairly closely related to the price distortion index (the coefficient of correlation between the two ratings is -0.67).

The results of regressions with country-specific variables added (models 3B, 3C, 5B, and 5C) are shown in table 3. The implementation delay and decomposed cost-overrun variables from models 3A and 5A have been retained. The Bank's economic management rating is an explanatory variable in models 3B and 5B; the Agarwala price distortion index is in models 3C and 5C. Most of the new variables are statistically significant.

The Agarwala price-distortion index performs statistically considerably better than the Bank's rating of economic management performance. This is surprising, since the latter is based on the same economic data plus management's judgments based on qualitative insights. Apparently the relatively simplistic procedure of adding up price distortions works better than a careful review process using qualitative judgments. In all model specifications, replacing the economic performance rating with the price distortion index results in statistically significant parameter estimates, a higher \( R^2 \), and considerably higher values of F-tests for inclusion of the new regressors. For the actual range of the price distortion index (from 1.14 to 2.86), the parameter estimates imply a 9.4 \( \left[\frac{2.86 - 1.14}{2.86 - 1.14} \times (-5.48)\right] \) percentage points (model 3C) lower \( \text{RERR} \) in a country with high price distortions (such as Ghana during the 1970s), compared with a country with low price distortions (such as Malawi). The adverse effects on project performance of government interventions through price controls, high tariffs, import restrictions, and so forth thus have been considerably underestimated in World Bank project appraisals.
Poor economic management and price distortions explain only about 2 percent of the rate-of-return gap, however, inching the total explained variance (model 3C) to only 24 percent. The level of income and adult literacy variables have been introduced as (albeit crude) indicators of the human capital stock, and their parameter estimates are statistically significant. Thus if per capita income decreases from $1,000 to $500, ex-post rates of return are lower by about 1.4 percentage points (model 3C), or about 11 percent (model 5C). This suggests that the Bank's project evaluators have tended to overestimate project implementation capabilities in the poorest countries. Surprisingly, the parameter estimate for the adult literacy variable has the wrong sign, indicating that reestimated rates of return are lower in countries with higher adult literacy rates (for similar projects and levels of income). This can be explained by the fact that countries with high rates of literacy tend to engage in projects involving more sophisticated technology, which brings higher rates of return, but at higher risk, so that the rate-of-return discrepancy also is greater.

Sectoral and Geographic Differences

There are several ways to analyze the differences between the various types of projects. One is to introduce dummy (0,1) variables comparing different groups of projects. Another approach would be to run the same set of regressions on different sectoral or geographic subsets of projects to see whether there are statistically significant differences in parameter estimates. Table 4 presents estimates of regressions with both sectoral and regional dummy variables added to models 3B and 5B, now labeled 3D and 5D, respectively. Although it would have been preferable to use models 3C and 5C instead of 3B and 5B (because the Agarwala index performs better), this would have limited the sample to only 31 countries and 612 projects, instead of the entire sample of 1,015 projects. Agriculture and South Asia were selected as the standard to which other sectors and regions are compared, so parameter estimates for sectoral and regional dummy variables indicate how, for example, the energy projects or projects in the Mediterranean region perform relative to agricultural projects in South Asia.

The explanatory power of both regressions increases considerably after dummy variables are introduced (from an adjusted $R^2$ of 0.21 to 0.31 for model 3D and from 0.03 to 0.12 for model 5D). These variables thus contribute more to the improved regression fit than all the previously introduced variables together (except for the appraisal rate of return in models 1 to 3). There thus appear to be clusters of projects with similar characteristics and problems.

Parameter estimates for sectoral dummy variables show that projects in our data sample fall roughly into two categories. Since the estimates for the intercept (that is, agriculture), energy, and industry all are insignificant, the results of model 3D indicate that, other things being equal, projects with an appraisal rate

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3. Calculated as $2.06 (\ln 1,000 - \ln 500) = 1.43$; and $15.66 (\ln 1,000 - \ln 500) = 10.85$, respectively.
Table 4. *Regressions with Sectoral and Regional Dummy Variables*

<table>
<thead>
<tr>
<th>Explanatory variables and regression statistics</th>
<th>Reestimated economic rate of return</th>
<th>Model 3D</th>
<th>Model 5D</th>
<th>Change in reestimated economic rate of return relative to the appraisal economic rate of return</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explanatory variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>0.45±</td>
<td>-175.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Appraisal rate of return</td>
<td>0.43</td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time overrun</td>
<td>-0.007±</td>
<td>-0.07±</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unexpected inflation</td>
<td>0.12</td>
<td>2.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real cost overrun</td>
<td>0.006±</td>
<td>0.12±</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unexpected change in commodity prices</td>
<td>6.45</td>
<td>90.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Economic management rating</td>
<td>0.83±</td>
<td>6.53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Log(GNP)</td>
<td>-0.50±</td>
<td>11.94±</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adult literacy</td>
<td>-0.04±b</td>
<td>-0.73</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sectoral dummy variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td>0.96±</td>
<td>27.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>7.62</td>
<td>63.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industry</td>
<td>-0.88±</td>
<td>-29.51b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>9.51</td>
<td>-8.55±a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional dummy variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Africa</td>
<td>-12.54</td>
<td>-94.82</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFA countries</td>
<td>-8.02</td>
<td>-52.88</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other West Africa</td>
<td>-9.92</td>
<td>-96.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Asia</td>
<td>-3.64</td>
<td>-24.24a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mediterranean</td>
<td>-6.92</td>
<td>-62.33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latin America</td>
<td>-7.11</td>
<td>-63.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regression statistics (ols)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>0.309</td>
<td>0.121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-test of the regression</td>
<td>13.6±c</td>
<td>8.1±d</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

n.a. Not applicable.

Note: Sample size 1,015 projects for both models.

a. Not significant at the 5 percent level.
b. Not significant at the 5 percent level, but significant at the 10 percent level.
c. Regression fit improved with respect to model 3B.
d. Regression fit improved with respect to model 5B.

Source: Authors' calculations.

of return of, say, 20 percent that are undertaken in these three sectors are expected to have a RERR of about 9 percent \((20 \times 0.43)\), or 11 percentage points below the estimate. However, transport projects are expected to have a RERR about 4 percentage points below the estimate \((7.62 + [20 \times 0.43])\), and urban development projects about 2 percentage points below the estimate \((9.51 + [20 \times 0.43])\). This pattern is roughly confirmed by the results of model 5D, where the greatest rate-of-return discrepancy is for industry, there is less discrepancy for agriculture and energy projects, and transport projects again have the lowest discrepancy in economic rates of return. (Correct interpretation of the figures in
Table 4 is more complicated, though, because we neglected the term \( \sigma \) \text{\[equation 2\]}; the scale parameter for model 3D is 11.4, and for model 5D it is 113.

Reestimated rates of return for projects in the transport and urban development sectors thus are generally closer to the appraisal rates of return than are projects in agriculture, energy, and industry. This pattern probably reflects two factors: the relatively simple technology and organization of transport and urban development projects compared with industrial and energy projects and the effect of international markets on industrial and agricultural projects. Projects producing traded goods seem to be exposed to a higher degree of downside risks, and this may be related to international competition (that is, competitors in other countries may be more productive, and this may lead to lower prices for outputs and sharply lower returns).

Parameter estimates for regional dummy variables all have a negative sign, implying that reestimated rates of return are highest in South Asia (the standard of comparison), followed by the projects in East Asia, with slightly lower (3.6 percent) rates of return. Projects in Latin America, the Mediterranean, and Francophone Africa (CFA) are next on the list, while projects in East and West Africa (other than the CFA zone) have performed particularly poorly. The better performance of CFA members compared with other African countries points to the importance of the institutional framework and, in particular, the conservative monetary policies. The project implementation performance in CFA member countries during the 1960s and 1970s is comparable with the average of developing countries in the Mediterranean and Latin America.

An analysis of failed projects indicates that out of 80 total project failures (that is, negative rates of return at project completion), 27 are in East Africa, with Tanzania alone accounting for 11. Failed projects are concentrated largely in agriculture, as nearly two-thirds of all project failures worldwide have been agricultural projects, particularly complex new-style area or rural development projects started in the mid-1970s (table 5). Agricultural projects in Sub-Saharan Africa have an unacceptable failure rate, with one-half of all projects in East Africa and more than one quarter of all projects in West Africa yielding reestimated rates of return below 5 percent. There is a strong distinction in West Africa between CFA members and other countries.

A more informative approach to the analysis of the regional performance of projects is to run regressions for each sector separately (table 6). Compared with the combined sample (table 4), the disaggregated regressions by sector have fewer statistically significant parameters, and parameter estimates for some variables are very different from sector to sector. For the appraisal rate of return, the parameter estimates are relatively high for infrastructure projects (0.61–0.67) and low for agricultural and industrial projects (0.21–0.25). Thus downside risks are larger (or have been underestimated) in the directly productive sectors. Unexpected movements in primary commodities (excluding energy) seem to have affected industrial projects even more than agricultural projects (most of the industrial projects in the sample are import-substituting raw materials projects, such as in the fertilizer industry).
### Table 5. Project Failures by Region and Sector

<table>
<thead>
<tr>
<th>Region</th>
<th>Projects 10 percent</th>
<th>Projects 5 percent</th>
<th>Projects 0 percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>All projects</td>
<td>25.2</td>
<td>13.6</td>
<td>7.9</td>
</tr>
<tr>
<td>East Africa</td>
<td>41.1</td>
<td>27.9</td>
<td>17.1</td>
</tr>
<tr>
<td>West Africa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFA member countries</td>
<td>21.8</td>
<td>18.2</td>
<td>10.0</td>
</tr>
<tr>
<td>Other West Africa</td>
<td>37.5</td>
<td>19.6</td>
<td>16.1</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>29.1</td>
<td>14.3</td>
<td>7.4</td>
</tr>
<tr>
<td>Latin America</td>
<td>25.1</td>
<td>10.2</td>
<td>5.1</td>
</tr>
<tr>
<td>South Asia</td>
<td>14.7</td>
<td>6.4</td>
<td>1.1</td>
</tr>
<tr>
<td>East Asia</td>
<td>12.5</td>
<td>5.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Agricultural projects</td>
<td>29.0</td>
<td>19.8</td>
<td>12.7</td>
</tr>
<tr>
<td>East Africa</td>
<td>61.4</td>
<td>52.9</td>
<td>37.1</td>
</tr>
<tr>
<td>CFA members</td>
<td>34.0</td>
<td>26.0</td>
<td>16.0</td>
</tr>
<tr>
<td>Other West Africa</td>
<td>45.8</td>
<td>33.3</td>
<td>29.0</td>
</tr>
</tbody>
</table>

*Source: Authors' calculations.*

### Table 6. Regressions by Sector

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>Agriculture</th>
<th>Energy</th>
<th>Transport</th>
<th>Industry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.66</td>
<td>10.26</td>
<td>7.36</td>
<td>-15.55</td>
</tr>
<tr>
<td>Appraisal rate of return</td>
<td>0.21</td>
<td>0.61</td>
<td>0.67</td>
<td>0.25</td>
</tr>
<tr>
<td>Time overrun</td>
<td>-0.02a</td>
<td>0.002a</td>
<td>-0.01a</td>
<td>-0.02a</td>
</tr>
<tr>
<td>Unexpected inflation</td>
<td>0.11a</td>
<td>0.29</td>
<td>0.11a</td>
<td>-0.05a</td>
</tr>
<tr>
<td>Real cost overrun</td>
<td>0.03</td>
<td>-0.02a</td>
<td>-0.01a</td>
<td>-0.04</td>
</tr>
<tr>
<td>Unexpected change in commodity</td>
<td>11.12</td>
<td>1.92b</td>
<td>4.36a</td>
<td>15.72</td>
</tr>
<tr>
<td>Economic management rating</td>
<td>0.61a</td>
<td>1.17</td>
<td>0.52a</td>
<td>-1.72</td>
</tr>
<tr>
<td>Log(GNP)</td>
<td>0.82a</td>
<td>-1.21a</td>
<td>0.62a</td>
<td>2.35a</td>
</tr>
<tr>
<td>Adult literacy</td>
<td>-0.09</td>
<td>0.03a</td>
<td>-0.03a</td>
<td>0.10b</td>
</tr>
<tr>
<td>Regional dummy variable</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Africa</td>
<td>-18.18</td>
<td>-5.09</td>
<td>-12.83</td>
<td>-14.06</td>
</tr>
<tr>
<td>CFA countries</td>
<td>-12.64</td>
<td>2.91a</td>
<td>-10.38</td>
<td>n.a.</td>
</tr>
<tr>
<td>Other West Africa</td>
<td>-17.37</td>
<td>-7.89</td>
<td>-6.33b</td>
<td>n.a.</td>
</tr>
<tr>
<td>East Asia</td>
<td>-3.29b</td>
<td>-4.42b</td>
<td>-7.65</td>
<td>5.24b</td>
</tr>
<tr>
<td>Mediterranean</td>
<td>-6.34</td>
<td>-7.46</td>
<td>-7.38b</td>
<td>-4.11a</td>
</tr>
<tr>
<td>Latin America</td>
<td>-8.34</td>
<td>-6.76</td>
<td>-6.97b</td>
<td>-2.81a</td>
</tr>
</tbody>
</table>

*Regression statistics (OLS)*

| Adjusted $R^2$                  | 0.25        | 0.30   | 0.32      | 0.33     |
| Adjusted $R^2$ without regional | 0.11        | 0.29   | 0.29      | 0.03     |
| dummies                         |            |        |           |          |
| Sample size                     | 411         | 216    | 310       | 56       |

*a.* Not significant at the 5 percent level.

*b.* Not significant at the 5 percent level, but significant at the 10 percent level.

*Source: Authors' calculations.*
Unexpected inflation seems to have affected particularly the more capital-intensive infrastructure projects but may also reflect delayed adjustments in government price regulations in the electric power sector, where the Bank's methodology does not conform to the principles of cost-benefit analysis. The economic management rating also shows some perplexing sectoral differences, with a negative parameter estimate for industrial projects, which may be the consequence of a few conspicuous project failures in countries with high performance ratings. A separate analysis for agricultural projects showed that the Agarwala price distortion index performs dramatically better than the economic performance ranking in that sector.

IV. Trends over Time

An analysis of appraisal and reestimated rates of return by year of approval shows that the gap in the rate of return has increased considerably over time (figure 2). Projects appraised in the 1960s showed little difference between average rates of return at appraisal and completion, and annual variations were tracked quite closely. Appraisal and reestimated rates of return started to diverge in the early 1970s. The main cause appears to have been the increasing optimism

Figure 2. Rates of Return by Year of Approval, 1961-80

Source: Authors' calculations.
of project evaluators, with average appraisal rates of return rising from about 16 percent for projects evaluated in the mid-1960s to 20-25 percent for projects evaluated in the mid- and late 1970s. By contrast, average rates of return at project completion showed a persistent downtrend for projects appraised during 1970-76 before recovering again for projects appraised around 1980 (and evaluated in 1985-87).

The downtrend in average reestimated rates of return for projects appraised in the early 1970s was most likely due to external circumstances, that is, the recession and low commodity prices at the time these projects were completed in the late 1970s and early 1980s. The increasing rates of return at appraisal during the 1970s probably reflect internal Bank factors, including the shift in Bank lending from infrastructure to agriculture and industry. In terms of average outcomes at project completion, the vastly expanded lending program of the 1970s does not compare too unfavorably. Reestimated rates of return for the 1970s are not very different from those for the 1960s. The sharp increase in reestimated returns for projects appraised in 1980 must be interpreted with caution, because it includes only a small percentage of projects of that appraisal year.

V. Conclusions

The statistical analysis of rates of return estimates before and after completion of project construction provides several interesting insights. First, it points to the large degree of uncertainty surrounding the rate-of-return estimates. Second, World Bank appraisal estimates of rates of return are biased, that is, too optimistic. If this degree of optimism is shared by other project evaluators, one should expect that the discount rate that just rations investment projects to the funds available exceeds the ex-post rate of return by a considerable margin. The analytical treatment of project risks thus deserves more attention in practice. Anderson and Quiggin (1990), for example, argue that project implementation variables usually enter project analysis on a “no surprises” basis, corresponding to the modal value of the distribution of possible outcomes. Since surprises are mostly unpleasant, the probability distribution of project implementation outcomes is skewed (a longer tail in the downside direction). If one were to allow for the skewed distribution (“bad surprises”), one could correct the bias in the estimate.

However, factors that have conventionally been associated with this bias (such as cost overruns and implementation delays) seem to explain only a very small part of the unexpected changes in project performance (measured by the rate of return gap). Interestingly, uncertainties seem to be higher in the directly productive sectors (such as agriculture and industry), where rates of return can be altered through external market forces or domestic policy shocks. Rate-of-return estimates seem to be more stable for infrastructure projects.

As an alternative to correcting modal estimates of implementation variables
for "bad surprises," one could set different minimum rate-of-return criteria for different types of project (for example, 10 percent for transport, but 15 percent for agricultural and industrial projects), based on observed divergences in rates of return.

The analysis also has pointed to the importance of the policy environment for successful project implementation. The economic management rating and price distortion variables both indicate that project evaluators did not take the adverse effects of poor economic policies at the macroeconomic level sufficiently into account. More puzzling though, is the fact that regional dummy variables also seem to operate partly as economic management variables and have considerably more explanatory power than direct indicators of the quality of economic management and institutions.

The fact that projects in CFA member countries seem to perform almost as well as those in other regions shows that the high failure rate of projects elsewhere in Sub-Saharan Africa seems to be related primarily to policies and institutions. However, the better performance of projects in CFA countries during the 1960s and the 1970s is no guarantee that this will be repeated during the 1980s, because the external competitiveness of the CFA zone has considerably deteriorated.

The analysis of observed rate-of-return divergences raises more questions than it can answer. The high degree of revealed uncertainty also raises the question whether, and what kind of, improvements in the methodology will contribute to better investment decisions.

Appendix. Derivation of Project Data in Constant Prices

Project cost estimates for World Bank projects are made in current U.S. dollars, since this is the unit of account for the Bank. Appraisal estimates for a project are made on the basis of prevailing prices at the time of appraisal; a forecast of price changes for internationally traded capital goods (in terms of U.S. dollars), and the projected expenditure (disbursement) profile. Project cost estimates also include a physical contingency for unexpected expenditures. Project costs at project completion are, similarly, the sum of annual expenditures in (actual) current prices ("mixed year dollars").

In periods of unexpectedly high inflation (or for projects with significant implementation delays) reestimated nominal project costs sometimes are substantially higher than appraisal estimates, but real project costs may not have increased at all. To separate nominal from real cost overruns, we derived real (constant price) cost estimates for each project for both appraisal and project completion, by deflating yearly project expenditures with the projected and actual price index for capital goods (the Bank's manufactured unit value (MUV) index for exports of manufactured goods of industrial countries).

Although forecasts for the MUV index were available for the past 10 years, we did not have earlier forecasts and had to estimate the price contingency vectors.
Visual inspection of price forecasts for the past 10 years suggested that the Bank’s price forecasts followed a pattern of “adaptive expectations”: projections seemed to be based on recent price trends. Several adaptive expectations models were tested, and we found that the projections were best approximated by a five-year moving average adaptive expectations model.

The first stage prediction of the MUV index was made by calculating the five-year moving average:

\[ \text{MUV}' = \frac{\text{MUV}_{t-1} + \ldots + \text{MUV}_{t-5}}{5} \]

The moving average values (MUV') were then used to calculate the average deviation from the actual value of the index (MUV' - MUV)/MUV, and this estimate was used as a correction parameter, \( \beta \), in the adaptive expectations model:

\[ \text{MUV}^*_t = \text{MUV}'_{t-1} + \beta (\text{MUV}_{t-1} - \text{MUV}'_{t-1}), \quad 0 < \beta < 1. \]

That is, the forecasting error for the previous period, \( \text{MUV}_{t-1} - \text{MUV}'_{t-1} \), is corrected with a fraction \( \beta \) (the average error), thereby improving upon (“adapting to”) the first-stage forecast.

The real cost at appraisal price projections, \( p^a \), is then:

\[ X^a(p^a) = \sum_{j=1}^{p^c} \frac{c^a_j}{p^a_j} \]

where \( X^a \) is real cost at appraisal, \( t^a \) is projected duration of project implementation, \( c^a \) is nominal cost estimate at appraisal, and \( p^a_j \) is projected price vector at appraisal. The real cost at actual prices is

\[ X^c(p^c) = \sum_{j=1}^{p^c} \frac{c^c_j}{p^c_j} \]

where \( X^c \) is real cost based on actual nominal expenditures \( (c^c) \), actual implementation duration \( (t^c) \), and actual prices \( (p^c) \).

The real cost overrun is then \( [X^c(p^c) - X^a(p^c)]/X^a(p^c) \), and the unexpected inflation, as defined in the article is \( [X^a(p^c) - X^a(p^a)]/X^a(p^a) \). Unexpectedly high inflation \( (p^c > p^a) \) is a negative number according to this definition. This is reflected in the minus sign before the percentage sign in the tables with the statistical results.

**References**

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The Business Cycle Associated with Exchange Rate-Based Stabilizations

Miguel A. Kiguel and Nissan Liviatan

This article examines the effects of disinflation on economic activity in countries characterized by chronic inflation. Such countries have a long history of inflation at rates exceeding those in industrial countries as well as labor and capital markets that have adjusted to function in an inflationary environment. A sample of disinflation programs in several Latin American countries and in Israel demonstrates that stabilization efforts in countries with chronic inflation often do not induce the usual Phillips curve tradeoff in the medium run. Specifically, stabilization programs that use the exchange rate as the main nominal anchor are often associated with a business cycle that begins with a boom and ends with a recession. Stabilization programs that use money supply as the nominal anchor generally induce the expected Phillips curve result: lower inflation is accompanied by a recession after the program is implemented.

This article examines the effects of disinflation on economic activity in countries characterized by chronic inflation, a term coined by Pazos (1972). In these countries there is a long history of inflation at rates exceeding those in industrial countries, and labor and capital markets have adjusted to function in an inflationary environment.

It is generally believed that stabilization programs aimed at stopping inflation involve an initial cost in loss of output because of rigidities in past nominal contracts (as in Fischer 1988 and Taylor 1979) or because of credibility problems. The costs of disinflation are therefore borne in the early stages of stabilization and fall later as the link with the past is severed and credibility is restored. This classical scenario of an initial recession followed by resumption of normal activity is indeed observed when low or moderate inflations are stopped. The best known recent examples from industrial countries are the stabilization policies in the United Kingdom and the United States in the early 1980s, whereas among developing countries Costa Rica (1982–83) and the Philippines (1983–84) had two recent programs. (For other examples, see Cline and Weintraub

Miguel A. Kiguel and Nissan Liviatan are both with the Country Economics Department at the World Bank. The authors are grateful to Michael Bruno, Guillermo Calvo, Vittorio Corbo, Allan Drazen, and Carlos Vegh for useful comments and discussions and thank Jariya Charoenwattana for research assistance.

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In all of these episodes inflation fell gradually but persistently, and once the objective of reducing inflation was achieved, economic activity recovered, usually reaching prestabilization levels.

The classical recessionary scenario is also observed in chronic inflation economies that implemented orthodox stabilization programs, which used money as the nominal anchor (money-based stabilizations or MBS). A good example is the monetarist Chilean program of 1974-75, in which tightened monetary and fiscal policies led to a deep recession. Likewise attempts in 1990 to bring down inflation in Argentina, Brazil, and Peru through a monetary crunch led to a fall in economic activity. These programs were not very successful in achieving significant and sustainable reductions in inflation.

The experience with stopping hyperinflations is different. As Sargent (1982), Dornbusch and Fischer (1986), and Sachs (1986) among others document, hyperinflations have been stopped quickly and with relatively small costs. These were orthodox stabilization programs, which relied on tight fiscal policy; stabilization of, or in some cases fixing, the exchange rate; and no use of price controls. Although new evidence suggests that these programs were recessionary (for example, Wicker 1986), the induced recessions were less severe than those resulting from programs aimed at eliminating moderate inflation.

In this study we show that the relation between disinflation and output assumes an entirely different form in chronic inflation countries that used the exchange rate as the nominal anchor (we shall refer to it as exchange rate-based stabilization or ERBS). These countries experienced a small (or no) recession initially, quickly followed by reductions in inflation, which were accompanied by expanding output above the historical trend and falling unemployment. The expansionary phase sometimes lasted for several years before ending in a recession. In most of these programs inflation was reduced gradually, and hence the programs did not achieve the spectacular results achieved in ending hyperinflations. The main exceptions were the heterodox programs, in which rapid reductions in inflation were achieved by combining the use of the exchange rate as the nominal anchor with price and wage controls.

Given the differences in the outcomes of ERBS programs aimed at stopping hyperinflations and chronic inflation, it is difficult to argue that the effect on output is primarily due to the exchange rate policy as such. The view taken here is that the business cycle observed in ERBS in chronic inflation countries results from the combination of using the exchange rate as the anchor and the lack of credibility in the program's success. The perception of the program as temporary induces a boom in demand in anticipation of a collapse, which raises the level of economic activity following implementation of the ERBS. It will be argued that an expected collapse of a MBS does not generate the same expansionary response.

There are several differences between hyperinflationary and chronic inflation economies, which lead to differences in the credibility of disinflation policy. In hyperinflations the stabilization program is credible because the inflation pro-
cess is explosive and agents realize that there is no alternative to immediate stabilization. In addition in hyperinflations it is easy to identify the change of policy regime, which occurs when the money financing of extremely large fiscal deficits is ended. Finally, hyperinflation in Europe and Bolivia occurred in traditionally low-inflation economies where price stability was considered the normal state of affairs, which made stabilization more credible. Chronic inflation economies, in contrast, have developed a highly sophisticated ability to live with inflation, which makes stabilization postponable and therefore less credible. Also accelerations of inflation in these economies are more difficult to diagnose; in particular they are quite often unrelated (directly) to fiscal causes. Uncertainty about the causes of inflation tends to reduce credibility in stabilization policies. Finally, a long tradition of failed stabilizations in most chronic inflation economies makes any new attempt rather dubious. (These considerations are discussed in greater detail in Kiguel and Liviatan 1988.)

The article is organized as follows. Section I develops a simple analytical framework that shows that 

MBs

and 

ERBS

programs are likely to have different outcomes. After briefly examining 

MBs

programs, section II discusses the main stylized facts concerning the business cycles in the 

ERBs.

Section III elaborates on the reasons for the differences in the outcomes of 

ERBss

and 

MBSs,

and section IV concludes with some policy issues.

I. DIFFERENCES BETWEEN MONEY-BASED

AND EXCHANGE RATE-BASED STABILIZATIONS

The possibility that disinflation programs that use money as the nominal anchor lead to different outcomes than those that use the exchange rate was raised by Rodriguez (1982, 1984), Fischer (1986), Helpman and Razin (1987), and Calvo and Vegh (1990) among others. Rodriguez (1984) develops a useful framework that produces the type of asymmetry in output cycles observed in the programs analyzed here. As in the work of Fischer, the results largely depend on the existence of inflationary rigidities (or price stickiness). The basic model assumes two goods: tradables and nontradables. The price of tradables is determined according to purchasing power parity, whereas the price inflation of nontradables is determined by expectations of future inflation and the excess demand prevailing in that market. Rigidities in the inflation process are introduced through the assumption of adaptive expectations. Finally, it is assumed that there is perfect capital mobility (in the sense that the interest rate parity condition holds), whereas the expected rate of depreciation is determined by the expected rate of inflation in nontradables and by the difference between the actual and the long-run equilibrium real exchange rate.

Under these conditions the real interest rate, \( r \), is given by

\[
(1) \quad r = i - \pi^e = i^* + \beta(e^e - \pi^e_k) + k
\]

where \( i \) is the nominal domestic interest rate, \( \pi^e \) is the expected rate of inflation,
\( i^* \) is the foreign interest rate, \( \beta \) is the weight of nontradables in the price index, \( \epsilon^e \) is the expected rate of devaluation, \( \pi^e_N \) is the expected rate of inflation in nontradables, and \( k \) is a constant risk factor. When the official rate of devaluation (\( \epsilon \)) is reduced, expectations on the devaluation rate will follow closely if the policy is credible. However, when inflationary expectations on nontradables exhibit downward rigidity (relative to \( \epsilon \)), the fall in the expected devaluation rate will depress the real interest rate, thereby stimulating demand.

Within this framework Rodriguez (1984) shows that a disinflation policy based on reducing the rate of growth of the money supply results in a real appreciation, increased real interest rates, reduced domestic absorption (that is, recessionary pressure), and an improved trade balance. Alternatively, a disinflation program based on reducing the rate of devaluation of the exchange rate, as in Rodriguez (1982), results in a reduced real interest rate and an appreciated real exchange rate (the latter effect resulting from price stickiness). Although the impact on aggregate excess demand is in principle ambiguous (because the changes in the real exchange rate and the real interest rate exert pressures in opposite directions), Rodriguez shows that initially the interest rate effect dominates. Eventually, the real appreciation effect dominates and eliminates excess demand. If the Rodriguez model is modified appropriately, the cycle in demand will be associated with corresponding cycles in output and the trade balance.

In Fischer (1986, 1988), where price stickiness results from staggered, long-term nominal wage contracts in a setting of rational expectations, the author arrives at conclusions similar to those in Rodriguez (1984) with respect to the recessionary effects of \( \text{MBS} \) programs. He also points out that \( \text{ERBS} \) programs can have an initial expansionary effect because of the falling real interest rate. On the basis of numerical simulations, however, he concludes that in \( \text{ERBS} \) programs the more likely outcome is the recessionary scenario.

As will be argued later, agents' perception of a stabilization program as temporary (the credibility problem) can introduce a difference between the output patterns in the two policies. This difference is likely to arise if agents shift expenditures to the present in anticipation of a failure of the \( \text{ERBS} \) that will be associated with a balance of payments crisis. However, a failure of a \( \text{MBS} \) does not lead to intertemporal expenditure switching because the central bank does not commit its reserves to support the exchange rate (so there is no anticipation of a balance of payments crisis).

These arguments provide a basis for expectations of an asymmetry in the adjustment of the economy under monetary and exchange rate rules. These issues will be discussed in more detail after the empirical evidence on stabilization programs under both rules has been reviewed.

II. Empirical Evidence on the Business Cycle in Exchange Rate-Based Stabilizations

This section presents the stylized features associated with \( \text{ERBS} \). As a background the outcomes associated with \( \text{MBS} \) are discussed.
Money-Based Stabilizations

The outcomes of MBS programs are well documented for industrial countries. Two recent programs are those of the United States under Volcker (see Dornbusch and Fischer 1987) and the United Kingdom under Thatcher (see Sargent 1986). Spain implemented a lesser known money-based program in the late 1970s. Examples of money-based programs in chronic inflation countries that will be referenced here are the 1958 program in Argentina under Frondizi, the Chilean program of 1974–75, the initial phase of the Argentine program under Martinez de Hoz in 1976–77 (all described in Kiguel and Liviatan 1988), and three programs launched in 1990 in Argentina, Brazil, and Peru aimed at stopping hyperinflation.¹

The monetarist phase of these programs consisted of a sharp tightening in monetary policy, although in most cases, and certainly in all of the Latin American experiences, the target rate of monetary growth was not explicitly announced. In two cases—Chile and Argentina in the mid-1970s—the monetary tightening was part of an initial stage of an anti-inflation process, and the programs later on switched to ERBS. This change in strategy has not yet materialized in the very recent stabilization attempts in Brazil and Peru but has already taken place in the Cavallo stabilization in Argentina in 1991.

As is well known, MBS programs are recessionary in industrial countries. A tightening of monetary policy in the United States and the United Kingdom in the late 1970s and early 1980s brought down inflation, but at the cost of higher unemployment and lower output growth. It is not difficult to find other money-based programs in industrial countries with similar outcomes. The disinflation program in Spain in 1977–80, for example, also induced a recession; a sharp contraction in monetary growth led to a drop in inflation and growth in gross domestic product (GDP) as well as an increase in unemployment during the first two years of the program.

The recessionary effect of money-based programs is also observed in chronic inflation countries. For example, the fiscal MBS programs of Argentina of the late 1950s and the Argentine and Chilean programs of the mid-1970s had a clear recessionary effect on domestic output and employment (especially in Chile). In the more recent (1990) programs in Argentina, Brazil, and Peru, where tight money was a central part of the stabilization effort, the initial reduction in inflation (from hyperinflation levels) was associated with a deepening of the prevailing recessionary trend. In the programs in which the exchange rate was allowed to float, the recessionary impact was accompanied by an increase in real interest rates and a real appreciation as predicted by theory (in Brazil the real appreciation was observed in the parallel (free) exchange rate) and in most cases by an improvement in the trade balance. Chile of the mid-1970s is the one case where the MBS did not lead to real appreciation, although this is perhaps ex-

¹. The recent programs in Argentina, Brazil, and Peru are not yet discussed in published form, but basic facts are available from the authors upon request.
explained by the fact that the exchange rate was sharply devalued to offset a severe deterioration in the terms of trade.

**Exchange Rate-Based Stabilizations**

This study concentrates on ERBS programs in chronic inflation countries in Latin America—namely Argentina, Brazil, Chile, Uruguay and Mexico—but includes also Israel, whose economy falls into the chronic inflation category. Each of these countries has pursued many stabilization programs, but only the 12 “major” ones, that is, those in which the public could recognize new initiatives that constituted a drastic break with previous policies, are included.2 (See table 1 for program characteristics). A common feature of these programs is that each had major effects on the economy (for better or worse) and brought about significant reductions in inflation. In most cases the programs failed to stabilize inflation over a long time span (in which cases inflation accelerated), but in some instances the programs were part of a longer-term stabilization effort during which inflation was kept at a low level.

To gain an historic perspective on stabilization efforts, the empirical analysis covers programs implemented during the past three decades. In general the stabilization programs of each decade shared important common elements concerning the diagnosis of the causes of the inflation and the design of the appropriate policies to deal with it. For example, the stabilization programs of the 1980s—which include the Austral plan in Argentina, the Cruzado plan in Brazil, the Israeli stabilization of 1985, and the Mexican Pacto of 1988—were all heterodox programs relying on income policies. By contrast the Southern Cone stabilizations, implemented by the military governments in Argentina, Chile, and Uruguay in the 1970s (known as the Tablitas) were orthodox programs with a free market approach and an emphasis on liberalizing foreign trade and capital flows as part of the stabilization process. The 12 programs in the study contain several versions of exchange rate management as part of a disinflation policy, including fixed exchange rates and crawling pegs with various degrees of capital mobility (see table 1 and Kiguel and Liviatan [1990] for a fuller discussion).

In discussing the effects of ERBS on output, the balance of payments, relative prices, consumption, and investment, only the programs in Chile and Israel are presented in detail. These two representative programs share some of the important features observed in the other programs. (The complete set of figures for all the programs is presented in Kiguel and Liviatan 1990.) The basic outcomes for

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all the programs are summarized in table 2, and figures 1–4 show more detailed results for Chile and Israel.

**Real activity.** In general economic expansion began soon after the stabilization programs were initiated. In Chile, where the use of the exchange rate for stabilization purposes began as early as the second semester of 1976, the whole period of ERBS up until 1982 was one of uninterrupted GDP growth. In Argentina the growth of output is evident in all five stabilizations. The upsurge of growth is also apparent in Uruguay after stabilization of the exchange rate in 1979. The more recent ERBS programs generally yielded similar results on output. Israel enjoyed high rates of growth in the business sector in the first three years of the programs; similar, although shorter, growth spans were observed in the Austral and Cruzado plans. The behavior of the unemployment rate was usually compatible with GDP growth, that is, unemployment fell in the growth phase of the cycle.

There is a slight difference between output behavior under orthodox and heterodox programs in the initial stage of the ERBS. In the orthodox programs the exchange rate policy was introduced when the inflation rate was already declining, having been dealt with initially by a monetary-fiscal package as in the Frondizi and Southern Cone stabilizations of the 1970s. In these cases there are no recessionary effects evident with the shift to a policy of reducing the rate of devaluation. In the heterodox stabilizations, however, exchange rate control was introduced along with income policies to stop the inflationary acceleration. In fact the income policies of the heterodox programs can be thought of as the counterpart to the monetary measures that preceded the ERBS in the orthodox programs of the Southern Cone. The fiscal adjustments induced an initial recessionary effect into those heterodox programs that undertook them, but the recessionary effect was both small and short-lived. When the period of exchange rate stabilization extended over a considerable time, as in the Southern Cone stabilizations of the 1970s, in Uruguay 1969, and in Israel, the recessionary phase began before the large maxi-devaluations set in.

In order to better gauge the cycle, figure 5 presents deviations of per capita income from the long-term trend. The trend was computed by fitting a linear or quadratic equation for log GDP per capita in a piecewise manner using appropriate intervals. (For Argentina the periods used to calculate the trend overlap, so the residuals from the overlapping parts were averaged.) These diagrams confirm that in 11 out of 12 cases there emerges an expansionary phase of output relative to trend in the course of the ERBS (the exception is the Brazilian stabilization of 1964–67, which was characterized by a continuous recession relative to trend). Moreover, except for the Krieger Vasena stabilization of 1967–70 in Argentina, all the expansions (relative to trend) begin around the time the exchange rate starts its role as the nominal anchor. In these respects the expansions in chronic inflation countries differ from those sometimes observed in post-hyperinflations, as in Germany, where industrial output remained well below

(Text continues on page 296.)
<table>
<thead>
<tr>
<th>Country and program dates (year, quarter)</th>
<th>Exchange rate</th>
<th>Incomes policiesa</th>
<th>Fiscal adjustment</th>
<th>Reduction in monthly inflation From To</th>
<th>Commercial policy reform</th>
<th>Preceded by corrective monetary or fiscal measures</th>
<th>Preceded by maxi-devaluation</th>
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</thead>
<tbody>
<tr>
<td>Israel 1985.1–present</td>
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<td>Yes (shock)</td>
<td>Large initial adjustment</td>
<td>21.2 6.1</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
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<td>Yes shock</td>
<td>Large transitory adjustment</td>
<td>24.9 2.6</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Brazil (Cruzado) 1986.1–1986.4</td>
<td>Fixed</td>
<td>Yes (shock)</td>
<td>No</td>
<td>11.1 1.7</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Mexico 1988.1–present</td>
<td>Fixed (first year) then crawl</td>
<td>Yes (small shock)</td>
<td>Main adjustment before program</td>
<td>8.2 2.6</td>
<td>Trade and capital account liberalization Fiscal adjustment</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Chile 1976.3–1982.3</td>
<td>Crawl, then preannounced then fixed</td>
<td>No</td>
<td>Yes</td>
<td>11.2 6.5</td>
<td>Trade and capital account liberalization</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Uruguay 1978.4–1982.4</td>
<td>Preannounced</td>
<td>No</td>
<td>Yes</td>
<td>3.4 4.6</td>
<td>Liberalization</td>
<td>Trade and capital adjustment</td>
<td>No</td>
</tr>
<tr>
<td>Country and program dates (year, quarter)</td>
<td>Exchange rate</td>
<td>Incomes policies¹</td>
<td>Fiscal adjustment</td>
<td>Reduction in monthly inflation</td>
<td>Commercial policy reform</td>
<td>Preceded by corrective monetary or fiscal measures</td>
<td>Preceded by maxi-devaluation</td>
</tr>
<tr>
<td>-----------------------------------------</td>
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<td>-------------------------------</td>
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<td>--------------------------</td>
</tr>
<tr>
<td>Argentina 1978.4–1981.1</td>
<td>Preannounced</td>
<td>No</td>
<td>Moderate adjustment</td>
<td>8.1</td>
<td>8.6</td>
<td>Trade and capital account liberalization</td>
<td>Yes</td>
</tr>
<tr>
<td>Argentina 1973.3–1975.2</td>
<td>Fixed</td>
<td>Yes</td>
<td>No</td>
<td>5.7</td>
<td>0.8</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Argentina 1967.2–1970.3</td>
<td>Fixed</td>
<td>Yes (gradual)</td>
<td>Yes</td>
<td>2.5</td>
<td>2.7</td>
<td>Incentives for capital inflows</td>
<td>No</td>
</tr>
<tr>
<td>Brazil 1964.2–1968.3</td>
<td>Fixed with step devaluation</td>
<td>Yes (gradual)</td>
<td>Yes</td>
<td>6.4</td>
<td>4.2</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Uruguay 1968.2–1972.1</td>
<td>Fixed</td>
<td>Yes (shock)</td>
<td>Initially yes, deterioration later on</td>
<td>9.5</td>
<td>1.9</td>
<td>Yes (6 months before)</td>
<td>Yes</td>
</tr>
<tr>
<td>Argentina 1959.3–1962.2</td>
<td>Fixed</td>
<td>No</td>
<td>Initially yes, deterioration later on</td>
<td>9.5</td>
<td>1.9</td>
<td>Incentives for foreign investment</td>
<td>Yes (IMF program 6 months before)</td>
</tr>
</tbody>
</table>

Note: For a graphic trend of the performance of these indicators during the program, see Kiguel and Liviatan (1990).

a. "Shock" means a drastic and immediate reduction in inflation—as in a price freeze. "Gradual"—incomes policies implemented in small steps, spread over time—as in gradual adjustments of staggered wage contracts.
Table 2. Outcomes of Exchange Rate-Based Stabilization Programs

<table>
<thead>
<tr>
<th>Country and program dates (year, quarter)</th>
<th>Year in which upswing in GDP growth relative to trend begana</th>
<th>Current account</th>
<th>Was there a consumption boom?</th>
<th>Was there an investment boom?</th>
<th>Real exchange rate</th>
<th>Fiscal deficit/GDP</th>
<th>Real wages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Israel 1985.1–present</td>
<td>First</td>
<td>Improves until 1987, then deteriorates</td>
<td>Yes</td>
<td>Yes, initially</td>
<td>Gradually appreciates</td>
<td>Decreases</td>
<td>Increases</td>
</tr>
<tr>
<td>Argentina (Austral) 1985.1–1986.3</td>
<td>First</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>Yes</td>
<td>Appreciates</td>
<td>Decreases initially, then increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>Brazil (Cruzado) 1986.1–1986.4</td>
<td>First</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>Unclear</td>
<td>Appreciates</td>
<td>No change</td>
<td>Increases</td>
</tr>
<tr>
<td>Mexico 1988.1–present</td>
<td>Second</td>
<td>Deteriorates</td>
<td>Maybe</td>
<td>Yes</td>
<td>Appreciates</td>
<td>Decreases</td>
<td>No change</td>
</tr>
<tr>
<td>Chile 1976.3–1982.3</td>
<td>First</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>Yes</td>
<td>Appreciates</td>
<td>Decreases until 1979, then appreciates until 1981, then depreciates</td>
<td>Increases until 1982.1, then decreases</td>
</tr>
<tr>
<td>Uruguay 1978.4–1982.4</td>
<td>First</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>No</td>
<td>Appreciates</td>
<td>Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>Argentina 1978.4–1981.1</td>
<td>First</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>Yes</td>
<td>Appreciates</td>
<td>Increases</td>
<td>Initially increases, then decreases in 1980</td>
</tr>
<tr>
<td>Country and program dates (year, quarter)</td>
<td>Year in which spurring in GDP growth relative to trend began</td>
<td>Current account</td>
<td>Was there a consumption boom?</td>
<td>Was there an investment boom?</td>
<td>Real exchange rate</td>
<td>Fiscal deficit/GDP</td>
<td>Real wages</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------------------------------------------------------------</td>
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<td>-----------</td>
</tr>
<tr>
<td>Argentina 1973.3–1975.2</td>
<td>First</td>
<td>Initially improves until 1974.1, then deteriorates</td>
<td>Yes</td>
<td>No</td>
<td>Appreciates</td>
<td>Increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Argentina 1967.2–1970.3</td>
<td>Second</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>Yes</td>
<td>Appreciates</td>
<td>Decreases until 1969, then increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Brazil 1964.2–1968.3</td>
<td>Fourth</td>
<td>Improves until 1965, then deteriorates</td>
<td>Not clear</td>
<td>Yes</td>
<td>Appreciates until 1967.1, then depreciates</td>
<td>Decreases</td>
<td>Increases</td>
</tr>
<tr>
<td>Uruguay 1968.2–1972.1</td>
<td>First</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>Yes</td>
<td>Appreciates, then depreciates</td>
<td>Decreases until 1970, then increases</td>
<td>Increases</td>
</tr>
<tr>
<td>Argentina 1959.3–1962.2</td>
<td>First</td>
<td>Deteriorates</td>
<td>Yes</td>
<td>Yes</td>
<td>Appreciates</td>
<td>Decreases 1960, then increases</td>
<td>Increases</td>
</tr>
</tbody>
</table>

*Note:* For a graphic trend of the performance of these indicators during the program, see Kiguel and Liviatan (1990).

a. Refers to number of years after beginning of program.
Figure 1. The Fiscal Deficit, Inflation, and Devaluation in Chile and Israel

Source: For Chile, Banco Central de Chile and INE; for Israel, Bank of Israel.
Figure 2. GDP Growth and the Current Account

For Chile, Banco Central de Chile; for Israel, Bank of Israel.
Figure 3. Real Exchange Rate and Real Wage in Chile and Israel

Note: The real exchange rate is the average of real prices of imports and exports.

Source: For Chile, Banco Central de Chile and World Bank (various years); for Israel, Bank of Israel (various years).
Figure 4. *Real Rates of Growth of GDP, Private Consumption, and Investment in Chile and Israel*

(percent)

Source: For Chile, Banco Central de Chile; for Israel, Bank of Israel.
Figure 5. Deviations of Log GDP per Capita from Trend

Argentina, 1955 - 89

Brazil, 1958 - 74

Brazil, 1982 - 89
Residual

Chile, 1961 - 88

Residual

Uruguay, 1963 - 83

Residual

Mexico, 1984 - 89

Residual

Israel, 1980 - 89

Source: IMF, IFS data (various years).
trend (Garber 1982). Also most of the ERBS programs were preceded by a recessionary period relative to trend, which indicated the existence of excess capacity that may have provided suitable conditions, from the supply side, for the upswing.

The balance of payments. All ERBS programs were associated with a deterioration of the trade balance and the current account during the program. The expansionary force of these programs, from the point of view of domestic uses, was therefore even more pronounced than with the output growth criterion. During the expansionary phase, the current account typically deteriorates (as illustrated in figure 2). The capital inflows that financed these deficits were, as a rule, reversed at some later stage of the program, thus coinciding with the beginning of the recessionary phase. The inability to finance the growing current account deficits was, in most cases, the immediate reason for the end of the boom. Two important exceptions are Brazil in 1964-67, in which capital inflows continued to finance the current account deficit and made growth sustainable for many years to come, and Israel, in which the boom ended without a marked deterioration of the current account.

Relative prices. As a rule, real wages increased with the upswing of economic activity (see figure 3), although in some cases this occurred with a lag, which may be explained by the following. First, the real wage may have been raised up front in order to compensate for its anticipated erosion if the reduction in inflation was sluggish. A temporary reduction in the real wage in the early phase of stabilization would then be observed, as in the Krieger Vasena stabilization. Second, the real wage may have been deliberately kept below its equilibrium level for some time by income policies, as in Israel. The normal behavior of the real exchange rate during the boom was (as expected) in the opposite direction to that of the real wage. During the periods of a full peg, the real exchange rate fell especially quickly.

Consumption and investment. Most of the expansions in output during ERBS were accompanied by a consumption boom (see table 2). Clearly, when GDP grows faster, consumption is expected to grow faster also, although the growth in consumption should lag behind the growth in output if the stimulus to GDP did not originate from the consumption side. The term "consumption boom" refers to the case in which consumption grows faster than GDP when growth in the latter accelerates or is above normal. The most conspicuous examples of a consumption boom took place in the Peronist and Martinez de Hoz stabilizations in Argentina, Uruguay in 1969, and the Israeli program (shown in figure 4).

Increased investment played a dominant role in the expansions during the Argentine programs of the 1960s, much of it induced by government policies. In the programs of the 1970s the Chilean ERBS was driven by a continual investment boom. Although investment booms were also characteristic of the pro-
grams of the 1980s, these booms were not as large as in earlier programs (with the possible exception of Mexico). This was partly related to reductions in capital inflows and to increases in macroeconomic instability following the debt crisis of the 1980s. In Israel a short-lived upsurge in investment occurred, but the ratio of investment to GDP was lower after the stabilization than before.

The fiscal deficit. The expansion in output following implementation of the ERBS occurred in spite of sharp reductions in fiscal deficits. This is most evident in Israel, where the elimination of the fiscal deficit in 1986 coincided with a sharp consumption boom. This boom is quite surprising because the increase in taxation clearly outweighed any possible reduction in the inflation tax. A similar phenomenon occurred in Chile, where the fiscal deficit was turned into a surplus during the ERBS. And the cut in the fiscal deficit before, or along with, the expansion in aggregate demand during the early phase of the ERBS is also characteristic of all Argentine programs except the Peronist stabilization, in which the deficit increased from the start.

In most stabilizations the initial reduction in the fiscal deficit was later reversed. In the Argentine programs, in particular, the loosening of fiscal policy undermined the disinflationary exchange rate policy. The systematic nature of the fiscal reversals lends support to the view that agents might have treated the stabilizations as temporary measures, which is important for understanding the nature of the cycle. In some cases, notably in Chile and Israel, the poststabilization increases in the fiscal deficit were largely endogenous to the recessionary phase of the business cycle. In these cases the reversal in the fiscal deficit was regarded as temporary; old inflationary expectations were not therefore rekindled.

III. THEORETICAL ASPECTS OF THE ERBS BUSINESS CYCLE

One cannot expect to obtain any useful insight into the cyclical behavior of ERBS from the classical models of the representative individual in an economy with flexible prices and fully credible policies. Indeed it has been shown by Obstfeld (1985) and Calvo (1986) that, in the foregoing framework, a permanent reduction in the constant rate of devaluation is entirely neutral. The same conclusion holds for MBs (see discussion in Kiguel and Liviatan 1990). In order to explain the boom in output and demands (and the subsequent recession), as well as the behavior of the current account and relative prices during ERBS programs, considerations of credibility and of price stickiness must be introduced.

In section I, following Rodriguez and Fischer, it was shown that since a reduction in the real interest rate stimulates aggregate demand, an ERBS implemented in the presence of inflationary rigidities or price stickiness can generate an expansionary phase. To what extent is this real interest rate factor relevant for the explanation of the actual cycles in ERBS programs? It seems that in the Southern Cone stabilizations in the late 1970s the reduction in the real interest
rates was quite evident. Thus Corbo (1985) reports that the Tablita policy in Chile, and the increased capital inflows with which it was associated, led to downward pressure on domestic interest rates, which stimulated a rise in aggregate demand. Similar findings are reported in Ramos (1986) for the early stages of all the Tablita policies for lending rates. It is also interesting that in all Southern Cone Tablitas of the late 1970s, recession along with high real interest rates began before the collapse of the exchange rate regime, as suggested by the modified Rodriguez model.

The fall in real interest rates in the early stages of the Tablitas is a property that was not shared by the stabilization programs of the 1980s, partly because the debt crisis limited capital flows. Real interest rates in Israel and Mexico rose to extremely high levels during stabilization, which may be related to the lower degree of credibility in these programs due to the sharp reduction of inflation with the aid of controls. The rise in the ex ante real rates was smaller but apparently still significant. In Israel an estimate of $\pi^*$ computed from capital market data shows that the ex ante real interest rate on bank loans rose quite significantly in the early stage of stabilization (Bank of Israel 1985). It seems therefore that in these cases something more than the Rodriguez interest rate mechanism is needed to explain the expansion.

The foregoing models of Fischer and Rodriguez assume that the disinflation program is eventually successful. The fact that so many stabilization programs fail, however, must lead to pessimistic views about the chances of any new program to succeed. The very expectation that the stabilization is only temporary may give rise, in the early stages, to an expansion of aggregate demand.

The issue of expectations that stabilization is temporary has been investigated in recent papers by Calvo (1986, 1987, 1991). These cash-in-advance models show that agents who expect stabilization to be temporary will shift part of their future consumption expenditures to the present. In the present, when the rates of devaluation and inflation are low, the cost of holding money (which is necessary to carry out purchases) is also low, whereas the opposite is true for future periods when high inflation is expected to resume. This gives rise to increased expenditures in the stabilization period, accompanied by current account deficits and real appreciation. All these features are clearly consistent with the phenomenon of the consumption boom and the related developments described earlier.

Calvo's model is a Ricardian one, with the property that a permanent reduction in the (constant) rate of devaluation is neutral. This underscores the fact that the initial consumption boom is related entirely to expectations of temporariness. Unlike the Rodriguez and Fischer models, where the boom is the result of an initial reduction in the real interest rate, the rise in consumption in Calvo's model is caused by a temporary reduction in the nominal interest rate. The level of the real interest rate, which is constant in Calvo's model, has nothing to do with the cyclical behavior of demands. This helps to explain the emergence of the consumption boom in programs where the real interest rate was very high, as in Israel.
The cash-in-advance setting, which stresses the role of liquidity, seems (implicitly) to be related more closely to a consumption boom in terms of durables. Indeed, the data for Israel show that durable purchases increased tremendously in 1986, (up 47 percent from the previous year) after the ERBS program was implemented in July 1985.

Somewhat paradoxically, one can arrive at similar conclusions about the consumption boom if one assumes that consumers view the stabilization as permanent and that the reduced uncertainty about relative prices and about government policies enhances productivity. This sort of expectation may raise agents' expected permanent income and thus raise consumption. This theory, however, cannot explain the cyclical nature of the consumption boom unless it is assumed that in each case the expectations were incorrect. The explanation based on expected temporariness of the ERBS is more robust in the sense that it can explain the cyclical behavior of consumption regardless of whether agents' expectations turn out to be correct or incorrect (see Kiguel and Liviatan 1990 and Calvo and Vegh 1990).

An alternative model of the cycle, which is again based on expectations of temporariness (but not in a cash-in-advance setting) and on a boom of durables purchases was formulated recently by Drazen (1990). He shows that when the fixed exchange rate policy is expected to collapse at some definite date, there will be a run on imported durables just before the collapse. This may be a result of hedging against devaluation when there is no free access to foreign exchange or in anticipation of the imposition of quantitative restrictions following a balance of payments crisis. In this case the ERBS will not induce an initial boom. When the date of collapse is uncertain, however, the wave of durables purchases will be spread over the span of the stabilization program. This will cause a boom in domestic output when expenditures on durables are complementary to consumption of domestically produced goods. Drazen's argument may be extended to claim that when the collapse takes the form of a balance of payments crisis, agents will expect a sharp tightening of credit conditions after the crisis and consequently will be motivated to advance all kinds of expenditures to the present. Drazen's model also can explain the phenomenon of the recession in output starting before the collapse of the exchange rate regime; this will occur when the realization of the collapse happens to occur at a relatively distant date in the future.

Drazen provides data on booms in expenditures on durables during ERBS programs in Argentina, Chile, and Mexico, which supplement the data here from Israel and provide more evidence supporting the theory that the motivation to advance purchases on durables is one of the important driving forces of the business cycle in an ERBS.

Since real wages tend to rise with the expenditure cycle, it is conceivable that the former may actually cause the latter because of the higher propensity to spend out of wage income. To be an adequate explanation, however, it has to be shown, first, that real wages affect demand more strongly than supply and, second, that real wages should rise more in an ERBS than otherwise.
The answer to the first question is certainly unclear from the theoretical point of view (see Krugman and Taylor 1978 and Lizondo and Montiel 1989). As for the second one, it is often mentioned (especially for the Chilean Tablita) that lagged wage indexation will cause real wages to rise when inflation is falling. However, this explanation does not work for the heterodox programs in which the foregoing type of inertia is eliminated at the outset.

Apart from the effects of disinflation on demand, there may be expansionary effects originating from the supply side. The strong effect of exchange rate stabilization on prices, which we often find in an ERBS, may increase efficiency by reducing excessive variation in relative prices and by shifting resources out of excessive financial and speculative activities. However, the latter effect operates only in the longer run. In the medium run the effect of restructuring the economy toward a low inflation environment may well be recessionary (see Garber [1982] for an example from the German stabilization).

The real interest rate effect, which is expansionary in the Rodriguez-Fischer models for an ERBS, works in an opposite manner in a MBS. With wage or price stickiness a monetary crunch will raise the real interest rate. (With perfect capital mobility this entails an initial real appreciation and an expected devaluation, as in Dornbusch's overshooting theory.)

If Calvo’s (1986) model is adapted to a MBS, temporariness will still lead to a consumption boom. This boom requires an initial drop in prices; consequently, downward price rigidity may nullify the expansionary effect. Calvo and Vegh (1990) show that, in a model with staggered prices, a temporary ERBS is expansionary whereas a MBS is contractionary.

If one takes the view that expectations of a collapse associated with a balance of payments crisis and imposition of quantitative restrictions induce an advancement of purchases that generate a business cycle in an ERBS, then it is easy to see this factor does not operate in a MBS. In a MBS the central bank does not commit its foreign exchange reserves to protect the disinflation policy, and therefore the issue of the balance of payments crisis does not arise.

The foregoing analysis dealt with some general considerations that may explain expansionary tendencies in ERBS programs. In practice one may usually identify specific factors that contributed to the expansion of output in individual cycles. It is conceivable that these factors were no less important in generating the booms than the exchange rate policy itself. In some other cases the interaction of the exchange rate stabilization strategy with other factors created a mechanism for unsustainable expansion.

Most ERBS programs were initiated under favorable external conditions, which made it possible in some cases to pursue expansionary policies simultaneously with disinflation policies. In some cases, especially in the early stabilizations in Argentina, the pegging of the exchange rate was part of a broader development strategy that favored foreign investment and considered a stable exchange rate as part of the required financial environment. This approach may have resulted in both disinflation and expansion.
In some cases, as in the Tablita policies in the Southern Cone, the ERBS was part of a package that included the liberalization of the trade and capital accounts. Some authors stress the expansionary effect of the latter (Corbo 1985 and Edwards and Edwards 1987), but liberalization of the trade account can also be expansionary if it is perceived to be temporary.

IV. POLICY ISSUES

The business cycle phenomenon associated with an ERBS does not in itself imply that this policy cannot be part of a longer-term successful process, as has been demonstrated in such countries as Chile and Israel. However, even in these cases the variation in economic activity and in consumption over time is undesirable for several reasons. First, a stable path of consumption will be preferred to a variable one when consumers have a concave utility function for consumption (see Calvo 1986). Second, excessive purchases of capital goods during the expansionary phase (in anticipation of a failure of the exchange rate policy) lead to an inefficient allocation of investment. Third, the difficulty in correcting both the overvaluation and the excessive real wages exacerbates the recessionary phase and leads to an unnecessary loss of output.

For most programs that turn out to be temporary, there are additional problems. In these cases the failure of an ERBS can destabilize the inflationary process, as was clearly the case in the aftermath of the Austral and Cruzado plans. The loss of credibility resulting from failure to stabilize implies that future stabilizations must employ even harsher policies, leading to more severe recession and loss of output.

This raises the question of whether the stabilization cycle is unavoidable in practice and, if not, what can be done to mitigate its effect? As for the first question, the evidence from the stabilizations of Brazil 1964–67 and Mexico 1988–89 show that the excessive expansionary phase can be avoided. This may have been possible in the Mexican case because fiscal adjustment was carried out long before 1988. In fact the fiscal deficit was drastically cut as early as 1983, and the budget even showed an operational surplus in 1987. Although the Mexican experiment is still very young and definite conclusions cannot yet be reached, it seems advisable to implement fiscal adjustment before stabilizing the exchange rate in order to enhance the credibility of the program. This, of course, may not be politically feasible; in Mexico this stepwise procedure was facilitated by the need to use recessionary fiscal measures to deal with the balance of payments crisis in the early 1980s.

Given the difficulties encountered in the ERBS, should policymakers prefer the MBS? Or can conditions be specified that can guide policymakers in choosing between the two strategies? It is certainly arguable that if the delayed recession cannot be avoided in the ERBS then it might be preferable to have it earlier by implementing a MBS. Formulation of this choice in terms of “recession now (MBS) or recession later (ERBS)” relates to the discussion in signaling theory (as in
Vicker 1986) of whether it is preferable to establish credibility up front by adopting a drastic policy (such as a MBS) or postponing the confrontation to a later date and accepting, for the time being, the cost associated with lack of credibility (as with the business cycle of the ERBS).

The conclusion from signaling theory (Kiguel and Liviatan 1988) is that a drastic policy may be preferable when initial credibility is low. In the current context this means that a MBS is preferable when the economy has a long history of failed stabilizations, as is quite common in Latin America. Indeed the recent preference for a strict MBS in Argentina and Brazil in 1990, after the failure of many stabilizations in the 1980s, seems to support this view. However, when credibility is relatively high (that is, relative to the standards of chronic inflation countries), perhaps as a result of a basic improvement in the external position, an ERBS is preferable because the cost of not establishing initial full credibility in nominal anchors is relatively low. An ERBS was thus the appropriate policy choice in the case of Israel. The ERBS strategy has the additional advantage of making the fiscal adjustment transparent because of the relative stability of prices. And it is much easier for the public to monitor the exchange rate rule as compared with the complexity of monitoring some money supply anchor. Thus the policymaker may hope to alter the public's views on credibility during an ERBS by adhering to the exchange rate rule and by adopting a strict fiscal adjustment. Consequently, the recessionary phase may turn out to be relatively mild.

Another policy option is to adopt a stepwise disinflation strategy with an ERBS followed by a MBS. This may allow the policymakers to reap some of the gains of both policies. Chile, for example, did quite well after abandoning its fixed exchange rate regime in 1982—economic growth resumed jointly with a real devaluation and a stable, low level of inflation. Two difficulties arise with the proposed switch of anchors. First, if the excessive real appreciation during the ERBS is due to lack of credibility in the adherence to the nominal anchor, then this credibility issue will reappear in connection with the money supply rule as well. Second, adopting the money supply anchor is problematic if the economy remains highly indexed. With indexation, monetary shocks are translated very easily into price shocks, which may undermine credibility in price stability (given incomplete information about the source of the shocks). Chile overcame this difficulty by abolishing formal wage indexation, a decision that was facilitated by the balance of payments crisis of 1982. By contrast Israel remains highly indexed and so must continue with a policy of infrequent step devaluations, thus relying on the exchange rate as the nominal anchor and going through the ERBS business cycle. Its comfortable external position continues to support this reliance on the exchange rate as the anchor.

3. The shift to an ERBS in Argentina in 1991 took place after considerable gains in credibility of the disinflation process.
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A Framework for Evaluating the Impact of Pricing Policies for Cocoa and Coffee in Côte d'Ivoire

Pravin K. Trivedi and Takamasa Akiyama

This article presents an approach to evaluating pricing policies for perennial crops. A flexible computational model is developed, which incorporates important features of perennial crop production that are not captured by other (usually static) frameworks. This framework produces sensible and plausible scenarios for pricing cocoa and coffee in Côte d'Ivoire, as well as descriptions of revenue tradeoffs. Key issues arise from considering major changes in the rules used to set domestic producer prices. An unambiguously best policy is not determined, but several policies improve substantially on the present situation. Most of these alternatives indicate the desirability of lowering the tax on coffee relative to cocoa.

Many low-income developing countries depend heavily on tree crops, or perennials, for export and tax revenue, so that the health of the perennial sector and the overall state of the economy are closely connected. The most important perennials are coffee and cocoa, but rubber, tea, and oil palm are sometimes also significant. It is expected that most of these countries will continue to depend heavily on these crops for export tax revenue, and many will retain policies fixing both producer prices and exchange rates. Thus the choice of the appropriate tax rate and producer price, given government objectives, will remain of key importance. The research reported here evaluates alternative tax and price policies quantitatively, with specific reference to cocoa and coffee production in Côte d'Ivoire. Côte d'Ivoire was chosen for this analysis because it currently faces serious economic problems, whose resolution is closely entwined with its pricing policies for cocoa and coffee.

The objective of the study was to develop an operational approach for quantitatively evaluating pricing and tax policies for perennials over the short and
medium run (7 to 15 years). An “operational” approach is one that is computationally implementable and that quantifies the implications for production, exports, and tax revenues of different price rules under alternative assumptions about related variables such as the exchange rate, age-yield profiles, new plantings, supply elasticities, and minimum feasible producer prices. Because of the dynamics of perennial supply response, projections should cover a time horizon of 10 years or more. The revenue implications of a policy change are not fully revealed over a shorter period, so that focusing on short-term revenue flows will lead to myopic policies. Long-term projections, however, can be made only conditionally on projections of world demand and supply for the crop.

The framework developed here is an alternative to other approaches, including both ad hoc and partial evaluations concerned largely with the short-term impact and other model-based equilibrium approaches that do not project the time paths of important variables. This study is limited in scope; it does not consider dynamic price uncertainty in the face of credit constraints and attempts by governments to stabilize prices to overcome such problems, nor does it consider the policy credibility and reputation of the policymakers.

Section I provides a brief literature review of several alternative frameworks. Section II contains the essential institutional and factual background concerning pricing policies for cocoa and coffee in Côte d'Ivoire. Section III provides an overview of the structure of the model and discusses the measurement of the impact of policy changes on welfare. Section IV summarizes simulations of the model and gives the results of model sensitivity exercises. Section V discusses the choice between alternative policies, and Section VI concludes.

I. A Review of the Literature

Alternative pricing policies for perennial crops are evaluated in two stages. First, theoretical and computing frameworks must be developed to generate time paths for the relevant critical variables. Second, a criterion for choosing among alternative policies that differ in their impact on various sectors of the economy must be established. The second aspect is conceptually more difficult because it involves many of the classic normative issues of applied welfare analysis.

The first stage requires a careful integration of a priori assumptions and factual information. Broadly speaking, there are three approaches to developing an analytical framework: the static, general-equilibrium approach related to the optimal tax literature (Stern 1987); the static, partial-equilibrium approach rooted in the optimal tariff literature (Repetto 1972; Imran and Duncan 1988); and the dynamic, multimarket, partial-equilibrium approach of this study. Each of these approaches requires different types of inputs and provides different kinds of output.

The analytical framework used by Repetto and by Imran and Duncan is fairly straightforward, but it necessitates some strong assumptions, including that of a constant supply elasticity. This approach does not shed light on issues of income
distribution between cocoa and coffee producers. It is complemented by other analyses, such as that of Deaton and Benjamin (1988), who examine the desirability of adjusting the relative producer price of coffee and cocoa in Côte d'Ivoire by bringing them both in line with world prices. On average, the administered coffee price has been around 36 percent of the world price, and the cocoa price has been about 47 percent of the world price. Deaton and Benjamin consider the outcome of this price adjustment under several different assumptions about the degree of linkage between world and domestic producer prices and the degree of risk sharing between producers and the government. But they (correctly) remain neutral about the likely consequences in the absence of greater knowledge of producer response. They emphasize, as others have before them (see Newbery 1987), that supply response is crucial to the issue; however, their own framework and method is of a partial-equilibrium type.

In discussing the same set of issues for Côte d'Ivoire, Akiyama (1988) takes the approach that is closest to that of this study. The new-planting and replanting responses of cocoa and coffee producers under alternative tax rules are specified in detail, and potential production is calculated using the vintage matrix approach previously used in studies of perennials by Akiyama and Bowers (1984) and Akiyama and Trivedi (1987a, 1987b). The world price of the crop is projected using reduced-form versions of global commodity models, and the tax revenue consistent with both period-by-period price equilibration in the world market and the exchange rate policy being pursued is calculated. The model is simulated for each year of the relevant time horizon to generate the long-term consequences of a policy for producers' revenue, government revenue, and export revenue.

This computational framework, however, does not allow for the comparison of alternative policies or the evaluation of possible tradeoffs between producers' incomes and government tax revenue with different policies. Because Akiyama's approach does not use an algorithm to make relevant comparisons and does not calculate producer welfare, it needs to be extended and refined. Furthermore a better computational framework is needed to permit greater speed and flexibility in evaluating policy. Flexibility is especially important because developing-country data are frequently fragmentary and of poor quality so that they cannot support precise estimation of key structural parameters. Consequently, sensitivity and fragility analyses are essential.

II. COCOA AND COFFEE PRODUCTION IN CÔTE D'IVOIRE

Cocoa and coffee together have accounted for about 50 percent of total exports, 40 percent of agricultural gross national product, and more than one-half of the employment of Ivoirien farmers in recent years. Although the contribution of cocoa and coffee to the Ivoirien economy was quite significant during the 1970s, the weakening and subsequent collapse of world prices of the two crops after 1985 and the sharp appreciation of the CFA franc relative to the U.S.
dollar after 1985 dramatically changed the picture. Government revenues declined sharply, and, because of aggressive exchange rate policies pursued by Côte d'Ivoire's competitors, the country's international competitiveness weakened.

These changes have motivated a reexamination of current policies. The main alternative policy under consideration would reduce administered producer prices and relative producer prices of the two commodities so that prices would more accurately reflect marginal export revenues. The future world price outlook for coffee is brighter than for cocoa; therefore, such a price restructuring implies significant costs in terms of foregone producer and tax revenues.

The Caisse de Stabilization et de Soutien des Produits Agricoles (CSSPPA) controls the marketing of cocoa and coffee primarily through two policy instruments. First, at the beginning of each crop year it specifies the payment system (bareme), which details producer prices and domestic and external marketing costs along the entire marketing chain. Second, it uses an export price reference system to stabilize the price received by exporters. Exporters receive the world market price, but, if the world price exceeds the reference price, the exporter pays the CSSPPA the difference between the two. If the world price is lower than the reference price, the exporter is paid the difference between the two by the CSSPPA, which draws from its financial reserves.

The "Caisse" system has significant limitations. It is clear that the system will perform poorly when the CFA franc appreciates or when the world price declines for an extended period, because these circumstances necessitate prolonged revenue outflows from the CSSPPA. The resulting liquidity problems may force delays or suspension of payments to producers, and eventually the producer price may have to be reduced. The CSSPPA has run large deficits since the mid-1980s, and, for the 1989/90 crop year, producer prices for cocoa were reduced by 50 percent and for coffee by 40 to 50 percent.

Administered producer prices can create a domestic relative price structure that is out of alignment with domestic production costs if changes in these costs are not taken into account. This has occurred in Côte d'Ivoire; cocoa was priced too high relative to coffee, thus leading to large increases in cocoa production. Recent economic analyses of pricing policies have typically concluded that producer prices need to be realigned to eliminate the difference in favor of cocoa. Any such change will affect the distribution of income, so that an informed discussion of the merits of altering current relative prices must consider detailed information on the current income distribution among Ivoirien cocoa and coffee producers as well as the links between changes in relative prices and the distribution of income.

Deaton and Benjamin (1988) have examined the links between prices and farmers' incomes by using data from the 1985 Living Standards Measurement Study. Their analysis emphasizes several facts that have an important bearing on the interpretation and use of the simulation results presented below. First, cocoa and coffee farmers are not mutually exclusive groups. In fact coffee farmers
derive more net income from cocoa than from coffee. Second, cocoa farmers have average household incomes close to the national average, whereas those of coffee farmers are 13 percent below the average. Third, agricultural income constitutes about 65 percent of total income for these farmers, and cocoa and coffee account for about a third of agricultural income on average. Home-produced food is the most important source of income, accounting for 44 percent of net agricultural income.

III. Structure of the Model

The Ivoirien cocoa and coffee sectors are represented within the model by a detailed specification of output supply. Because both crops are cultivated in the same area, it is reasonable to postulate considerable output substitution between cocoa and coffee by farmers. Furthermore it is reasonable to postulate that substitution between annual food crops and perennials may be especially important. Because of the lack of data, however, this latter possibility has been ignored here (see Weaver 1989). Cocoa and coffee are viewed as substitutes from the producer's viewpoint, and the interaction between the two sectors is embedded in parametrically specified short-run supply equations and new-planting equations. It is assumed that the entire output of these sectors is exported. The interaction of the two sectors with the government is represented by a set of equations linking export prices with producer prices and export revenues with production and world prices as well as equations detailing the government's revenue and cost structure. The model does not include the interaction between the cocoa, coffee, and government sectors, on the one hand, and the rest of the Ivoirien economy, on the other. In other words the model can evaluate only the impact of macro policies, such as exchange rate adjustment, from a sectoral viewpoint.

The model used is nonlinear but essentially recursive and hence easy to solve. In broad terms the calculations proceed as follows. First, a regime for cocoa and coffee producer prices is specified together with assumptions about the exchange rate, age-yield profiles for both crops, and the time paths of Ivoirien production and world prices in the absence of production shocks in Côte d'Ivoire. An example of a policy regime is a cut of 30 percent in the producer prices of cocoa and coffee from base levels. It is also assumed that producers believe the announced price policy to be permanent and nonreactive and that they base their expectations and new-planting and production plans on the announced policy. That is, there are no issues of government credibility in the discussion.

Second, given producer prices, the model determines new plantings and the potential and actual production of cocoa and coffee. Third, given the cocoa and coffee supply curves, the production and profits of producers can be immediately obtained because, under the export price reference system, they do not depend upon yet-to-be-determined world prices. Next, together with world supply and demand, the policy-induced deviation of Ivoirien production from its
base production determines the deviation of the world price from its base. For a
specified exchange rate this then determines the Ivorian export revenue and,
given the cost structure for marketing and transportation, the size of govern-
ment deficit or surplus in any given year. One simulation consists of solving
the model, year by year, for a time horizon of up to 14 years (1987–2000) under
specified initial conditions and a selected policy rule. To compare alternative
policies, the results are aggregated for the entire horizon; to study the impact of
any one policy, the results are presented as a time series. All ingredients for a
welfare evaluation are available at this stage.

The model is calibrated using historical data and parameter estimates that are
subject to considerable uncertainty because of the limited time series data used in
their estimation. It should be emphasized that data constraints preclude the use
of a fully econometric model. A not-inaccurate description of the model would
be that it is a numerical model that has been calibrated using econometric
evidence and a priori restrictions. Most of the important restrictions have been
subjected to sensitivity analysis, which will be noted where appropriate.

The Supply Sector

The heart of the model is the specification of cocoa and coffee supply. For
each crop, the block of supply equations is based on the vintage capital ap-
proach, which uses data on new plantings, the age-yield profile, and death rates
of trees by age group. A distinction is drawn between high-yielding and tradi-
tional varieties. For the assumptions made in constructing vintage matrices, see

A simple sketch of the supply sector is as follows. Let \( Q^p(t) \) denote aggregate
potential or expected average output and \( Q(t) \) denote actual output, at time \( t \),
where \( Q^p(t) \geq Q(t) \). Actual output is related to potential output via the short-
run output supply equation

\[
Q(t) = g_1[Q^p(t)]g_2[p^d(t - i)],
\]

where \( g_1 \) is a measure of the percentage of potential production that is actually
produced in any year, and the second term \( g_2p^d(t - i) \), represents the current
and lagged effects of own and substitute output prices, denoted by the vector \( p^d \).
Aggregate potential output is the sum of potential output from each of the
different surviving age classes, assuming that the productivities of these cohorts
remain at their historic level, that is,

\[
Q^p(t) = \sum_v Q^p(t, v)
\]

where \( v \) denotes the vintage or age class.

Given an age-yield profile, \( \delta(t, v) \), \( Q^p(t, v) \) depends upon the size of the
surviving stock of vintage \( v \) trees, \( K(t, v) \), through a production function relation

\[
Q^p(t, v) = \delta(t, v) \ K(t, v)
\]
where \( K(t, v) \) is given by the accumulation equations

\[
(4) \quad K(t, v) = K(t - 1, v) - R(t, v)
\]

\[
(5) \quad K(t, t) = N(t)
\]

where \( R(t, v) \) denotes removals, death, and losses from the stock exiting at \( t - 1 \) and \( N(t) \) denotes new plantings. New planting of cocoa is a function of real producer cocoa and coffee prices, and the equation for new plantings of coffee is specified analogously:

\[
(6) \quad N(t) = N[p^d(t - 1)]
\]

where \([p^d(t - 1)]\) is a proxy for the expected future real producer prices. (It would be desirable to restrict the form of the new-planting equation, for example, to impose constant returns to scale, but this would require data on planted areas by age class (Trivedi 1988), which are unavailable for Côte d'Ivoire.) The new-plantings specification implies static expectations, which is a strong assumption, but which has considerable appeal in the context of a study that explores the revenue and cost implications of particular fixed producer price regimes.

Calibration of the Model

Potential production in the model is determined by the stock and age composition of the trees. Figures for these do change, of course, as new planting occurs. Attempts at estimating these new planting equations using time series were summarized in Akiyama (1988). Although econometrically reliable estimates are difficult to obtain, there is evidence that aggregate new plantings respond to changes in real prices of the two commodities. Hence the equations used are based on the assumption that the two crops compete and that new planting in each sector responds to the relative price ratio. The best estimates for the own-price elasticity of new plantings of coffee are around 4.0 and for the cross-price elasticity are around \(-1.5\). For cocoa the corresponding elasticities are 1.9 and \(-0.6\), respectively.

On a priori grounds, however, the model uses variable, rather than fixed, new-planting elasticities. The rationale for this has been given elsewhere (Trivedi 1988), the essential idea being that the new-planting response to relative prices will be nonlinear in real prices. At a low relative price the elasticity will be small, and at a high relative price it will be high. The nonlinearity is calibrated to produce own- and cross-price elasticities similar to those given above at the real prices prevailing in 1986. When simulations incorporate a period of comparatively low real prices, however, planting elasticities are significantly reduced. Although it would be desirable to specify new-planting elasticities that decline as the supply of suitable land declines and as additional expansion uses agronomically inferior land, most of the policy options explored involve expa-
sion in only one of the two sectors, usually coffee. Given the assumption that the two crops compete, it seems consistent to assume that the decline in one sector releases land usable in the other so that expansion is not limited or halted by the exhaustion of suitable land.

The supply equations used for cocoa and coffee contain a multiplicative factor that depends upon feasible or potential production. The construction of vintage capital matrixes allows one to estimate the feasible production from each age cohort using a fixed age-yield profile. Aggregating these provides a measure of potential (expected average) production in any period. Assuming that potential and actual production differ by a scale factor, this scale factor may be obtained by regression of actual on potential production. The scale factors thus determined for cocoa and coffee are 1.02 and 0.99, respectively.

Time series regressions yield imprecise estimates of (Marshallian) own- and cross-price supply elasticities. Akiyama (1988) used point estimates of 0.22 for own-price elasticities of both coffee and cocoa, 0.08 for cocoa-coffee cross-price elasticity, and 0.04 for coffee-cocoa cross-price elasticity, these being close to values obtained using a short time series. Although the assumption of constant output supply elasticities is restrictive, the data needed for estimating a more flexible elasticity specification are not available. Instead an a priori belief is imposed that the supply response decreases as the actual price approaches the "shut-down" price, below which no production will take place. The 1982/83 average cost of production for coffee and cocoa for different plantation types (de Graaff 1986, table 9.8) is used as the minimum price below which production will not occur. The elasticities are specified as functions of prices such that at the real prices prevailing in 1986 the implied elasticities are close to the time series estimates given above, but at higher or lower prices their values change. These functions are given in table 1. The actual numerical values in those functions with such properties were obtained by a grid search of elasticities around the sample mean value estimated using a time series regression.

In the context of a static market-clearing model of demand and supply, the (absolute value of the) demand elasticity for Ivoirien production, denoted by $E^d$, is given by

$$E^d = \frac{E^{w,d} + (1 - s)E^{w,s}}{s}$$

where $E^{w,d}$ and $E^{w,s}$ denote the rest-of-the-world demand and supply elasticities and $s$ denotes the Ivoirien share of the world market. Let the domestic price, $P^d$, and the world price, $P^w$, be linked by $P^d = (1 - T)P^w$ where $T$ is the export tax rate; then the relation between the (policy-induced) domestic price perturbation and the change in the world price is

$$\frac{dP^w}{dP^d} = -\left[1/(1 - T)\right]\frac{SE^s/[E^{w,d} + (1 - s)E^{w,s}]}$$

where $E^s$ is the domestic elasticity of supply.

The world price of coffee is taken as exogenous, because the average Ivoirien share of world exports is only around 5 percent. The world price of cocoa,
Table 1. Production and Planting Elasticity Equations

<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>$EP_{1CF} = \exp(-BCF \cdot MCF) \cdot \exp(BCF \cdot RFP)$</td>
<td>Own-price production elasticity of coffee</td>
</tr>
<tr>
<td>$EP_{2CF} = 0.0012 \cdot RFP$</td>
<td>Cross-price production elasticity of coffee</td>
</tr>
<tr>
<td>$EP_{1CC} = \exp(-BCC \cdot MCC) \cdot \exp(BCC \cdot RCP)$</td>
<td>Own-price production elasticity of cocoa</td>
</tr>
<tr>
<td>$EP_{2CC} = 0.00058 \cdot RCP$</td>
<td>Cross-price production elasticity of cocoa</td>
</tr>
<tr>
<td>$\eta_{1CF} = 1.0 + 0.0434 \cdot \frac{RFPMA}{3}$</td>
<td>Own-price new-planting elasticity of coffee</td>
</tr>
<tr>
<td>$\eta_{2CF} = 0.0236 \cdot \frac{RFPMA}{3}$</td>
<td>Cross-price new-planting elasticity of coffee</td>
</tr>
<tr>
<td>$\eta_{1CC} = 1.0 + 0.013 \cdot \frac{RCPMA}{3}$</td>
<td>Own-price new-planting elasticity of cocoa</td>
</tr>
<tr>
<td>$\eta_{2CC} = 0.00869 \cdot \frac{RFPMA}{3}$</td>
<td>Cross-price new-planting elasticity of cocoa</td>
</tr>
</tbody>
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Notation:
- MCC: Estimated minimum cost of production of cocoa/kg
- MCF: Estimated minimum cost of production of coffee/kg
- RFP: Real producer price of coffee
- RCP: Real producer price of cocoa
- RFPMA: Lagged 3-period moving sum of RFP
- RCPMA: Lagged 3-period moving sum of RCP
- EP: Own-price elasticity
- ETA: Cross-price elasticity
- $BCC = -1.514 / (69 - MCC)$
- $BCF = -1.514 / (65 - MCF)$

However, cannot be treated as exogenous, because Côte d'Ivoire has close to 30 percent of the world share of cocoa exports. Ivoirien production and the world price are linked using a static market-clearing model of the world cocoa market. The rest-of-the-world supply elasticity is taken to be 0.30 and the demand elasticity $-0.27$, both close to those estimated in time series regressions. Furthermore, given a time series of the world cocoa price representing the base price, deviations from it can be computed using the above elasticities together with the assumption that a change in the world price arises when Ivoirien production deviates from its base level. The impact of an Ivoirien production shock on the world price is inversely related to the size of the shock relative to world production. The computation of the world price is done period by period; hence the generated perturbed solution incorporates the interdependence of the world price and policy-induced supply changes in Côte d'Ivoire.

Measures of Policy Impact and Welfare Evaluation

The key consideration in the evaluation of the impact of policy is the induced change in the distribution of income. The numerical model detailed above can be used to calculate the tradeoffs in terms of discounted net revenues that would
accrue to cocoa producers, coffee producers, and the government under alternative hypothetical pricing policies. An important qualification is that cocoa and coffee producers do not constitute mutually exclusive groups; therefore, they may be aggregated into a single "private sector," and the tradeoff between the government and the private sector can be considered.

Changes in producer prices directly affect production and profits in the cocoa and coffee sectors. At an aggregate sectoral level, the conventional measure of welfare change is the change in the producer surplus, or net profits of the producers. In the static production model, producer surplus is conventionally measured as the area bounded by the price and the supply function. Given the parametric specification of the supply function and the potential production for year $t$, the producer surplus, $\Pi(t)$, can be calculated as

$$\Pi(t) = \int Q(p^d) \, dp^d$$

where the range of integration is from the shut-down price to the government's current set price. This integral has an explicit, closed-form solution for the parameterization of the supply function used here and can be readily evaluated. A complication arises, however, from the dynamic adjustment process modeled here, which shifts the supply function intertemporally.

The presence of a multiplicative shift factor in the output supply equation means that as new planting occurs and potential output expands, the supply function shifts out, or the supply function is time-indexed. Aggregate producer surplus for the full time horizon is the discounted sum of the producer surplus in each year. The output supply function specified in equation 9 reflects only variable production costs and ignores the fixed costs of purchasing land and establishing a planted area, that is, the cost of capital inputs. This may be appropriate for a short-run analysis but will result in overestimation of producer surplus in the long run. To correct for this, Just, Hueth, and Schmitz (1981) suggest that the imputed value of the cost of preplanned capital inputs into current production can be subtracted from the static annual measure of producer surplus. This is roughly equivalent to subtracting the amortized value of capital costs from the producer surplus calculated in the conventional way and takes into account the costs of shifting resources into an expanding sector. Producer surplus was thus calculated as

$$\Pi(t) = \int Q(p^d) \, dp^d - Z(t)$$

where $Z(t)$ denotes annual amortized establishment cost of new plantings.

Most of the policies simulated here result in either an expansion of coffee production and a contraction of cocoa production or an increase in net government balance and a reduction in producer surplus. Choosing the optimum pricing policy, defined as that which maximizes aggregate social welfare, involves implicit or explicit weighing of the gains and losses of different groups. Explicit welfare weights will not be assigned here; instead the tradeoffs generated by alternative pricing policies will be presented. The choice of any point on the
tradeoff implies some social valuation of the relative gains and losses of all affected sectors. Deaton and Benjamin (1988) have concluded that the income distribution effects that resulted from shifts in the relative prices of cocoa and coffee were probably rather small. Assuming that this conclusion is valid, the key consideration in the choice of pricing policy is the social valuation of government tax revenue versus aggregate private revenue.

IV. Alternative Pricing Policies

Several simulations were carried out using the model, four of which are reported here. In the base case simulation it is assumed that the current pricing policies are continued. Then a policy of reducing both prices, along with a reduction in the relative price of cocoa, is simulated. Next the exchange rate is altered (the CFA franc is devalued), but absolute and relative producer prices remain unchanged. Finally, the effects of a system of nonfixed producer prices, which vary according to changes in the world price, are simulated. The projected time paths of relevant variables for these cases are illustrated in figures 1–6.

Base Case Projections and Simulation Results

The assumptions made to generate the base case projections are summarized in table 2, and the main results are as follows: annual cocoa production rises from about 620,000 tons in 1987 to 861,000 tons in 2000, while annual coffee production falls significantly, from 244,000 tons to 191,000 tons (figures 1 and 2). The cocoa sector’s annual producer profit increases from CFAFr146 bil-

<table>
<thead>
<tr>
<th>Table 2. Assumptions Underlying the Base Run</th>
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<tbody>
<tr>
<td>Exchange rate (CFAF/$)</td>
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<tr>
<td>Producer price for cocoa</td>
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<tr>
<td>Producer price for coffee</td>
</tr>
<tr>
<td>World c.i.f. price</td>
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<tr>
<td>Domestic marketing and transportation (CFAF/kg)</td>
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<td>Freight and insurance (CFAF/kg)</td>
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<tr>
<td>Export tax (CFAF/kg)</td>
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<tr>
<td>Cost to CSSPPA (CFAF/kg)</td>
</tr>
<tr>
<td>Cost to government</td>
</tr>
<tr>
<td>Cocoa: minimum production cost/kg (1987 CFA)</td>
</tr>
<tr>
<td>Coffee: minimum production cost/kg (1987 CFA)</td>
</tr>
<tr>
<td>World cocoa demand elasticity</td>
</tr>
<tr>
<td>Rest-of-the-world cocoa supply elasticity</td>
</tr>
<tr>
<td>Annualized cocoa establishment cost/ha</td>
</tr>
<tr>
<td>(thousands of 1987 CFA)</td>
</tr>
<tr>
<td>Annualized coffee establishment cost/ha</td>
</tr>
<tr>
<td>(thousands of 1987 CFA)</td>
</tr>
</tbody>
</table>
Figure 1. Projected Cocoa Production under Three Price Rules

Thousands of metric tons


Source: Authors' calculations.

Figure 2. Projected Coffee Production under Three Price Rules

Thousands of metric tons


Source: Authors' calculations.
lion\(^1\) to CFAF203 billion, measured in 1987 prices. The cumulative surplus for cocoa is CFAF2,524 billion. For the coffee sector, annual producer profit falls from CFAF48 billion to CFAF34 billion, in 1987 prices. The cumulative surplus is CFAF537 billion. The net government balance from cocoa is in deficit in most years (figure 3), with the projected cumulative deficit for the full horizon being a massive CFAF1,957 billion. The annual deficit becomes smaller from 1992 onward, when the world cocoa price is projected to improve. For coffee the cumulative deficit is just CFAF26 billion (figure 4). Real cocoa export revenues are projected to increase from $743 million in 1990 to $1,340 million in 2000, while real coffee export revenues are expected to decline from $436 million to $406 million during the same period. Figures 5 and 6 show net producer revenue from cocoa and coffee. Quantitatively, these results indicate a considerably worse outlook than in Akiyama (1988), especially for government revenue (figures 3 and 4). The difference from Akiyama's results arises partly because lower average projected cocoa prices are used here. The continuation of current pricing policies implies massive deficits and, consequently, serious liquidity problems for the government.

Simulation of producer price changes at an unchanged exchange rate. The simulation reported here is for a policy of reducing the producer price of cocoa by 40 percent and of coffee by 10 percent. These reductions appear to be the minimum required, at an unchanged exchange rate, to produce modest government surpluses (of CFAF113 billion and CFAF90 billion for cocoa and coffee, respectively) for the full 14-year period and to lead to a diversification away from cocoa and into coffee and other crops.

Under this pricing policy, the sum of revenue for the government and profits for the cocoa and coffee producers for the full 14 years is CFAF2,292 billion compared with CFAF1,078 billion in the base run. Although this is an aggregate improvement, it is accompanied by massive changes in the relative sizes of the cocoa and coffee sectors, thereby precluding unambiguous statements about the welfare effects of such a policy. The cocoa sector's accumulated profit declines from CFAF2,524 billion in the base run to CFAF909 billion, while the coffee sector's accumulated profit increases from CFAF537 billion to CFAF1,179 billion. The net government balance from cocoa is not positive in every year, but for the period as a whole it is a surplus of CFAF113 billion, compared with an accumulated deficit of CFAF1,957 billion in the base run.

Cocoa production declines sharply with the change in relative prices, peaking at 623,000 tons in 1995 and declining to 585,850 tons in 2000. Relative to the base simulation, cocoa production is 38 percent lower by 2000. Côte d'Ivoire's share of the world cocoa market falls to 24 percent in the year 2000 compared with nearly 33 percent in the base run. Coffee production increases and by 2000 exceeds the base case by about 5 percent. As a consequence of the reduction in Ivoirien cocoa production, world prices throughout the period are significantly

---

1. A billion is 1,000 million.
Figure 3. Projected Net Government Balance from Cocoa under Three Price Rules

Billions of CFA francs

Source: Authors' calculations.

Figure 4. Projected Net Government Balance from Coffee under Three Price Rules

Billions of CFA francs

Source: Authors' calculations.
Figure 5. Projected Net Producer Revenue from Cocoa under Three Price Rules

Billions of CFA francs

Source: Authors' calculations.

Figure 6. Projected Net Producer Revenue from Coffee under Three Price Rules

Billions of CFA francs

Source: Authors' calculations.
higher than those in the base simulation, exceeding the base world price by 9.4 percent in 2000.

Simulation of a 50 percent devaluation with no change in producer prices. If a 50 percent devaluation is adopted, there will be an immediate improvement in the net government balance. Because relative prices are unchanged, the sizes of the cocoa and coffee sectors are unaffected. The cocoa surplus is nearly CFAF350 billion in 1987; it declines steadily (as the world price declines) to a deficit of CFAF2.3 billion in 1992 and then improves steadily to a surplus of more than CFAF260 billion in 2000. Similarly, the coffee surplus also improves sharply; between 1990 and 2000 it rises steadily from about CFAF56 billion to about CFAF94 billion. The cumulative surpluses over the simulation period are CFAF226 billion for cocoa and CFAF872 billion for coffee. Indeed the surplus would persist even if the coffee producer price were raised by 10 percent, 20 percent, or even 30 percent over the base case price. Therefore devaluation of the CFA franc represents a powerful option for dealing with the problem of persistent net government deficits.

Simulation of a moving average producer price system. To reduce producer price variability, some economists, for example, Mirrlees (1988), have suggested various forms of price adjustment in which changes in the producer price are some small fraction of the change in the expected world price; that is, producers are offered high, but not full, insurance. An example of such an adjustment rule is a moving average price in which the producer price equals a proportion of the moving average of the expected world price.

The effects of instituting a three-year lagged moving average pricing rule were simulated, with producers receiving 70 percent of the average world price. A strong assumption is made that the supply response and the rest of the model will remain unchanged by such a switch in the pricing rule. Although the supply response may change, the absence of any historical experience makes it difficult to make concrete alternative assumptions. Without the price insulation previously provided by the government, the producer surplus and the government deficit will be reduced when the market price falls below the price guaranteed in the base run. This rule amounts to paying the producers in some years approximately one-third of the price of cocoa in the base run. Relative to the base run there is a sharp reduction in cocoa producer surplus and an increase in the average annual coffee surplus. On average the government runs surpluses on its cocoa and coffee accounts.

Sensitivity Analysis

To examine the robustness of the conclusions of the simulations, sensitivity analysis was undertaken. Variations in the length of the policy horizon, the use of discounting when aggregating revenues over time, and variations of the assumption about the shutdown price did not lead to significant changes in simula-
tion results. The main focus of sensitivity analysis is on alternative settings of the key elasticities. However, the use of a simulation design in which the key elasticities are varied over a grid of values, one at a time, typically leads to a large volume of simulation output. To summarize this, a response surface was estimated. This involved estimating regression equations that described how the changes in certain key parameters generated changes in the variables of interest. The regression coefficients and their t-statistics indicated the size and statistical significance of the sensitivity. The key parameters in the present context were the sum of the absolute values of world supply and demand elasticities, the Ivoirien supply elasticities for cocoa and coffee, the planting elasticities for cocoa and coffee, and the percentage reductions in the producer prices of cocoa and coffee.

The sensitivity of key variables to parameter variation within and between two regimes—the fixed producer price (FPP) regime and the moving average price (MAP) regime—was investigated. For the FPP case, beginning with the base run setting, the sum of world supply and demand elasticities was varied from 0.10 to 0.60 in steps of 0.05, the cocoa price reduction was varied from 0 to 70 percent in steps of 10 percentage points, and the coffee price reduction was varied from 30 to 60 percent, also in steps of 10 percentage points. Thus 800 combinations were used. These changes also induced variation in Ivoirien planting and supply elasticities because these elasticities vary with the producer price, as described in tables 1 and 2. For the MAP case the procedure used was similar except that the percentage of the lagged three-year moving average world price that is paid to the cocoa and coffee producers was varied from 40 to 80 percent in steps of 10 percentage points—a procedure that, together with the 10 settings of the sum of world supply and demand elasticities, yielded 250 distinct parameter combinations. Post simulation, response surface regression equations were estimated with four dependent variables: aggregate net government balance from cocoa and from coffee and aggregate net producer profit from cocoa and from coffee. The regression results are shown in tables 3 and 4. A tight fit of the regression indicates that the included parameter settings provide a good explanation of the simulation variance of the variables of interest, and large t-statistics indicate that sufficient independent variation in parameter settings was allowed for in the simulation design.

In the fixed-price case (table 3) producers are sheltered from variations in the world price, so that only the net government balance from cocoa is sensitive to variations in the sum of world supply and demand elasticities. The higher this sum, the lower the tax yield is from a given reduction in producer price relative to the base run. Similarly, the higher the own-price supply elasticity, the lower the tax yield is for a given tax setting. Relative to the other elasticities, sensitivity to the planting elasticities was found to be quite small. The sensitivity of net government balance for cocoa and coffee to cross elasticities, while statistically significant in the case of cocoa (but not coffee) is smaller than for own-price elasticities. For the producer profit regressions, there is again significant sensitivity to the value of supply elasticities, with larger absolute values of these
Table 3. *Estimation Results for the Response Surface Regressions for Fixed Producer Price Regime*

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Percentage fall in cocoa price</th>
<th>Percentage fall in coffee price</th>
<th>Sum of world supply and demand elasticities</th>
<th>Ivoirien cocoa supply elasticity</th>
<th>Ivoirien cocoa planting elasticity</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net government balance from cocoa</td>
<td>$1.02 \times 10^4$</td>
<td>$-2.17 \times 10^2$</td>
<td>$-1.16 \times 10^1$</td>
<td>$-1.04 \times 10^4$</td>
<td>$-1.89 \times 10^3$</td>
<td>0.978</td>
</tr>
<tr>
<td></td>
<td>(7.23)</td>
<td>(9.83)</td>
<td>(22.89)</td>
<td>(45.86)</td>
<td>(1.18)</td>
<td></td>
</tr>
<tr>
<td>Net government balance from coffee</td>
<td>$-21.18$</td>
<td>$8.67 \times 10^2$</td>
<td>0.0</td>
<td>1.83</td>
<td>$-0.37$</td>
<td>0.930</td>
</tr>
<tr>
<td></td>
<td>(0.026)</td>
<td>(83.51)</td>
<td>(0.0)</td>
<td>(0.0197)</td>
<td>(0.0)</td>
<td></td>
</tr>
<tr>
<td>Net cocoa producer profit (in logs)</td>
<td>$-12.90$</td>
<td>1.51</td>
<td>0.0</td>
<td>$-12.49$</td>
<td>$-19.42$</td>
<td>0.980</td>
</tr>
<tr>
<td></td>
<td>(8.60)</td>
<td>(64.06)</td>
<td>(0.0)</td>
<td>(61.59)</td>
<td>(11.21)</td>
<td></td>
</tr>
<tr>
<td>Net coffee producer profit (in logs)</td>
<td>6.18</td>
<td>$-4.72$</td>
<td>0.0</td>
<td>$-2.23$</td>
<td>2.77</td>
<td>0.900</td>
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<tr>
<td></td>
<td>(1.08)</td>
<td>(60.50)</td>
<td>(0.0)</td>
<td>(4.15)</td>
<td>(0.43)</td>
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</tbody>
</table>

*Note: Absolute values of t-statistics are in parentheses.
Source: Authors' calculations.*
<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>World price of cocoa</th>
<th>World price of coffee</th>
<th>Sum of world supply and demand elasticities</th>
<th>Ivoirien cocoa supply elasticity</th>
<th>Ivoirien coffee supply elasticity</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net government balance from cocoa</td>
<td>$-4.43 \times 10^3$</td>
<td>$-94.09$</td>
<td>$2.40 \times 10^2$</td>
<td>$-4.41 \times 10^3$</td>
<td>8.01</td>
<td>0.993</td>
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<tr>
<td></td>
<td>(72.07)</td>
<td>(1.11)</td>
<td>(12.78)</td>
<td>(35.70)</td>
<td>(0.08)</td>
<td></td>
</tr>
<tr>
<td>Net government balance from coffee</td>
<td>$-37.48$</td>
<td>$-1.74 \times 10^3$</td>
<td>3.09</td>
<td>23.90</td>
<td>$-1.55 \times 10^3$</td>
<td>0.999</td>
</tr>
<tr>
<td></td>
<td>(21.41)</td>
<td>(495.00)</td>
<td>(3.48)</td>
<td>(9.45)</td>
<td>(389.00)</td>
<td></td>
</tr>
<tr>
<td>Net cocoa producer profit (in logs)</td>
<td>0.47</td>
<td>$-2.52$</td>
<td>0.57</td>
<td>$-5.82$</td>
<td>1.20</td>
<td>0.997</td>
</tr>
<tr>
<td></td>
<td>(6.98)</td>
<td>(17.68)</td>
<td>(18.34)</td>
<td>(61.73)</td>
<td>(7.39)</td>
<td></td>
</tr>
<tr>
<td>Net cocoa producer profit (in logs)</td>
<td>$-2.29$</td>
<td>$-4.13$</td>
<td>0.51</td>
<td>$-0.58$</td>
<td>$-13.23$</td>
<td>0.994</td>
</tr>
<tr>
<td></td>
<td>(12.32)</td>
<td>(14.71)</td>
<td>(5.64)</td>
<td>(2.40)</td>
<td>(36.82)</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Absolute values of t-statistics are in parentheses.  
**Source:** Authors' calculations.
elasticities leading to larger reductions in producer revenues when producer price is reduced.

The most obvious difference between the MAP case (table 4) and the FPP case is that in the MAP case, all government and producer revenues are sensitive to the sum of world supply and demand elasticities; larger values are associated with higher (not lower) revenues. Because the moving average rule generates a different time path of producer prices from the fixed price cases, however, caution must be exercised in comparing the regimes. Once the government no longer provides full-price insurance to producers, export tax revenues are less sensitive to the sum of world supply and demand elasticities, whereas producer revenues are considerably more sensitive. As in the fixed price case, government and producer revenues are again sensitive to the domestic supply elasticities.

The response surface estimates indicate that comparisons of producer and government revenues under alternative tax rates in the MAP regime are sensitive to the elasticity assumptions. Only government revenues are sensitive to elasticity assumptions in the FPP regime, but even that sensitivity is greater in the MAP case relative to the FPP case. This conclusion does not invalidate the exercise undertaken here but warns of the importance of the numerical assumptions in this article.

V. THE CHOICE BETWEEN ALTERNATIVE POLICIES

In choosing a pricing policy, several tradeoffs must be considered. First, if the relative producer price is varied in Côte d'Ivoire, there will be short- and long-run changes in the producer revenues in the two sectors. The difference between short- and long-run changes reflects the latter's incorporation of the supply response. Second, there will be both a direct and an indirect impact on short- and long-run government revenues; the direct impact comes from changes in production and exports at the constant world price, and the indirect impact comes from a change in the world price resulting from the change in Côte d'Ivoire's share of world cocoa production. To illustrate the tradeoffs, two cases were considered. In the first the cocoa producer price was cut to 40 percent below the base price and kept at that lower level, while the coffee price change was varied between a cut of 60 percent and an increase of 30 percent. In the second case the coffee price was cut to 10 percent below the base price and kept at that lower level, while the cocoa price cut was varied between 0 and 70 percent. Figures 7 and 8 show the effect of each combination of price changes on sectoral revenues during the 14-year time horizon. From these figures one can easily infer the tradeoff between the revenues of the two producing sectors and the tradeoff between the government revenue, on the one hand, and total producer revenue, on the other. Because the net government balance schedule is steeper in figure 8 than in figure 7, we can infer that revenue is more readily affected by a given change in the price of cocoa rather than of coffee. Furthermore, because devaluation of the CFA franc will shift the net government balance
Figure 7. Aggregate Sectoral Revenues with Cocoa Price Cut Held at 40 Percent

Billions of CFA francs

3,924

Cocoa revenue

1,962

Coffee revenue

Net government balance

Source: Authors' calculations.

Figure 8. Aggregate Sectoral Revenues with Coffee Price Cut Held at 10 Percent

Billions of CFA francs

3,106

Cocoa revenue

1,553

Coffee revenue

Net government balance

Source: Authors' calculations.
schedule to the right, it will always improve the tradeoff between government and producer revenues.

In analyzing these tradeoffs, however, the possibilities for substituting alternative productive activities for cocoa and coffee production must be considered. There is a danger of exaggerating the impact of pricing policy on producers' welfare. Analogously, there is a danger of underestimating the impact on net government revenues as a consequence of producers shifting out of cocoa and coffee because of (say) reductions in prices. The empirical importance of this point depends upon the extent of substitute activities.

The analysis offered here may be combined with the optimal tax approach, in which the optimal tax rate is the reciprocal of the country's demand elasticity for a commodity, defined earlier as $E_d$. With Côte d'Ivoire's world cocoa market share at 0.3, the world elasticity of demand at 0.25, and the world elasticity of supply at 1.2, the optimal cocoa tax rate is estimated to be 27 percent. For coffee, if the market share is 0.04, the world elasticity of demand 0.25, and the world elasticity of supply 0.8, the optimal tax rate for coffee is 4 percent. (Because the period is 14 years, the supply elasticities are relatively large.) Thus this approach leads to substantially different tax rates for cocoa and coffee.

VI. Summary

This article has presented an approach to evaluating pricing policies for perennial crops. The main contribution is the development of a flexible computational model, which incorporates important features of perennial crop production that are not captured by other (usually static) frameworks. Applied to cocoa and coffee pricing in Côte d'Ivoire, the framework has produced sensible and plausible scenarios as well as useful descriptions of revenue tradeoffs. The study has highlighted many of the key issues that arise from considering major changes in the rules used to set domestic producer prices. It has not produced an unambiguously best policy but has identified several that improve substantially on the present situation, thus generally indicating the desirability of a lower tax on coffee than on cocoa.

The conclusions about Côte d'Ivoire policy are necessarily conditional on the assumptions about the future time paths of world cocoa and coffee prices and the choice of a 14-year policy horizon. The base scenario is characterized by massive deficits in the government cocoa account, rising cocoa production, and declining coffee production. If this scenario is to be avoided, clearly policy changes are needed. At an unchanged exchange rate, reducing the cocoa price about 40 percent and the coffee price about 10 percent would eliminate the government deficits on cocoa and coffee. To generate positive tax revenue, therefore, the price cuts would have to be larger. The devaluation of the CFA franc in conjunction with price cuts, or even on its own, would be a powerful way to reduce government deficits. This is, not surprisingly, a robust finding.

In October 1989 the Ivoirien government announced changes in the pricing of
cocoa and coffee, which, beginning with the 1989/90 growing season, would reduce the nominal cocoa producer price by 50 percent and the nominal coffee price by about 45 percent. A simulation of this policy shows that if it is maintained, the cocoa sector would continue to grow, but coffee production would decline even though the projected world price outlook for coffee is relatively more favorable than that for cocoa. Also, whereas the net government balance will be much improved, the deficit on cocoa will not be eliminated in every year, given the current projection of world cocoa price.

The scenario generated by the newly announced policy has some undesirable features, such as maintaining domestic relative prices or perhaps even distorting them further from their respective marginal export revenues. The consequences of this policy would be especially unfortunate if the projections of future cocoa and coffee prices do in fact materialize. The new policy may yield more tax revenue than would result from the adoption of the moving average price rule, with cocoa and coffee producers receiving 73 and 96 percent of the world price, respectively, but at the cost of a significant decline in coffee production. It is possible that aggregate producer and government revenues could be substantially lower. The simulation results based on the three-year moving average price rule show that such a policy effectively eliminates the large government deficits. However, since the projected outlook for cocoa prices is poor until the mid-1990s, the production of cocoa would decline very significantly under such a policy, even if the producers were paid a high proportion of the world price.

The system of setting producer prices in Côte d'Ivoire has parallels in many other countries and with many other crops (Varangis, Akiyama, and Thigpen 1989). Therefore the method and the results of this report have relevance extending beyond Côte d'Ivoire. Given a suitable data base, the present approach, suitably modified, can be applied to other countries with important perennial crops.

References

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The Short- and Long-Run Effects of Fiscal Policy

Edward F. Buffie

This article develops a dynamic, dual-economy general equilibrium model that can be adapted to analyze the short- and long-run effects of a variety of fiscal policies. The model provides a complete description of how the private capital stock, underemployment, and real wages evolve during the adjustment process. The main policy message conveyed by the results is that the method by which the fiscal deficit is lowered is important. There is a strong presumption that higher prices for publicly produced intermediate inputs and cutbacks in government expenditure to support social infrastructure will reduce private investment, real wages in both the formal and informal sectors, and the share of the labor force employed in the high-wage manufacturing sector. By contrast, layoffs in the final goods and services sectors can potentially improve the external balance without sacrificing output and employment growth.

A central dilemma facing policymakers in developing countries today is how to revive economic growth while maintaining debt service. After the debt crisis in 1981–82, IMF-type stabilization programs were widely adopted. Austerity measures along with high interest rates and recession in the countries of the Organisation for Economic Co-operation and Development led to sharp reductions in real output in most debtor nations. The real side repercussions of macro-economic austerity have cut deeper and been more damaging than was anticipated by many observers (Sachs 1989).

Two striking aspects of the adjustment after 1982 in many developing countries have been the collapse of investment (both public and private) and the sharp increase in underemployment. Table 1 provides data on real per capita growth rates of gross domestic product (GDP) and investment in 15 major debtor nations and in developing countries not burdened by debt service problems. The investment rate in the major debtor nations fell 32 percent between 1981 and 1984. It has increased slightly since 1984 but remains some 10 points below the average investment rate in countries not experiencing debt-servicing difficulties.

Low rates of growth and investment have been accompanied by rising underemployment. Public sector layoffs and stagnation in the industrial sector have
Table 1. *Per Capita Growth and Investment, 1980–89*

<table>
<thead>
<tr>
<th>Year</th>
<th>Major debtors</th>
<th>Developing countries without debt servicing problems</th>
<th>Major debtors</th>
<th>Developing countries without debt servicing problems</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>3.1</td>
<td>3.5</td>
<td>24.2</td>
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</tr>
<tr>
<td>1981</td>
<td>−2.6</td>
<td>3.2</td>
<td>23.5</td>
<td>27.8</td>
</tr>
<tr>
<td>1982</td>
<td>−2.5</td>
<td>2.7</td>
<td>21.6</td>
<td>27.0</td>
</tr>
<tr>
<td>1983</td>
<td>−4.7</td>
<td>4.6</td>
<td>17.1</td>
<td>27.1</td>
</tr>
<tr>
<td>1984</td>
<td>—</td>
<td>5.4</td>
<td>16.0</td>
<td>27.0</td>
</tr>
<tr>
<td>1985</td>
<td>1.6</td>
<td>4.3</td>
<td>16.8</td>
<td>28.6</td>
</tr>
<tr>
<td>1986</td>
<td>1.9</td>
<td>3.8</td>
<td>17.2</td>
<td>28.3</td>
</tr>
<tr>
<td>1987</td>
<td>0.1</td>
<td>4.3</td>
<td>17.4</td>
<td>27.7</td>
</tr>
<tr>
<td>1988</td>
<td>−1.1</td>
<td>6.7</td>
<td>17.0</td>
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</tr>
<tr>
<td>1989b</td>
<td>−1.4</td>
<td>3.2</td>
<td>17.3</td>
<td>27.5</td>
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— Not available.

a. Average figure for 1970–82.
b. Preliminary figures.

*Source:* International Monetary Fund (various years).

greatly slowed or brought to a halt employment growth in the principal high-wage sectors of the economy. It is particularly noteworthy that higher unemployment has often occurred in conjunction with large decreases in real wages. Tables 2 and 3 show that in several Latin American countries industrial employment declined during the 1980s despite real wage cuts of 10–30 percent.

Although the adjustment process has proven to be quite lengthy, there is little formal analysis in the existing literature of the long-run repercussions of stabilization policy. Few development macromodels afford a perspective that stretches beyond the short run (Arida and Taylor 1989). Public finance theorists have analyzed the interdependence of public and private investment but not in a context that sheds light on the adjustment problems facing developing countries. Most of this literature seeks only to determine the implications for the social discount rate of distortionary taxes and different types of government budget constraints (Boadway 1978; Pestieau 1974, 1975; Marchand, Pestieau, and Weymark 1982; Yoshida 1986). Moreover the orientation in the literature is largely static. Arrow and Kurz (1970) and Boadway (1978) are exceptions, but their dynamic analysis is based on dubious, ad hoc specifications for private investment. None of the literature allows for labor market distortions of the type seen in developing countries or develops an explicit dynamic analysis of capital accumulation consistent with optimizing behavior in the private sector.

This article develops a dynamic, dual-economy general equilibrium model that can be adapted to analyze the short- and long-run effects of a variety of fiscal policies. The dynamics are grounded in optimizing behavior and provide a complete description of how the stock of private capital, sectoral employment, and real wages evolves during the adjustment process. The focus is on fiscal policy because fiscal adjustment has been a prominent part of many recent
stabilization programs, and there appears to be a strong, direct link between labor market developments and certain types of fiscal policies.

The main policy message conveyed by the results is that the success of the adjustment program depends in large part on the method by which the fiscal deficit is lowered. Certain fiscal measures commonly adopted in highly indebted countries produce contractionary supply-side effects. There is a strong presumption that higher prices for publicly produced intermediate inputs and cutbacks in government expenditure to support social infrastructure will reduce employment in the high-wage manufacturing sector and lower the equilibrium capital stock. Labor bears the brunt of the difficult adjustment as lower employment in manufacturing is accompanied by (possibly large) real wage cuts in both the formal and informal sectors.

Table 2. Industrial Employment in Highly Indebted Latin American Countries, 1981–88

(1980 = 100)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
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<td>87.4</td>
<td>82.8</td>
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<td>90.7</td>
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<td>90.4</td>
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<td>96.2</td>
<td>99.3</td>
<td>99.8</td>
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<td>84.4</td>
<td>83.4</td>
<td>88.4</td>
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</tr>
<tr>
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<td>102.0</td>
<td>100.3</td>
<td>98.9</td>
<td>99.9</td>
<td>102.6</td>
<td>110.7</td>
<td>119.3</td>
</tr>
</tbody>
</table>

a. Industrial employment in the nine major metropolitan areas.
b. Manufacturing employment in the Lima metropolitan area.

Table 3. Average Real Wages in Highly Indebted Latin American Countries, 1981–88

(1980 = 100)

<table>
<thead>
<tr>
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<td>127.1</td>
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<td>Costa Rica</td>
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<td>70.8</td>
<td>78.5</td>
<td>84.7</td>
<td>92.2</td>
<td>97.8</td>
<td>89.2</td>
<td>87.5</td>
</tr>
<tr>
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<td>104.4</td>
<td>80.7</td>
<td>75.4</td>
<td>76.6</td>
<td>72.3</td>
<td>72.8</td>
<td>n.a.</td>
</tr>
<tr>
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<td>110.2</td>
<td>93.4</td>
<td>87.2</td>
<td>77.6</td>
<td>97.5</td>
<td>101.3</td>
<td>77.4</td>
</tr>
<tr>
<td>Uruguay</td>
<td>107.5</td>
<td>107.1</td>
<td>84.9</td>
<td>77.1</td>
<td>88.1</td>
<td>94.0</td>
<td>98.5</td>
<td>99.7</td>
</tr>
</tbody>
</table>

Note: Figures are usually for workers employed in manufacturing or industry. For more detailed descriptions of the individual wage series, see the notes to table 11 in United Nations 1988.
a. Preliminary figures.
b. Average real wage in basic industry in Rio de Janeiro.
By contrast layoffs in the final goods and services sectors can potentially improve the external balance without sacrificing output and employment growth. The layoffs stimulate investment by returning real resources to the private sector. Private capital accumulation eventually creates enough new employment in the high-wage manufacturing sector to fully compensate for the loss of public sector jobs; in the long run, real output is higher and formal sector employment and real wages are unchanged.

The article is organized into seven sections. Sections I to III develop the basic model and analyze the impact of public sector price hikes and employment cuts. Section IV investigates the repercussions of reducing infrastructure investment. Section V contrasts the adjustment processes associated with the different fiscal measures and discusses the extent to which capital decumulation and lower employment in the high-wage sectors increase the cost of adjustment. Section VI examines how the results change when endogenously varying tax revenues make the fiscal and real adjustment mechanisms interdependent. Section VII expands on the broad policy implications of the analysis.

I. A Pure Supply-Side Model

The models in this and subsequent sections highlight the supply-side effects of fiscal austerity. To abstract from demand-side complications, I assume the economy is small and completely open. Two traded goods are produced: an agricultural export good and a manufactured good. The price of each good is fixed at unity. Production in the manufacturing sector requires labor, capital, and an intermediate input (such as gas or electricity) purchased from the public sector. The agricultural good is produced by just labor and land. Introducing capital and intermediates as factors in the agricultural sector does not substantively alter the results, provided the manufacturing sector is relatively capital- and intermediates-intensive.

Numerous empirical studies conclude that sectoral wage differentials in developing countries are far too large to be explained by the payment of compensating differentials (Gregory 1975; Merrick 1976; Squire 1981, chapters 7 and 8; Mazumdar 1976, 1989a, 1989b; House 1984; Portes, Blitzer, and Curtis 1986; Gindling 1989). The labor market is highly dualistic, with wages in the modern formal sectors sometimes being more than double those paid elsewhere in the economy. In keeping with the findings of these studies, the agricultural sector in the model is equated with the low-wage informal sector; government and manufacturing comprise the high-wage formal sector. A genuine labor market distortion thus exists because there is too little employment in private manufacturing relative to agriculture.

Although the sectoral wage gap generates underemployment, there is no open unemployment. All those unable to obtain work in the government or manufacturing sectors are employed in the agricultural sector, where the wage adjusts to clear the market. The labor market is represented by equation 1:
where \( L^m, L^x, \) and \( L^g \) denote employment in manufacturing, agriculture, and the public sector, respectively, and \( L \) denotes total labor supply. Total labor demand consists of private sector labor demand plus public sector employment. The total supply of labor is constant.

The most troublesome issue in modeling the labor market concerns the appropriate way to make the manufacturing sector wage endogenous. In theory it may be set in implicit contracts to provide insurance to workers by unions, by socio-political norms embodied in minimum wage laws, or by efficiency wage considerations. Unfortunately, empirical work on the wage-setting process in developing countries is scarce and does not single out one theory as clearly superior. Furthermore, although the aforementioned theories may explain wage rigidity in manufacturing, the only restriction they place on how the wage responds to various shocks is that, other things being equal, the manufacturing sector wage should be positively related to the agricultural sector wage. As neither theory nor empirical studies offer much guidance, I choose a particularly simple specification

\[
\hat{w}^m = bw^x,
\]

where \( w^m \) and \( w^x \) denote wages in manufacturing and agriculture, respectively, a circumflex indicates a percentage change in a variable, and \( b \) is constant (and positive to ensure the existence of a steady state). This specification is consistent with the Solow condition (when \( b = 1 \)) in efficiency wage models and with certain variants of the optimizing union model. The parameter \( b \) plays a crucial role in the adjustment process because it determines the degree of real wage rigidity in manufacturing. If \( b = 1 \), the labor market is distorted by a sectoral wage gap, but both agriculture and manufacturing are flex-wage sectors. However, when \( b \) is small the real wage in the formal sector is largely impervious to economywide employment conditions. More of the burden of adjustment to contractionary policies is then borne by wage cuts in the informal sector and increases in underemployment (that is, greater layoffs in the manufacturing sector).

Firms are perfectly competitive and operate with technologies characterized by constant returns to scale. The zero profit condition is therefore satisfied in each sector

\[
1 = C^m(w^m, r, P)
\]
\[
1 = C^x(w^x, \nu)
\]

where \( C^m \) and \( C^x \) denote the unit cost function in the manufacturing and agricultural sector, respectively; \( r \) and \( \nu \) are the capital and land rentals; and \( P \) is the price of the intermediate input purchased from the public sector.

For simplicity I assume technology in each sector can be represented by a
(non-nested) constant elasticity of substitution (CES) production function. Private sector demands for manufacturing and agricultural labor and for the intermediate input (denoted by $Z$) are then (in percentage changes)

\begin{align}
L_m^m &= -\sigma^m \frac{1 - \theta_Z}{\theta_K} \dot{w}^m - \sigma^m \frac{\theta_Z}{\theta_K} \dot{p} + \dot{K} \\
L_s^s &= -\frac{\sigma^s}{\theta_T} \dot{w}^s \\
Z &= -\sigma^m \frac{\theta_L}{\theta_K} \dot{w}^m - \sigma^m \frac{1 - \theta_L}{\theta_K} \dot{p} + \dot{K}
\end{align}

where $\sigma^m$ and $\sigma^s$ are elasticity of substitution in the manufacturing and agricultural sectors, respectively; $\theta_L$, $\theta_Z$, and $\theta_K$ are, respectively, the cost shares of labor, the intermediate input, and capital in the manufacturing sector; $\theta_T$ is the cost share of land in the agricultural sector; and $K$ denotes capital. The only characteristic of CES technology that is important for the results that follow is gross complementarity of factors (that is, an increase in the price of the intermediate input lowers demand for labor and capital in manufacturing). This is not a particularly strong restriction to place on technology. According to production theory, factors are normally gross complements (Rader 1968). Empirical studies also find, with rare exceptions, that complementarity holds.

Capital accumulation is governed by factor returns and the intertemporal preferences of a representative, infinitely-lived family firm. The firm is endowed with perfect foresight and chooses investment to maximize an additively separable utility function

\begin{align}
\text{Max}_{\{E, I\}} \int_0^\infty V(E)e^{-\rho t}dt
\end{align}

subject to

\begin{align}
E + I &= R(K, L^m, L^s, P) + w^s L^s - T \\
K &= I - \delta K,
\end{align}

where $E$ is aggregate consumption expenditure, $I$ is investment, $T$ is a lump-sum tax, $\rho$ is the pure rate of time preference, $w^s$ is the public sector wage, $\delta$ is the depreciation rate, and an overdot signifies a time derivative. Current utility is represented by an increasing, strictly concave indirect utility function $V(\cdot)$.

Equation 9, the budget constraint, states that consumption and investment spending must equal disposable income. (Neither the private agent nor the government has access to foreign credit.) On the right side, private sector value added is measured by the value added function $R(\cdot)$, in which the fixed total supplies of labor and land are suppressed. The value added function has the
usual properties that an increase in the capital stock raises real output by an amount equal to the real capital rental and an increase in the real price of the intermediate input lowers output by an amount equal to the initial demand for intermediates. Also, since employment increases in other sectors of the economy come at the expense of employment in agriculture, higher public sector employment lowers private value added by an amount equal to the agricultural wage, while the marginal gain from expanding employment in manufacturing is measured by the existing sectoral wage gap \((w^m - w^x)\).

The government must respect the budget constraint

\[ w^g L^g + D = PZ + T \]

where \(D\) denotes debt service. Total public sector expenditure is the sum of the wage bill and debt service (net of new capital flows). The profile of debt service is determined by negotiations with foreign creditors and is treated as strictly exogenous. The public sector wage is constant, and, of the \(L^g\) workers hired by the government, \(L_1\) are employed in producing the intermediate input \([Z = Z(L_1)]\). But although \(L_1\) is endogenous, the extent to which public sector employment varies with private sector demand for the intermediate input is a policy variable. When the demand for intermediates contracts, labor needed by the parastatal sector falls by \(dL_1 = (Z/Z') \dot{Z}\), whereas the change in total public sector employment is

\[ dL^g = \beta(Z/Z') \dot{Z}, \quad 0 \leq \beta \leq 1. \]

\(\beta\) defines the government’s layoff policy. When \(\beta < 1\), redundant labor is kept on the payroll or transferred to other activities where it produces “government services.” In either case the short- and long-run results and the qualitative nature of the dynamics are unchanged.

Government revenue derives from two sources: a lump-sum tax \((T)\) and sales of the intermediate input \((PZ)\). The unrealistic assumption of a lump-sum tax is made at this point to simplify the analysis. The impact on the budget of variations in private sector demand for the intermediate input is offset by adjustments in the lump sum tax so that higher debt service can be dealt with by a one-time adjustment in the price of the intermediate.

Equations 1 to 12 form the complete model. Since private sector saving and investment are equal, the trade balance is \(PZ + T - w^g L^g = D\); thus the overall balance of payments equals zero. In what follows, debt service increases from an initial value of zero and a fiscal instrument is adjusted to extract the required trade surplus.

II. THE SHORT- AND LONG-RUN IMPACTS OF PUBLIC SECTOR PRICE INCREASES ON OUTPUT, EMPLOYMENT, AND REAL WAGES

The manipulations involved in solving a perfect foresight general equilibrium model are straightforward but also lengthy and tedious. To keep the main ideas
clearly within view, the exposition here is mostly verbal and graphical. Solution
procedures for the short- and long-run outcomes and proofs of saddle point
stability may be found in a more technical version of the article that is available
from the author upon request.

The Short-Run Impact

An increase in the price of the intermediate input lowers labor demand in
private manufacturing and in the parastatal sector at existing wages. Aggregate
high-wage employment thus contracts, forcing the agricultural wage to
decrease.

Labor demand in the manufacturing sector is subject to two conflicting ef-
fects. While the decrease in the agricultural wage triggers a fall in the manufactur-
ing sector wage, the higher price of intermediates shifts the labor demand
schedule to the left. Employment rises or falls depending on whether

\[ \sigma^m > \frac{L_x(1 - s)\theta_L}{L^m \theta^m b^2} \]

where \( s = (\omega^m - PZ')/\omega^m \) denotes the percentage gap between the marginal
product of labor in private manufacturing and in the parastatal sector. If \( b^2 \) is
small either because the government maintains the level of public sector employ-
ment \( (\beta = 0) \) or because the manufacturing sector wage responds weakly to
changes in the agricultural wage \( (b \) is small), the adverse productivity effect
domines, and manufacturing sector employment declines. More generally,
employment in both high-wage sectors is likely to contract unless technology is
far more flexible in manufacturing than in agriculture. Since the share of the
labor force employed in private manufacturing is small \( (\text{the ratio of agricultural
to manufacturing sector employment generally lies between two and seven}) \),
the term multiplying the elasticity of substitution in the agricultural sector \( (\sigma^x) \) in
expression 13 will usually be quite large.\(^1\) Even when the government takes a
tough line on layoffs \( (\beta = 1) \), real wages are equally flexible in the formal and
informal sectors \( (b = 1) \), and the productivity gap between labor in the public
and private manufacturing sectors is 50 percent \( (s = 0.5) \), the elasticity of
substitution in the manufacturing sector has to be substantially larger than the
elasticity of substitution in the agricultural sector in order for employment in the
manufacturing sector to increase.

Dynamics and the Long-Run Impact

The adjustment process stretches beyond the short run because fiscal austerity
affects the incentive to accumulate capital. As investment gradually alters the

---

\(^1\) In 1980 the employment share of the industrial sector \( (\text{a rough proxy for the employment share of the formal sector}) \) was 13 percent in low-income developing countries, 23 percent in middle-income developing countries, and 31 percent in upper middle-income developing countries. In our dual economy model, the corresponding values for \( L^x/L^m \) are 6.7, 3.4, and 2.3.
capital stock, the temporary equilibrium is displaced and further changes occur in real output, sectoral labor demands, and real wages.

The important qualitative features of the adjustment process are depicted in figure 1. The steady state is a saddle point with a unique convergent path to equilibrium. In the first quadrant the positively sloped \( KK \) schedule shows the set of points for which net investment is zero. Above \( KK \) net investment is positive and the capital stock is increasing; below the schedule, the capital stock is falling. The saddle path \( SS \) may be positively or negatively sloped. Regardless of the slope of \( SS \), the capital stock approaches its steady-state level monotonically.

The \( WW \) and \( LL \) schedules in the third and fourth quadrants complete the description of the equilibrium path. These schedules track the paths of the agricultural wage and high-wage sector employment as the economy traverses the saddle path \( SS \). Both schedules are positively sloped because an increase in the capital stock bids up the market clearing value of the agricultural wage by raising labor demand in the high-wage sectors.

**Figure 1. Major Qualitative Features of the Adjustment Process**

![Diagram showing the adjustment process](image-url)
The dynamics of the adjustment process depend entirely on how the policy package affects the steady-state capital stock. Across steady states
\[
\frac{\dot{K}}{\dot{P}} = \left[ \sigma^m(s + \beta - 1) - \sigma^x \frac{L^x(1 - s)}{L^m \theta_T b} \right] \frac{\theta_Z}{N}
\]
where \( N = \theta_L(1 - s) + \beta \theta_Z \).

The impact on the equilibrium capital stock depends on whether the increase in the price of the intermediate and the induced decrease in the manufacturing sector wage combine to raise or lower the profitability of investment. Although initial conditions (that is, \( L^x/L^m \)) and the nature of technology influence the outcome, equation 14 yields several well-defined results. First, for small \( b \) the potentially positive term involving the elasticity of substitution in the manufacturing sector (\( \sigma^m \)) is dominated by the negative term on the right side of equation 14. Thus \( K \) declines when there is a high degree of real wage rigidity in the manufacturing sector because the manufacturing sector wage does not adjust enough to preserve profitability. Second, the capital stock always decreases when the parastatal sector "properly" belongs to the high-wage sector (\( s = 0 \)). Third, capital decumulation occurs if the government resists making layoffs. More precisely, the smaller the productivity gap between manufacturing and parastatal labor, the tougher must be the government layoff policy. There is no hope whatsoever of stimulating capital accumulation unless \( \beta > 1 - s \).

In the most general case there is a strong presumption that the capital stock will fall. Even when the productivity gap (\( s \)) is quite large, the government adopts a tough layoff policy, and the real wage in manufacturing is highly flexible, capital decumulation is to be expected. For the example considered earlier in which the government lays off workers strictly as dictated by the decrease in demand for intermediates (\( \beta = 1 \)), the productivity gap is 50 percent (\( s = 0.5 \)), and labor in the formal sector accepts the same percentage wage cut as labor in the informal sector (\( b = 1 \)), the capital stock still decreases if \( \sigma^m < \sigma^x L^x/L^m \theta_T \). As in the condition governing the short-run impact on manufacturing labor demand, the capital stock falls if the elasticity of substitution in the manufacturing sector is not many times larger than the elasticity of substitution in the agricultural sector.

The high probability that the capital stock will decrease implies that manufacturing employment is more likely to fall in the long run than in the short run. The change in employment in manufacturing across steady states is
\[
\frac{L^m}{P} = \frac{\theta_Z}{\theta_L N} \left[ \sigma^m \beta(1 - \theta_K) - \sigma^x \frac{L^x(1 - s)}{L^m \theta_T b} \right].
\]

The critical value of \( \sigma^m \) required for \( L^m \) to increase is \((1 - \theta_K)^{-1}\) times larger than the critical value defined in expression 13. Hence the condition for manufacturing employment to increase is roughly twice as demanding in the long run (the cost share of capital in the manufacturing sector in developing countries is around 50 percent) as it is in the short run.
The preceding analysis argues that the increase in the price of the intermediate will usually provoke capital decumulation. Figure 1 describes the workings of the adjustment process in this the normal case. The initial equilibrium is \((A,B,C)\). Immediately following the price increase, investment, employment in the high-wage sectors, and the wage rate in the agricultural and manufacturing sectors all decline. As the capital stock decreases over time, employment conditions continue to worsen, and real wages and investment continue to fall.\(^2\) The failure of repeated real wage cuts to forestall further reductions in investment and further decreases in nonagricultural employment reflects an inherent feature of the adjustment process. Falling real wages on the transition path are an induced response to weakened labor demand brought on by capital decumulation and consequently do not stimulate employment growth or investment spending.

When the productivity gap \((s)\) is exceedingly large, it is possible that the capital stock will increase, as indicated by the dynamics resulting from the initial equilibrium \((D,E,F)\) in figure 1. After the initial shock, capital accumulation bolsters labor demand in the high-wage sectors, thus driving up the agricultural and manufacturing sector wages. Real output may eventually increase,\(^3\) but the labor market never fully recovers. In the new steady state \((X,Y,Z)\), formal sector employment and real wages are lower.

### III. Public Sector Layoffs

Cuts in public sector employment release resources to the private sector. Layoffs connected with higher prices for intermediate inputs are part of a policy package that subjects the private sector to a joint supply shock. By contrast layoffs in those branches of the government that produce final goods and "services" (broadly defined) combine the release of labor resources with a cut in consumption. Layoffs of this type can be analyzed by deleting the intermediate input from the model and letting \(Q(L^g)\) represent the value of government services measured in units of tradable goods. Assuming the government cannot charge for its services, a reduction in public sector employment of \(-dD/wg\) maintains fiscal balance when debt service increases.

Initially, the cut in public sector employment increases the supply of labor to...
the agricultural sector, thereby depressing agricultural and manufacturing sector wages. Real output may rise or fall in the short run depending on the productivity of public sector labor and the division of new hires between manufacturing and agriculture.

If there is an initial contractionary phase, it ultimately proves to be temporary. Lower real wages spur greater investment spending, and, as the capital stock grows, employment in manufacturing increases further and the agricultural wage starts rising. Over the long run the capital stock increases enough that all of the laid-off workers are absorbed in the high-wage manufacturing sector without lowering real wages. (In terms of figure 1, point $E$ is horizontally to the left of point $Y$, and $F$ is vertically below $Z$.) To establish this result, observe that in long-run equilibrium the capital rental $(r)$ is tied down by the rate of time preference $(r = \rho + \delta)$. It then follows from the zero profit conditions that real wages and the land rental are also constant across steady states. Thus employment in agriculture is unchanged at the new long-run equilibrium, and clearing of the labor market implies that the increase in employment in the manufacturing sector is equal to the decrease in the public sector $(dL_m = -dL_g)$.

What is appealing in these results is that eventually higher debt service is financed partially or wholly by an expansion in economic capacity. It is, however, a long step from this to the conclusion that public sector layoffs (in the final goods and services sectors) constitute an easy remedy to the debt problem. A potentially difficult intertemporal tradeoff exists when output decreases in the short run. Furthermore, even if layoffs generate a favorable output path, the distributional repercussions may not be judged acceptable. Real wages and formal sector employment are lower everywhere on the transition path until the new steady state is reached. A prolonged bout of greater inequality is the price paid for higher output in the long run.

IV. REDUCTIONS IN PUBLIC INVESTMENT

Fiscal belt tightening often takes its greatest toll on public investment. Cuts occur not only in planned infrastructure and industrial projects, but also in a wide variety of education, health, and training programs. I investigate below the repercussions of reducing infrastructure investment. A very similar analysis applies, however, to cuts in government expenditures that foster human capital formation (see Buffie forthcoming).

Infrastructure capital serves to enhance the productivity of private capital and labor. The simplest way to capture this complementarity of social infrastructure and private inputs is to introduce urban infrastructure capital as a third distinct factor in the manufacturing sector. The stock of social infrastructure $(K_i)$ is fixed in the short run and rises or falls over time depending on whether net public investment is positive or negative. All rents generated by social infrastructure accrue to private capitalists—there is no charge for the productive services yielded by the stock of social infrastructure.

Consider now what happens in the long run when greater debt service forces a
cut in infrastructure investment \( (P) \). With factors being complementary, the productivity of labor in private manufacturing declines. Consequently, real wages and employment in private manufacturing fall across steady states.

In view of the countervailing effects exerted by a smaller stock of social infrastructure and a lower manufacturing sector wage, it might appear that the impact on the incentive to accumulate capital is generally ambiguous. This is not the case. The decrease in the wage is an induced, second-round response; as such it is too weak to offset the drop in the productivity of private capital caused by the reduction in the stock of social infrastructure. Disinvestment in social infrastructure thus leads to capital decumulation on a broad front. In the new steady state the capital stock is lower by the amount

\[
\hat{K} = \frac{\theta \left( \sigma^m L^x + \sigma^m L^m b \theta \right)}{\sigma^m L^m \theta b(1 - \theta_K) + \sigma^m L^x \theta}
\]

where \( \theta_i \) is the cost share of social infrastructure. \( (\theta_i = r^i K^i / C^m, \text{where } r^i \text{ is the implicit rental attached to social infrastructure, and } C^m \text{ is total costs in the manufacturing sector).} \)

With two capital stocks varying over time, the dynamics are intrinsically complex, and a variety of adjustment paths are possible. On a "normal" adjustment path, private investment jumps downward on impact but does not overshoot its steady-state level. The two capital stocks, manufacturing sector employment, and real wages all decline monotonically en route to the steady state.

In the normal case the lower equilibrium capital stock elicits an immediate reduction in private investment. There is also, however, the intriguing possibility that investment will increase initially. When the government announces a reduction in infrastructure investment, the representative family firm foresees a declining path for future income and the capital rental. The lower stream of quasi-rents earned by the capital stock implies that eventually investment will decline. But if the family firm has a strong preference for a smooth consumption path, it may increase investment temporarily to shift some consumption from the present to the future. This gives rise to the dynamics shown in figure 2. The possibility of this type of adjustment underscores the importance of bringing the medium and long run into view when evaluating stabilization policy. Over phase \( AB \), private and public investment appear to be substitutes, and, if the economy experiences a downturn, it is likely to be mild. The short-run response, however, is a faulty guide to how the policy affects the economy's growth prospects. Phase \( AB \) is only one part of a much longer adjustment process in which public and private capital ultimately prove to be strongly complementary.

V. THE ADJUSTMENT PROCESS AND THE SACRIFICE RATIO

There are many ways to raise revenue and lower expenditure to achieve a desired reduction in the fiscal deficit. The simple but important point of the analysis in sections II to IV is that the real repercussions of fiscal austerity depend sensitively on how the fiscal deficit is lowered.
Tables 4 and 5 present evidence on the adjustment costs for public sector price increases and cutbacks in infrastructure investment. These tables show the decrease in net national income (GDP minus external debt service) relative to the increase in debt service. I call this ratio the "sacrifice ratio." In a world in which lump-sum taxes could be employed to service the debt, the sacrifice ratio would equal unity.

In tables 4 and 5 the elasticity of substitution in manufacturing, the degree of labor market dualism (the ratio of the manufacturing wage to the agricultural wage), and the degree of real wage rigidity are allowed to vary. The other parameter values underlying the solution grids for both tables are the elasticity of substitution in agriculture ($\sigma^*$) at 0.50, the cost share of land in agriculture ($\theta_L^*$) at 0.475, the cost share of labor in manufacturing ($\theta_L$) at 0.40, the rate of time preference ($\rho$) at 0.10, the depreciation rate ($\delta$) at 0.05, and the ratio of agricultural to manufacturing sector output ($Q^*/Q^m$) at 1.7. In table 4 the cost share of the intermediate input ($\theta_z$) is 0.10, the parameter that defines the government's layoff policy ($\beta$) is 1, and the percentage gap between the marginal product of labor in private manufacturing and in the parastatal sector ($s$) is 0.3. In table 5 the cost share of social infrastructure ($\theta_i$) is 0.2.

The values for the ratio of agricultural to manufacturing sector output and the cost shares are set to yield output and employment shares for the manufacturing sector close or equal to those of the industrial sector in the highly indebted developing countries in 1980, the last year before the debt crisis. The ratio of
Table 4. The Sacrifice Ratio with Adjustment through an Increase in the Price of the Intermediate Input

<table>
<thead>
<tr>
<th>Degree of real wage rigidity (b)</th>
<th>Elasticity of substitution in manufacturing</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of manufacturing wage to agricultural wage = 1.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.50</td>
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<td>4.3</td>
<td>4.0</td>
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</tr>
<tr>
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</tr>
<tr>
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<td>2.2</td>
<td>1.8</td>
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<tr>
<td>Ratio of manufacturing wage to agricultural wage = 1.50</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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<tr>
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</tr>
<tr>
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<td>3.4</td>
<td>3.1</td>
<td>2.7</td>
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<tr>
<td>Ratio of manufacturing wage to agricultural wage = 1.75</td>
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<td></td>
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</tr>
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<td>7.9</td>
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<tr>
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<tr>
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<td>4.3</td>
<td>4.0</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>Ratio of manufacturing wage to agricultural wage = 2.00</td>
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<td></td>
<td></td>
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</tr>
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<td>5.2</td>
<td>4.9</td>
<td>4.5</td>
<td></td>
</tr>
</tbody>
</table>

Note: The sacrifice ratio is the decrease in net national income relative to the increase in debt service.
Source: Author's calculations.

Table 5. The Sacrifice Ratio with Adjustment through an Increase in Investment in Infrastructure

<table>
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<th>Elasticity of substitution in manufacturing</th>
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Note: The sacrifice ratio is the decrease in net national income relative to the increase in debt service.
Source: Author's calculations.
employment in manufacturing to employment in agriculture varies so as to be consistent with the values chosen for other parameters. (This implies that the distribution parameter changes in the CES production functions. Technology differs across the cells in tables 4 and 5.) The employment ratio \( L^x / L^m \) is thus higher the more distorted the labor market, rising from 2.79 when \( w^m / w^x = 1.25 \) to 4.46 when \( w^m / w^x = 2 \). At \( w^m / w^x = 1.5 \), the proportion of the private labor force employed in the manufacturing sector assumes the same value (23 percent) as the weighted average employment share of the industrial sector in the highly indebted countries in 1980. The share of the manufacturing sector in GDP (37 percent) equals the 1980 output share of the industrial sector in the highly indebted countries. (The figures for the output and employment shares of the industrial sector are from the World Bank [1988].)

In table 4 it is assumed that the productivity gap between parastatal and private manufacturing labor is fairly large (\( s = 0.3 \)) and that the government summons the political will to enforce a tough layoff policy (\( \beta = 1 \)). (Since \( \beta = 1 \), production of government services does not change, and the results measure the impact on total output, not just private sector value added.) To generate the solution grid in table 5, it was necessary to make some assumption about the return on infrastructure capital. I imposed the condition that the initial direct return (the return ignoring the impact on employment in manufacturing and the labor market distortion) equal the return on private capital.

What stands out in both tables is that the sacrifice ratio is so far above unity. The large values reflect the fact that capital decumulation and greater allocative inefficiency in the labor market substantially increase the costs of adjustment. If the capital stock and employment in manufacturing were unchanged, the sacrifice ratio would be unity in table 4 and three in table 5. The actual values for the sacrifice ratio indicate that the real loss of output attributable to adverse general equilibrium repercussions is usually several times larger than the combined loss owing to higher debt service and the direct contractionary effect produced by the policy shift. It is notable that real wage flexibility helps a good deal in table 4 but not much in table 5. Increasing the percentage wage cut in the formal sector from 50 to 100 percent of the percentage wage cut in the informal sector (that is, \( b = 1 \) versus \( b = 0.5 \)) seldom lowers the sacrifice ratio for a reduction in infrastructure investment by more than 10 percent.

Is it sensible to take seriously the quantitative predictions of a simple model? In this instance I believe the answer is yes. Sacrifice ratios on the order of 5–10 do not seem particularly unrealistic. Since the growth rate is zero across steady states in the model, a sacrifice ratio of eight should be interpreted as saying that the adjustment to an increase in debt service equal to 3 percent of gross national product would entail a cumulative output loss of 24 percent before the economy recovered its previous trend growth rate. This might take the form of the per capita growth rate being (approximately) two points lower for 10 years. In light of the deep contractions suffered by many debtor countries, it is not obvious whether the sacrifice ratios in tables 4 and 5 are too large or too small.
VI. FEEDBACK EFFECTS AND THE GOVERNMENT BUDGET CONSTRAINT

So far I have assumed that taxes are lump sum. Because of this assumption, the previous analysis, grim as it was, understates the difficulty of adjustment. Under the more realistic specification that tax revenues depend upon output, one-shot fiscal adjustments no longer suffice to meet the debt service target. Any measure that lowers real output lowers tax revenues as well, necessitating further fiscal retrenchment. It is all too easy for the economy to fall into a vicious, contractionary spiral in which capital decumulation, worsening underemployment, and fiscal difficulties become mutually reinforcing.

For illustrative purposes, return to the model of section IV and replace the lump-sum tax by a flat value added or income tax $t$. As tax revenues are now endogenous, infrastructure investment must be adjusted to satisfy the government budget constraint. This makes public and private investment strongly interdependent. A decrease in the private capital stock leads to a reduction in tax revenues and a matching cut in public investment. The subsequent decrease in the supply of social infrastructure depresses private capital accumulation still more, which results in a further loss of tax revenues, and so forth.

The joint dependence of the two capital stocks (the private capital stock and social infrastructure) is depicted in figure 3. The upward sloping $KK$ schedule is

![Figure 3. The Joint Dependence of the Stock of Social Infrastructure and the Private Capital Stock](image-url)
based on equation 16 and reflects the positive relationship between the equilibrium capital stock and the stock of social infrastructure. The \( HH \) schedule shows how social infrastructure varies with the capital stock as needed to comply with the government budget constraint. A stable underlying adjustment mechanism requires that, after taking account of the induced reduction in output (for a given private capital stock), the fiscal surplus increases in the long run when social infrastructure is reduced. Given this, \( HH \) is also positively sloped.

An increase in debt service shifts \( HH \) vertically downward while leaving the \( KK \) schedule in place. If taxes were lump sum, point \( B \) would be the new long-run equilibrium. But when revenues derive from a value added tax, the lower level of output at \( B \) produces a fiscal deficit. Facing a revenue shortfall, the government further reduces investment in infrastructure, which leads to another round of capital decumulation, lower tax collections, and additional expenditure cuts. If \( HH \) intersects \( KK \) from below, private and public capital decumulation feed back upon one another in a destabilizing fashion, and the downward spiral continues until either debt service is suspended or a greater share of the adjustment is shifted onto fiscal instruments less harmful to investment. In figure 3 a stable process operates (\( HH \) intersects \( KK \) from above), so the economy eventually converges to point \( C \). The distance between \( B \) and \( C \) measures the additional capital decumulation (private and public) owing to the feedback effects. This may well exceed capital decumulation directly attributable to higher debt service. It can be shown, for example, that when \( 2t > \delta r' \) (where \( r' \) is the implicit rental on infrastructure capital) the respective decreases in the capital stock, social infrastructure, and the agricultural wage are more than twice as large as the decreases that occur under lump-sum taxes.

The message here accords, I believe, with recent macroeconomic history in several developing country debtors. The adjustment to higher debt service is long and traumatic because, once growth decelerates, fiscal problems become nearly systemic and the government finds it is compelled, year after year, to make cuts in productive expenditures. Experience to date and the large sacrifice ratios in tables 4 and 5 suggest that this vicious cycle, if not actually unstable, requires considerable time to work itself out. Macroeconomic austerity can acquire a life of its own.

### VII. Summary and Concluding Remarks

One of the fundamental, unresolved puzzles in development macroeconomics concerns why austerity programs have produced such deep and prolonged recessions in many debtor nations. In this article I have argued that part of the answer to the puzzle may lie in the measures directed at lowering the fiscal deficit. There are sound reasons for thinking that fiscal policy exerts a stronger influence on private investment than is commonly believed. Cuts in public infrastructure investment and higher prices for publicly produced intermediates depress private
investment by lowering usage of factors complementary to capital. Once capital
decumulation sets in, employment growth slows in the high-wage sectors of the
economy. As a result, formal sector employment declines at the same time as real
wages are subject to general downward pressure. Moreover the adjustment
process is likely to be protracted by ongoing budgetary problems. If slower
growth leads to lower tax collections, further fiscal retrenchment becomes nec-
essary as the economy contracts. It may take a long time to escape the strong,
interlocking grip of slow growth and chronic fiscal deficits. In fact, as shown in
section VI, endogenously driven fiscal austerity may account for the greater part
of the losses suffered when adjusting to higher debt service.

Public sector wage cuts and layoffs in the final goods and services sectors offer
better prospects for maintaining growth in the face of increased debt service.
Wage cuts are a pure absorption-reducing policy that need not have any lasting
adverse impact on real output. Layoffs in the final goods and services sectors are
actually conducive to adjustment through growth. But although these two poli-
cies appear to work better than other fiscal measures, neither can be recom-
mented without qualifications. For public sector layoffs, the adjustment process
that brings gains over the long run also entails lower real wages and lower
formal sector employment in the short and medium run. Given the valid concern
of policymakers to minimize the impact of adjustment policies on the poor,
layoffs will often have to be phased in slowly.

Public sector wage cuts are less objectionable on distributional grounds but
have other drawbacks. After eight years of adjustment further wage cuts may no
longer be a real policy option in some highly indebted countries. In several Latin
American and African nations real public sector wages have fallen to the point
where moonlighting, long lunch breaks, and shirking have severely undermined
the government's capacity to carry on normal operations.

There are two broad lessons for policy in this analysis. First and most ob-
vious, something must be done to revive investment. In addition to increased
spending on social infrastructure and human capital formation, substantial in-
vestment subsidies are needed to overcome the divergence between social and
private returns caused by underemployment. In short, a “big push” in productive
government expenditures is required. This points, of course, to the urgency of
tax reform. Without a wider tax base and heavier taxation of factors in inelastic
supply, there is little hope the fiscal bind will loosen enough to allow per capita
growth rates to again reach respectable levels.

The second broad lesson is that adjustment should be gradual. Large-scale
fiscal adjustments are often necessary. But if all adjustment is to take place
within just a year or two, it is inevitable that a wide range of contractionary
measures will be adopted, including many that are incompatible with policy-
makers' output and employment targets. With new capital inflows financing a
longer timetable for reform, more of the burden of adjustment can be shifted
onto the small set of fiscal instruments that do not damage the economy's long-
run prospects for development.
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