Agriculture, Rural Labor Markets, and the Evolution of the Rural Nonfarm Economy

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Agriculture, Rural Labor Markets, and the Evolution of the Rural Nonfarm Economy

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ABSTRACT

This paper first examines the empirical evidence on the relationship between agriculture, labor markets and the transformation of the rural nonfarm economy in developing countries. A formal model of the farm-nonfarm rural economy is then introduced that extends the standard agriculturally-led, demand linkage models of rural nonfarm growth by adding a rural labor market, population growth and alternative agricultural technologies. Such additions are shown to alter conclusions about the magnitude of the farm-nonfarm linkages. Moreover, the model reveals how agricultural growth, through the labor market and changing rural wages, fosters a shifting composition of rural nonfarm activity.

INTRODUCTION

The size of the rural nonfarm economy depends primarily on agricultural demand. As farm income grows, it generates spillover growth in the rural nonfarm economy, since rising farm income increases rural purchases of nonfarm goods and services. The well-known debate on agricultural growth linkages revolves around how powerful these demand linkages are (Mellor, 1975; Johnston and Kilby, 1975; and Bell and Hazell, 1980).

Yet agriculture affects the supply of nonfarm goods and services as well. Operating primarily through the labor market, these supply-side linkages have been largely overlooked in the growth linkage discussions. This is unfortunate, because a focus on the labor market alters conclusions about the magnitude of farm–nonfarm linkages. It also highlights how agriculture affects not only the size but also the composition of the rural nonfarm economy.

This paper explores the relationship between agricultural growth, the rural labor market, and the size and composition of rural nonfarm activity. It begins by reviewing what is known about the rural nonfarm economy in developing countries, followed by a review of empirical evidence on the relationship between agriculture, labor markets, and the transformation of the rural nonfarm economy. The paper then introduces a simple price-endogenous model that projects the nonfarm employment, wage, and income effects of alternative forms of agricultural growth. The model highlights the labor market interactions that contribute importantly to the shifting composition of rural nonfarm activity.

PROFILE OF THE RURAL NONFARM ECONOMY

Static Profile

Nonfarm activities form an important and integral part of the rural economies of developing countries. They provide 20-45 percent of full-time employment and 30-50 percent of rural household income (Chuta and Liedholm, 1979; Haggblade and Hazell, 1989; and Liedholm and Kilby, 1989).

Amid wide variation, the composition of rural nonfarm employment typically includes one-third manufacturing and one-third commerce, with services, mining, and construction making up the remainder (Chuta and Liedholm, 1979). Most nonfarm enterprises are small. Self-employed, one-person firms predominate. Unlike the formal wage labor force, women constitute 40 percent or more of those engaged; frequently they account for the majority of the rural nonfarm entrepreneurs. Because of extremely low capital requirements and seasonal demand, most businesses operate with excess capacity (Liedholm and Mead, 1987).

Dynamic Profile

Employment data, the only indicator routinely available, suggest that rural nonfarm activity has increased across continents and over time (Anderson, 1982; Chuta and Liedholm, 1979; Haggblade and Hazell, 1989; and Liedholm, 1990). Yet employment growth can signal good news or bad. In prosperous regions, where rising wages and buoyant demand stimulate growth in increasingly productive

nonfarm activity, nonfarm employment growth signals prosperity. But in stagnant rural regions, a surge in nonfarm employment may reflect the bad news that population growth is forcing nonfarm activities to act as a sponge, soaking up excess workers in marginal, low-paying jobs (Shand, 1986). Differences in wage rates and the composition of nonfarm activity help in interpreting the employment data to distinguish between the two.

In prosperous regions, employment growth concentrates increasingly in rural towns and in full-time enterprises with hired employees. The composition of activity also changes, with a decline in labor-intensive activities that are often household based, and an increase in higher-investment, higher-productivity enterprises. Transport, food preparation, repair, and other services normally grow while household manufacturing industries decline. A great deal of churning accompanies this aggregate growth; 10 percent or more or total enterprises disappear each year while other, new firms emerge. Among the deceased, one-person firms predominate (Liedholm, 1990).

Women typically bear the brunt of this adjustment. They predominate in weaving, basket making, pottery, and many of the household-based activities that decline. Although many growing nonfarm services — milling, food preparation, and many domestic services — employ women, the necessary capital investment in mechanical milling, transportation, some food processing, and manufacturing can form an intimidating barrier preventing women from participation in this transformation and growth. Although rural transformation offers improved opportunities for nonfarm laborers and for the rural poor in general, women's access to the larger, full-time, higher-investment, and higher-productivity nonfarm businesses is not assured. Limited access to investment funds and education combine with child rearing and other household obligations to constrain women as they try to respond to new opportunities.

TRANSFORMATION OF THE RURAL NONFARM ECONOMY

Driving Forces

A complex interaction of forces drives the evolution of the rural nonfarm economy. On the demand side, growth in agricultural income, changes in urban and foreign preferences, and income transfers from urban areas all influence the growth and composition of demand for nonfarm goods and services. On the supply side, natural resource availability, technological change, the supply of investment capital, as well as physical and institutional infrastructure influence the magnitude and shape of the rural nonfarm economy.

Agriculture, however, plays a central role in this process. As the principal source of rural income, agriculture generates the principal source of demand for rurally produced consumer and intermediate goods. Through the rural labor market, agriculture also affects the supply side of the rural nonfarm economy.

Agriculture and the Magnitude

As farm production and income grow, they generate increased demand not only for more production inputs but also for rurally produced consumer goods. Recent estimates suggest that agricultural growth multipliers lie in the range of 1.3 to 1.8, which means that every dollar of

technologically induced agricultural income generates an additional 30 to 80 cents in rural nonfarm income (Haggblade and Hazell, 1989). Irrigated rice regions in Asia growing high-yielding varieties generate the largest multipliers, while traditional smallholder regions in Africa and Latin America produce the smallest. About two-thirds of the total of agricultural growth multipliers stem from consumption linkages, with production linkages providing the remainder.

Agriculture and the Composition

Rapid agricultural growth affects the composition of rural nonfarm activity in two important ways. First, where agricultural income growth outpaces population, rising per capita agricultural income leads to consumption diversification into a broader array of nonfoods, many of which are produced in rural areas.

Second, on the supply side of the rural nonfarm economy, agricultural growth affects the rural wage and hence the opportunity cost of labor available for nonfarm activities. This induces a movement away from many low-return nonfarm activities toward those that are more remunerative. In contrast, in regions where agricultural growth lags and employment prospects in agriculture cannot keep pace with population growth, low-return nonfarm activities proliferate, with no increase in wage rates. In these cases, the rural nonfarm economy becomes an employer of last resort, a sponge, absorbing by default labor force increments unemployed in agriculture. Whether buoyant or anemic, agriculture plays a key role in the structural transformation of the rural nonfarm economy.

Recent evidence from Bangladesh describes this combined effect of agricultural growth on the composition of rural nonfarm activity (Table 1). Employment in services, the highest-return nonfarm activity, increases dramatically in prosperous agricultural regions. In contrast, villagers reduce time spent in low-return cottage industries, earth hauling, and petty trading. Within cottage industry and trading, the doubling and tripling of labor returns suggests a considerable shift in the composition of activity.

Labor Market Interactions

Green revolution farm technology has typically increased demand for farm labor. In its early phases, biological innovations increase labor demand 20-40 percent (Jayasuriya and Shand, 1986; Lipton, 1989). In contrast, the mechanical technologies normally lower the demand for agricultural labor. Village studies reveal declines ranging from 6 percent in India (Sisler and Coleman, 1979), to 8 percent in Sierra Leone (Byerlee, Eicher, Liedholm, and Spencer, 1977), and to 26 percent, 33 percent, and 34 percent in Thailand, the Philippines, and Indonesia, respectively (Jayasuriya and Shand, 1986). Mechanical innovations, especially in thrashing and soil preparation, normally arrive after the biological ones. Induced by rising rural wages, they reduce initial gains in farm labor demand.

Labor supply, in the short run, depends on the willingness of households to forgo leisure. In the medium and long run, labor supply depends on population growth and ease of migration. Most household studies indicate short-run household labor supply to be inelastic, in the 0.1-0.26 range (Singh, Squire, and Strauss, 1986; Rosenzweig, 1988). Yet, over time, aggregate estimates point to a growing rural labor force in all regions, spurred importantly by the growth of population (Leiserson and Anderson, 1978).

TABLE 1

DIFFERENCES IN THE SIZE AND COMPOSITION OF RURAL NONFARM ACTIVITY IN AGRICULTURALLY DEVELOPED AND UNDERDEVELOPED REGIONS OF BANGLADESH, 1982[a]

	Income per Hour in Agriculturally Underdeveloped Regions (taka/hour)	Percent by which Agriculturally Developed Regions Exceed Underdeveloped Areas		
		Income/ Hour[b]	Employment, Hours/Week	Income per Household
Agriculture	5.14	29%	8%	40%
Nonagriculture				
Services	11.41	4%	30%	35%
Cottage Industry	4.35	90%	-81%	-63%
Wage Labor[c]	2.82	6%	-41%	-38%
Trade	2.30	195%	-28%	113%
Total Nonagriculture	4.35	59%	-29%	12%

[a] Agriculturally developed and underdeveloped regions are distinguished by a number of criteria: access to irrigation, use of modern rice varieties, and fertilizer consumption, among others. In the agriculturally developed regions, modern varieties cover 60% of cropped area compared with only 5% in the underdeveloped areas.

[b] Calculated based on Hossain (1988), Tables 48 and 64.

[c] Nonfarm wage labor includes earth hauling, construction, transport, and "other" employment.

Source: Hossain (1988), pp. 95, 120.

Trends in the rural wage rate reveal the relative strength of these supply and demand forces in the rural labor market. Real wages have increased in some areas following the introduction of biological innovations in farm technology, for example in the Punjab region of India (Chanda, 1986), Thailand, and Malaysia (Lipton, 1989). Yet, in countries with similar new farm technology — Indonesia, the Philippines, and Mexico — real rural wages declined or stagnated, indicating that increases in agricultural demand were insufficient to offset increases in the rural labor supply. In countries with mechanical innovations or with stagnant agricultural sectors, such as most of Sub-Saharan Africa, real rural wages have frequently declined (Griffin, 1989).

Changing rural wage rates signal a shifting opportunity cost of labor in rural nonfarm activity. Increasing rural wage rates raise costs of nonfarm production but at the same time offer prospects of higher-productivity employment for landless and poor households that have only their labor to sell. Changing wage rates affect the rate of nonfarm output growth as well as the composition of rural nonfarm activity. A formal model of the farm-nonfarm rural economy — one that includes a labor market — allows us to trace these different effects more clearly.

MODELING LABOR MARKET LINKAGES AND THE RURAL NONFARM ECONOMY

Objectives

All prior work has modeled rural nonfarm activity as a purely demand-driven spin-off of agricultural income growth. Analysts have not embellished the supply side of rural nonfarm economy; they simply assume nonfarm output supply to be perfectly elastic. Implicitly, this assumption requires excess capacity in fixed nonfarm inputs as well as a perfectly elastic supply of nonfarm labor.

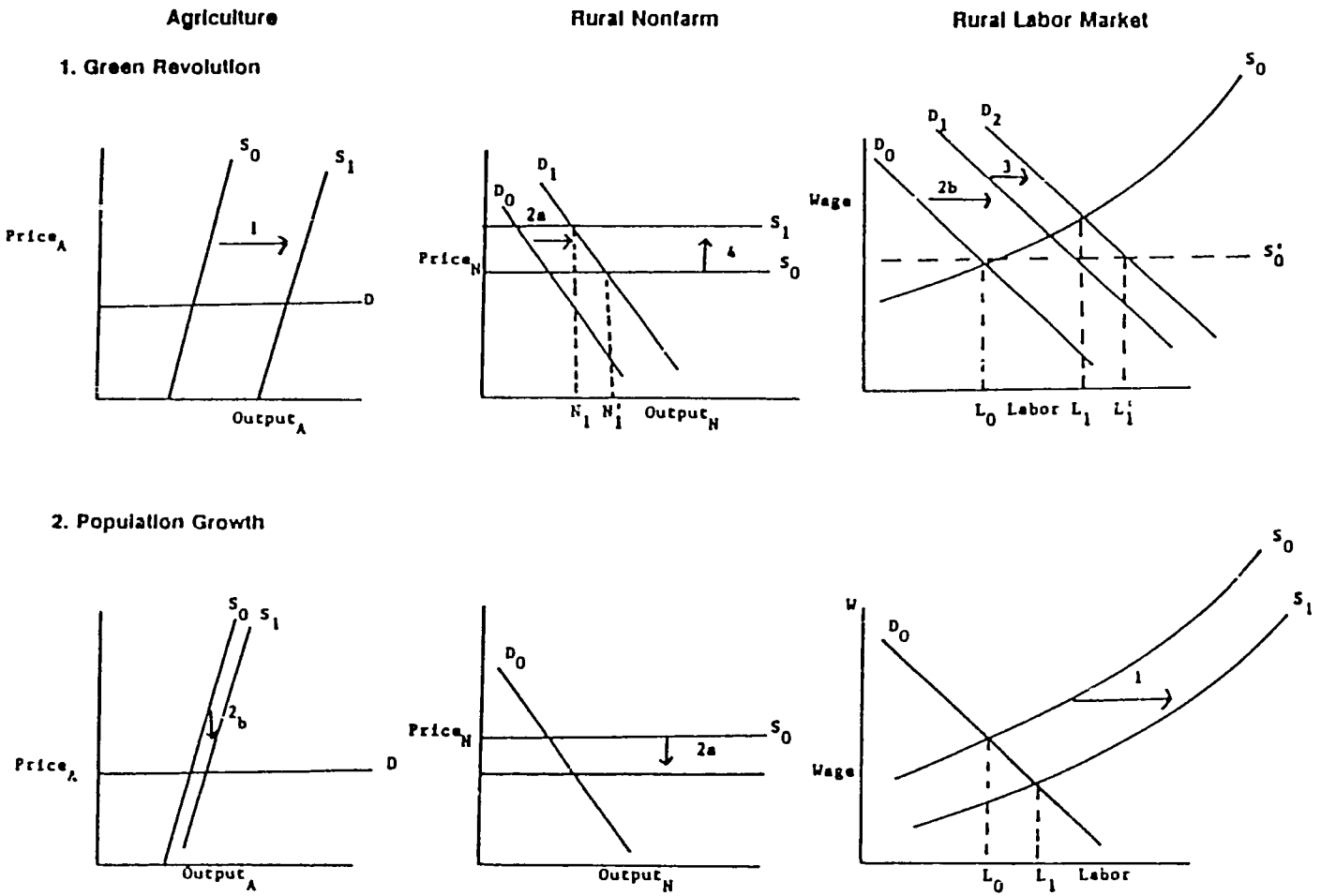
This model begins to build up the supply side of the rural nonfarm economy by adding a labor market to the standard demand linkage models of rural nonfarm growth. Modelling the classic demand linkages allows estimates of the impact of agricultural growth on the size of the rural nonfarm economy. The addition of a labor market enables the tracking of changing wage rates and employment, and hence offers a window onto the shifting composition of rural nonfarm activity.

A Graphical Introduction

The model compares two sources of growth in rural nonfarm activity: technological change in agriculture and population growth. The first raises farm income, thereby increasing demand for rural nonfarm output and simultaneously raising demand for nonfarm labor (Figure 1, Panel 1). To the extent that the new agricultural technology requires additional labor, labor demand and wage rates will rise even further. Note that where labor supply is upward sloping, the inclusion of the labor market dampens nonfarm income and output response from N_1' to N_1. Population growth, on the other hand, increases labor supply, lowers wage rates, spurs demand for labor, and thereby increases rural nonfarm employment (Figure 1, Panel 2). By contrasting the changes resulting from these two driving forces, the model examines analytically the characteristics of nonfarm activity in stagnant and growing agricultural regions.

Figure 1

Graphical Interpretation of the Model



Within prosperous agricultural regions, the model considers three forms of technological progress: labor-neutral, labor-using, and laborsaving. Figure 1 depicts labor-using technological change, the most common experience in the green revolution. Labor-neutral change would differ only in that the labor demand shift 2b would not occur, and hence wage increases and the cost-push inflation in the rural nonfarm supply curve would diminish. Laborsaving technological change would further dampen wage increase and hence lead to the largest nonfarm output response.

The three technological options can be thought of, respectively, as investment in irrigation infrastructure that allows expansion and replication of existing agricultural technology, introduction of high-yielding packages of seed and fertilizer, and mechanization. Because the biological packages are perfectly divisible and normally labor-using, many associate them with employment-oriented, small farmer growth strategies. Mechanization, which displaces labor, is associated with large-farmer growth, what Johnston, Kilby, and Mellor call a bimodal agricultural growth strategy.

The Model

The model presented here is a slightly embellished version of one developed by Haggblade, Hazell, and Hammer (1991). It includes two sectors, one tradeable and one nontradeable. For simplicity, this application assumes all agricultural commodities are tradeable outside of the rural region. Given the predominance of foodgrains and cash crops in much of the Third World, this assumption is not unreasonable. In contrast, the model assumes nonfarm activity to be nontradeable. This also does not depart dramatically from reality, since nonfarm income typically accounts for over 80 percent of incremental nontradeable income (Haggblade and Hazell, 1989).

The model takes the price of agricultural tradeables as fixed outside the rural region, invoking the standard assumption that imports will stabilize prices at border cost plus transport. In contrast, because nonfarm goods and services are not tradeable, the model must determine their price endogenously.

The model incorporates a simple, neoclassical rural labor market. Rural households supply labor in response to the real wage rate and population pressure. Farms and nonfarm businesses demand labor as a function of the nominal wage and technology. In response to shifting labor supply and demand, the rural wage rate adjusts until the labor market clears. A single rural wage prevails in both farm and nonfarm activity.

Although the model accommodates any production function technology, the experiments that follow adopt simple assumptions. In both agriculture and nonfarm activity, Leontief technology governs the demand for intermediates. Nonfarm businesses enjoy excess capacity in fixed inputs. For agriculture, land and technology constrain output supply, making it inelastic.

The two exogenous shifters in this system, agricultural technology and population growth, trace out changes in the model's four endogenous variables — the price of nonfarm output (P_n), the nominal rural wage rate (w), the rural inflation rate (I), and rural income (Y). Because the formal mathematics have been developed elsewhere (Haggblade, Hammer, and Hazell, 1991), they are merely summarized in the Appendix. The present model differs from the original version in two ways. First, it introduces population as a determinant of labor supply. Second, it considers alternative forms of technological change in agriculture.

The data for the experiments summarized in Table 2 represent a stylized Asian rice-growing economy. The production parameters are drawn from the Muda River region of Malaysia. Data from a wide range of sources scale the stylized economy as follows:

- Foodgrains account for 25 percent of both income and employment;
- New agricultural technology increases output by 80 percent among adopting farmers and increases their foodgrain income by 50 percent;
- Farmers accounting for 50 percent of cropped area adopt the improved technology; and
- Labor-using technology increases labor demand in foodgrains by 20 percent (low) to 40 percent (high), while laborsaving technology reduces foodgrain labor demand by 20 percent.

Results

The series of experiments summarized in Table 2 suggest four principal conclusions about the relationship between agriculture and evolution of the rural nonfarm economy.

1. **Rising wage rates dampen nonfarm income growth.** If the rural labor supply is perfectly elastic, a demand injection from any new agricultural technology will stimulate the same increases in rural nonfarm income and employment. The rural wage rate will not rise, even in the face of increasing labor demand by both farm and nonfarm businesses (Table 2, Experiment 1). With no cost-push inflation in nonfarm supply, spin-off growth in nonfarm activity is highest in this setting.

But unlimited supplies of labor rarely occur. And where labor supply comes only at increasing wage rates, labor-using technology will generate the smallest increase in rural nonfarm income.[1] In the stylized rice-growing region described in Table 2, mechanization, or similar labor-saving farm technology, raises nonfarm income by an amount equal to 3 percent of total rural income. Yet labor-using biological innovations raise nonfarm income by only 1.1-1.7 percent, one-third to one-half as much (Table 2, Experiment 2).

The smaller income multipliers result because when agricultural technology increases the demand for labor, it raises the rural wage rate. This raises the cost of production in nonfarm activity and hence the price of rural nonfarm output. At the higher price, rural households demand fewer nonfarm goods and services. The dampened output response lowers rural nonfarm income.

Of course, smaller income multipliers do not represent unambiguously bad news. The opposite side of a dampened nonfarm income growth is higher wage rates and consequently improved living standards for labor-selling households, typically the very poor. Note that the rural wage rises 6.6 percent

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[1] These experiments compare technological options for raising farm output. All raise foodgrain income by 50 percent, equivalent to a 6.3-percent increase in rural income. This green revolution income injection assumes foodgrains constitute 25 percent of rural income and 50 percent of all foodgrain output shifts from traditional to improved varieties. Thus, $0.5 \times 0.25 \times 0.5 = 6.25\%$. The technologies differ only in that some demand more labor in agriculture, while others demand less.

TABLE 2

MODELING THE IMPACT OF THE GREEN REVOLUTION AND POPULATION GROWTH ON THE RURAL NONFARM ECONOMY IN A STYLIZED ASIAN RICE-GROWING ECONOMY

	Initial Change in Agriculture			Resulting Change in			
				Rural Nonfarm		Total Rural	
	Income	Employ-ment	Rural Wage	Real Income per Capita[a]	Employ-ment	Real Income per Capita[a]	Employ-ment
	(Change as percent of regional totals)						
ır Supply Elasticity Infinite							
. Green Revolution (Improved Agricultural Technology)							
a. Laborsaving	6.3	-2.5	0.0	3.7	5.2	10.0	2.7
b. Labor-neutral	6.3	0	0.1	3.7	5.2	10.0	5.2
c. Labor-using, low	6.3	2.5	0.1	3.7	5.2	10.0	7.6
d. Labor-using, high	6.3	5.0	0.1	3.7	5.1	10.0	10.1
ır Supply Elasticity = 1							
. Green Revolution (Improved Agricultural Technology)							
a. Laborsaving	6.3	-2.5	1.7	3.0	4.3	9.3	1.7
b. Labor-neutral	6.3	0.0	3.3	2.4	3.5	8.7	3.3
c. Labor-using, low	6.3	2.5	5.0	1.7	2.7	8.0	5.0
d. Labor-using, high	6.3	5.0	6.6	1.1	1.9	7.4	6.6
The Sponge (Population Growth with Stagnant Agriculture)							
Population growth, 6.0%	0	0	-3.9	-4.7	1.9	-4.4	2.1
Green Revolution plus Population Growth							
a. Slow population growth, 1.8% for 4 yrs = 7.4%	6.3	5.0	1.8	-0.4	4.3	1.9	9.2
b. Rapid population growth, 2.8% for 4 yrs = 11.7%	6.3	5.0	-1.0	-3.8	5.7	-1.3	10.7

[a] Real Income includes a deduction for inflation in the price of nonfarm goods and service. Using the small country assumption, however, e price of agricultural tradeables in the rural region remains unchanged. Note that the per capita adjustment only affects Experiments 3 id 4.

under labor-using agricultural technology and only 1.7 percent when increased farm output results from introduction of laborsaving technology. Total rural employment also increases most with labor-using agricultural change. It grows by 6.6 percent compared to 1.7 percent in response to laborsaving technology (Table 2, Experiment 2).

So the pure labor market effect suggests a trade-off between employment and growth in alternative agricultural development strategies. Models that consider only demand linkages ignore this tension. To the extent that small-farmer growth strategies are synonymous with labor-using technological change, the labor market effects suggest that a small-farmer focus may lower income growth in return for greater equity and employment. Of course, consumption patterns, savings rates, and investment propensities may also differ among large and small farmers. So the conventional wisdom in favor of a small-farmer focus (Mellor, 1975; Johnston and Kilby, 1975) cannot be overturned on the wage dampening effects alone. A final pronouncement will require simultaneous comparison of demand, investment, and labor market linkages, an important excursion that ventures beyond the scope of the current paper.

2. **The composition of rural nonfarm activity changes most following labor-using technological change in agriculture.** Rural wage rates rise most in the face of growing labor demand in agriculture, 6.6 percent compared to 1.7 percent with laborsaving farm technology (Experiment 2). This jump in the opportunity cost of nonfarm labor signals a sizeable shift in the composition of rural nonfarm activity. Evidence from Table 1 and elsewhere suggests the shift involves an increase in high-value services and trade and a decline in low-productivity nonfarm activity — often labor-intensive manufacturing and, most prominently, female-dominated cottage industries.

In contrast, where population pressure outpaces agricultural output growth, returns to farming labor decline. In these settings, the rural nonfarm economy operates as a sponge, absorbing labor force into increasingly low-paying activities. This scenario plays out frequently in South Asia and Sub-Saharan Africa, where observers lament growing rural nonfarm employment as a signal of diminished opportunities. Experiment 3 in Table 2 describes this situation: wage rates and per capita income decline while nonfarm employment increases in increasingly unrewarding activity.

3. **Employment data alone can mislead.** Because of this, employment data can be dangerously misleading if considered by themselves. As Table 2 indicates, rural nonfarm employment grows at the same rate, 1.9 percent, in both Experiments 2.d and 3. Yet trends in rural welfare differ dramatically in the two settings. Where new technology makes agricultural advance possible, the rising nonfarm employment brings with it rising income and rising returns to labor and a shift to increasingly remunerative activities. The poor benefit especially as the labor they sell brings increasing remuneration.

To avoid misinterpreting employment data, students of the nonfarm economy must track changes in rural wage rates together with the employment figures. Activity breakdowns of the employment data, if sufficiently detailed, can also signal shifts in the composition of nonfarm activity and enable diagnosis of employment growth as a harbinger of opportunity or malaise.

4. **The race between population and technology.** The last panel of Table 2 measures the impact of population growth together with new agricultural technology. Panel 4.b. indicates that population growth of 2.8 percent per year, over four years, will nullify the wage and income gains resulting from typical new foodgrain technology. This result closely matches the common empirical finding of stagnant or declining real wages in areas where rapid population growth accompanies the green revolution.

CONCLUSIONS

Labor market linkages between agriculture and rural nonfarm enterprises highlight the potential trade-off between employment and growth in alternative agricultural development strategies. Because labor-using agricultural technology raises wage rates, it dampens nonfarm output supply response and reduces income gains as well. Thus, the pure labor market effects suggest that an employment-oriented small-farmer strategy will lead to a lower growth than laborsaving farm technology, except where labor supply is perfectly elastic. Because consumption and investment patterns may also differ between small and large farmers, this result does not constitute the final word on the small- versus large-farm debate.

Agriculture affects not only the size but also the composition of rural nonfarm activity. Through the labor market and the rising opportunity cost of nonfarm labor, agricultural growth fosters a shifting composition of nonfarm activity. Although much of the literature on structural transformation highlights changing sectoral shares, this review suggests that intrasectoral shifts, especially within manufacturing, may be equally important in assessing rural welfare.

Women are especially vulnerable. They predominate in the declining, household-based activities and at the same time enjoy opportunities in the growing, high-return market segments. Although they have the most to gain from a shift to higher-return nonfarm activities, institutional rigidities often make this difficult. To facilitate transformation of the rural nonfarm economy, policy makers will need to pay particular attention to opportunities and constraints facing women, both in agriculture and off the farm.

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APPENDIX

A Labor Market Linkages Model

Six equations summarize the formal model:

$$(1) \quad T(P_t, P_n, w, \theta) = H_t(P_t, P_n, Y) + D_{tt}(P_t, P_n, Y) + G_t + V_t + X_t$$

$$(2) \quad N(P_t, P_n, w) = H_n(P_t, P_n, Y) + D_{nt}(P_t, P_n, w, \theta) + D_{nn}(P_t, P_n, Y) + G_n + V_n$$

$$(3) \quad L_s(w, Z) = L_{dt}(P_t, P_n, w, \theta) + L_{dn}(P_t, L_n, Y)$$

$$(4) \quad \bar{w} = w/I$$

$$(5) \quad I = P_{nb} P_{t(1-b)}$$

$$(6) \quad Y = \pi_t(P_t, P_n, w) + \pi_n(P_t, P_n, w) + w \cdot L_s.$$

The first two equations set supply equal to demand in agricultural tradeables (T) and nontradeable nonfarm activities (N). Supply of both depends on input and output prices, in other words, on the price of nontradeables (P_n), tradeables (P_t) and the wage rate (w). The supply of tradeables is also influenced by a technology shift parameter (θ). Through its effect, input demand in tradeables (D_{tt}, D_{nt}, and L_{dt}), θ offers the flexibility to model a wide array of new technology, including neutral, input-using or input-saving technical change.

The demand for tradeables and nontradeables depends on household consumption (H_i) of each, intermediate input requirements (D_{ij}), and exogenous government (G_i) and investment (V_i) demand for each sector's output. In addition, because it can be imported or exported, tradeable demand includes net exports (X_t) from the region. Household consumption (H_i) depends on relative commodity prices (P_n and P_t) as well as household income (Y).

A full-employment, neoclassical labor market clears through Equation (3), which sets labor supply (L_s) equal to sum of labor demanded in each sector (L_{dt} and L_{dn}). Labor demand depends on nominal input and output prices, while supply is a function of the real wage rate ($\bar{w}$) and population (Z). The inflation rate (I) is defined in Equation (5). Finally, Equation (6) defines regional income as the sum of profits (π_n, π_t) and wages ($w \cdot L_s$).

When solved, the model traces changes in four endogenous variables (P_n, w, I, and Y) in response to exogenous changes in agricultural technology (θ) and population (Z). Using ($\hat{}$) to represent percentage changes, the model's solution becomes:

$$\hat{E} = A^{-1}\left[B \cdot d\theta + C \cdot Z\right],$$

where $\hat{E}$ is a 4 $\times$ 1 column vector representing percentage changes in the four endogenous variables, A^{-1} is a 4 $\times$ 4 matrix of multipliers, and B and C are 4 $\times$ 1 column vectors containing shift parameters for

each exogenous variable. Because it is additive, the model can solve for any combination of exogenous shifts. Or it can isolate the effect of any single exogenous shock.

The full model mathematics have been presented elsewhere (Haggblade, Hazell, and Hammer, 1991) for A and B. For the population vector in C as well as the parameter restrictions associated with alternative forms of technical change in agriculture (θ), a Technical Appendix is available on request from the authors.

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