Differential human capital and structural evolution in agriculture

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Accepted 7 December 1993

Abstract

The growth of market capitalism and the technological advances of the last two centuries underlie the relentless process of structural change in agriculture. Substantial occupational migration out of farming and geographical migration from rural to urban areas is a characteristic of most, if not all, economies in the 20th century. The process of rural-urban migration, and the resulting urban problems have received considerable attention. The fate of the residual farm population has received less scrutiny and is less well understood. In the United States we observe considerable farm poverty, increasing farm-size inequality, and a disturbing decay of rural communities. For the last half century, the problem of low farm incomes has been perceived as a farm problem amenable to solution by appropriate farm policy. In this paper, a model is proposed which suggests that farm poverty and inequality are inevitable consequences of a rural-urban migration process in which two types of human capital play a fundamental role. General human capital determines a person's expected nonfarm income, while farming-specific human capital determines his/her productivity in farming. It is argued that inadequate human capital combined with positive rural-urban migration cost, positive farm technology adoption costs, and inelastic demand for farm output, can explain persistently high levels of farm poverty, and increasing farm size inequality. The model suggests that traditional farm policies are inappropriate. Programs that directly address the problems of inadequate human capital are advocated.

1. Introduction

This century has witnessed many remarkable technological, political and social changes. Space exploration, electronic computers, the rise and fall of communism, and changes in the economic status of women are among the most obvious. Equally important to social organization, although less dramatic, is the ubiquitous decline in the economic importance of farming, in terms of employment and contribution to GDP, which has occurred in the last half century. For example, in 1930 the United States farm sector contributed about 8% of GDP from 6.3 million farms employing 10.4 million persons (about 20% of the U.S. labor force); today it contributes less than 2% of GDP from fewer than 2.2 million farms employing 2.8 million persons (less than 3% of the labor
force) \(^1\). It is reasonable to suppose that the 21st century will witness similar declines elsewhere.

Table 1 shows employment in agriculture as a percentage of total civilian employment in the early 1960’s and in more recent years for most OECD countries, and various large non-OECD countries. It has been observed previously that development implies a decrease in the economic importance of agriculture (for example, Mellor, 1966, pp. 16–17; Schultz, 1964, p. 15). In the last 30 years or so, a mere fraction of human history, there has been an extraordinary decrease in the proportion of economically active people who are engaged in agriculture in both developed and developing countries, and in both capitalist and socialist countries. In the absence of convincing arguments to the contrary, it is reasonable to expect that this trend will continue.

The apparent victory of market capitalism over various forms of socialism is likely to accelerate occupational emigration from farming because socialist planning usually imposed artificial impediments to adjustment processes. As market forces are allowed greater freedom, the relative importance of agriculture as an economic activity will continue to decrease. The malevolent consequences of this inexorable and gradual process are likely to receive less attention than that given to events which more violently disrupt social organization. Alternatively, they may be perceived as transitory problems amenable to solution by temporary measures such as price subsidies or similar supports. In some cases, farm-subsidy programs may be implemented as a concession to powerful, conservative, land-owning constituents rather than for reasons of economic efficiency or equity.

This paper analyses the process and economic consequences of the decline of agriculture. The paper is not concerned with the precise mechanisms which underlie rural-to-urban migration; rather it is concerned with the consequential structural change in agriculture and the subsequent economic fate of the residual farm population. As the economic importance of agriculture decreases, what happens to people remaining in agriculture? How does their economic well-being change? What happens to the distribution of

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Table 2
Farm structure in the United States, 1900–87

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of farms (000s)</th>
<th>Average farm size (acres)</th>
<th>Part-time farming (%) a</th>
<th>Farm population (%) b</th>
<th>Farm employment (%) c</th>
<th>Farm population (000s)</th>
<th>Farm employment (000s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>5739</td>
<td>147</td>
<td>n.a.</td>
<td>n.a.</td>
<td>37.5</td>
<td>37529</td>
<td>12497</td>
</tr>
<tr>
<td>1910</td>
<td>6366</td>
<td>139</td>
<td>n.a.</td>
<td>n.a.</td>
<td>31.0</td>
<td>31920</td>
<td>10979</td>
</tr>
<tr>
<td>1920</td>
<td>6453</td>
<td>149</td>
<td>30.1</td>
<td>26.9</td>
<td>29.9</td>
<td>29618</td>
<td>10316</td>
</tr>
<tr>
<td>1930</td>
<td>6295</td>
<td>157</td>
<td>24.9</td>
<td>22.7</td>
<td>30529</td>
<td>12497</td>
<td></td>
</tr>
<tr>
<td>1940</td>
<td>6102</td>
<td>175</td>
<td>23.2</td>
<td>20.1</td>
<td>30547</td>
<td>10979</td>
<td></td>
</tr>
<tr>
<td>1950</td>
<td>5388</td>
<td>216</td>
<td>15.3</td>
<td>12.2</td>
<td>23048</td>
<td>9262</td>
<td></td>
</tr>
<tr>
<td>1959</td>
<td>3710</td>
<td>303</td>
<td>9.4</td>
<td>8.9</td>
<td>16592</td>
<td>7342</td>
<td></td>
</tr>
<tr>
<td>1969</td>
<td>2730</td>
<td>389</td>
<td>5.1</td>
<td>4.6</td>
<td>10307</td>
<td>4596</td>
<td></td>
</tr>
<tr>
<td>1978</td>
<td>2257</td>
<td>449</td>
<td>3.7</td>
<td>3.5</td>
<td>8005</td>
<td>3957</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>2240</td>
<td>440</td>
<td>3.0</td>
<td>3.4</td>
<td>5628</td>
<td>4043</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>2088</td>
<td>462</td>
<td>2.0</td>
<td>2.4</td>
<td>4986</td>
<td>2897</td>
<td></td>
</tr>
</tbody>
</table>

a Percentage of farm operators working at least 100 days per annum off farm.
b Farm population as a percentage of the total population.
c Farm employment as a percentage of total employment.

Definition of a farm

<table>
<thead>
<tr>
<th>Year</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1900</td>
<td>at least 3 acres or at least $500 sales per annum</td>
</tr>
<tr>
<td>1910–40</td>
<td>at least 3 acres or at least $250 sales per annum</td>
</tr>
<tr>
<td>1950</td>
<td>at least 3 acres or at least $150 sales per annum</td>
</tr>
<tr>
<td>1959–69</td>
<td>at least 10 acres and at least $50 sales per annum, or if less than 10 acres, at least $250 sales per annum</td>
</tr>
<tr>
<td>1978–87</td>
<td>at least $1000 sales per annum</td>
</tr>
</tbody>
</table>

Sources: Columns 2–4: U.S. Census of Agriculture, various years.
Columns 5–8: Statistical Abstract of the United States, various years.

farmers' incomes? What happens to the size distribution of farms? A satisfactory model of this process of structural evolution should be consistent with what we observe. In this discussion, we shall focus on the process as observed in the United States, which has experienced remarkable rural-urban migration in the post-World War II period. The assumption is that the United States exemplifies outcomes where market forces prevail.

Table 2 shows some of the changes which have occurred in the structure of U.S. agriculture in the 20th century. The present number of farms is less than one-third the number existing in 1910, while the average farm size has increased more than threefold since then. Since the beginning of the 20th century, farm employment in the United States has decreased from one-third of those employed to less than one-fortieth. Farm employment has decreased from 9.9 million to less than 2.9 million between 1950 and 1987.

Two attributes of farming observed in the United States are: (1) farm-family poverty rates are persistently greater than those of most non-farm subpopulations; and (2) there is increasing inequality in farm incomes and in farm size which appear to be associated with emigration from agriculture. Table 3 shows that the poverty rates in the farm population have been consistently higher than in other segments of the population. In Table 4, the Gini coefficients which increase with time, indicate that the size distribution of farm firms has widened. In addition, Table 4 indicates that the share of the largest 10% of farms is increasing. For example, of the land in farms, 62.2% was used by the largest 10% of farms in 1974, and by 1987 this had increased to 66.1%.
Table 3
Poverty rates for family heads \(^a\) in the United States, 1960–91

<table>
<thead>
<tr>
<th>Year</th>
<th>All families</th>
<th>White families</th>
<th>Black families</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Non-Farm</td>
<td>All Non-Farm</td>
<td>All Non-Farm</td>
</tr>
<tr>
<td>1960</td>
<td>18.1 15.8</td>
<td>14.9 12.9</td>
<td>49.0 44.2</td>
</tr>
<tr>
<td>1961</td>
<td>18.1 16.4</td>
<td>14.8 13.3</td>
<td>49.0 45.9</td>
</tr>
<tr>
<td>1962</td>
<td>17.2 16.0</td>
<td>13.9 12.9</td>
<td>48.0 45.0</td>
</tr>
<tr>
<td>1963</td>
<td>15.9 14.6</td>
<td>12.8 11.6</td>
<td>43.7 41.4</td>
</tr>
<tr>
<td>1964</td>
<td>15.0 13.5</td>
<td>12.2 10.9</td>
<td>40.0 37.5</td>
</tr>
<tr>
<td>1965</td>
<td>13.9 12.9</td>
<td>11.1 10.2</td>
<td>39.7 37.2</td>
</tr>
<tr>
<td>1966 (^b)</td>
<td>11.8 11.3</td>
<td>9.3  8.5</td>
<td>35.5 33.7</td>
</tr>
<tr>
<td>1967</td>
<td>11.4 10.8</td>
<td>9.0  8.9</td>
<td>33.9 32.6</td>
</tr>
<tr>
<td>1968</td>
<td>10.0  9.5</td>
<td>8.0  7.5</td>
<td>29.4 28.3</td>
</tr>
<tr>
<td>1969</td>
<td>9.7  9.3</td>
<td>7.7  7.3</td>
<td>27.8 26.9</td>
</tr>
<tr>
<td>1969 (^c)</td>
<td>13.8  9.3</td>
<td>7.7  7.3</td>
<td>27.9 27.1</td>
</tr>
<tr>
<td>1970</td>
<td>10.1  9.7</td>
<td>8.0  7.5</td>
<td>29.5 28.7</td>
</tr>
<tr>
<td>1971</td>
<td>10.0  9.6</td>
<td>7.9  7.5</td>
<td>28.8 28.0</td>
</tr>
<tr>
<td>1972</td>
<td>9.3  9.2</td>
<td>7.1  6.9</td>
<td>29.0 28.7</td>
</tr>
<tr>
<td>1973</td>
<td>8.8  8.6</td>
<td>6.6  6.4</td>
<td>28.1 27.7</td>
</tr>
<tr>
<td>1974</td>
<td>9.2  8.9</td>
<td>7.0  6.8</td>
<td>27.8 27.4</td>
</tr>
<tr>
<td>1974 (^d)</td>
<td>8.8  8.6</td>
<td>6.8  6.5</td>
<td>26.9 26.6</td>
</tr>
<tr>
<td>1975</td>
<td>9.7  9.5</td>
<td>7.7  7.5</td>
<td>27.1 26.7</td>
</tr>
<tr>
<td>1976</td>
<td>9.4  9.2</td>
<td>7.1  6.9</td>
<td>27.9 27.5</td>
</tr>
<tr>
<td>1977</td>
<td>9.3  9.1</td>
<td>7.0  6.7</td>
<td>28.2 27.9</td>
</tr>
<tr>
<td>1978</td>
<td>9.1  9.1</td>
<td>6.9  6.8</td>
<td>27.5 27.4</td>
</tr>
<tr>
<td>1979 (^e)</td>
<td>9.2  9.1</td>
<td>6.9  6.8</td>
<td>27.8 27.7</td>
</tr>
<tr>
<td>1980</td>
<td>10.3 10.2</td>
<td>8.0  7.8</td>
<td>28.9 28.9</td>
</tr>
<tr>
<td>1981 (^f)</td>
<td>11.2 11.0</td>
<td>8.8  8.4</td>
<td>30.8 30.7</td>
</tr>
<tr>
<td>1982</td>
<td>12.2 12.1</td>
<td>9.6  9.3</td>
<td>33.0 32.9</td>
</tr>
<tr>
<td>1983</td>
<td>12.3 12.1</td>
<td>9.7  9.4</td>
<td>32.4 32.3</td>
</tr>
<tr>
<td>1984</td>
<td>11.6 n.a.</td>
<td>9.1  n.a.</td>
<td>30.9 n.a.</td>
</tr>
<tr>
<td>1985</td>
<td>11.4 11.2</td>
<td>9.1  8.8</td>
<td>28.7 28.6</td>
</tr>
<tr>
<td>1986</td>
<td>10.9 10.8</td>
<td>8.6  8.5</td>
<td>28.0 27.9</td>
</tr>
<tr>
<td>1987</td>
<td>10.8 10.8</td>
<td>8.2  8.1</td>
<td>29.9 29.9</td>
</tr>
<tr>
<td>1988</td>
<td>10.4 10.4</td>
<td>7.9  7.9</td>
<td>28.2 28.1</td>
</tr>
<tr>
<td>1989</td>
<td>10.3 10.3</td>
<td>7.8  7.8</td>
<td>27.8 27.7</td>
</tr>
<tr>
<td>1990</td>
<td>10.7 10.7</td>
<td>8.1  8.1</td>
<td>29.3 29.2</td>
</tr>
<tr>
<td>1991</td>
<td>11.5 11.5</td>
<td>8.8  8.8</td>
<td>30.4 30.3</td>
</tr>
</tbody>
</table>

\(^a\) Head as of March the following year.
\(^b\) Beginning in 1966, data are based on a revised methodology.
\(^c\) Beginning in 1969, data are based on 1970 census population controls.
\(^d\) Beginning in 1974, data are based on a revised methodology.
\(^e\) Beginning in 1979, data are based on 1980 census population controls.
\(^f\) For 1981, data are based on a modified poverty definition. See Current Population Reports, Series P-60, No. 134 for explanation.


The U.S. experience is likely to be indicative of future structural change in countries where family farming predominates (for example, Poland); less so where agriculture has been collectivized. However, even where agriculture has been collectivized, we might soon observe considerable private farming with substantial farm size variability. Given some system of private land ownership, or alternative form of secure land tenure, free market incentives (already apparent...
Table 4
Measures of farm size distribution – United Sates, 1974–87

<table>
<thead>
<tr>
<th>Year</th>
<th>Farm size (area)</th>
<th>Value of agricultural products sold</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Acres</td>
<td>Gini coefficient</td>
</tr>
<tr>
<td>1974</td>
<td>440</td>
<td>0.7201</td>
</tr>
<tr>
<td>1978</td>
<td>449</td>
<td>0.7119</td>
</tr>
<tr>
<td>1982</td>
<td>440</td>
<td>0.7324</td>
</tr>
<tr>
<td>1987</td>
<td>462</td>
<td>0.7537</td>
</tr>
</tbody>
</table>

a The measures of size distribution used here are scale-invariant and so will be the same no matter whether the values are expressed in current or constant dollars.
b The farm products PPI values to adjust for price level changes were: 77.4, 87.7, 100, 95.5, respectively. They were obtained from The Economic Report of the President, 1993, Table B-63.

10% CR = 10% concentration ratio is the amount used/produced on the largest 10% of farms (= top decile) as a percentage of total.

Source: Data used to compute Gini coefficients and 10%CR values were obtained from U.S. Census of Agriculture Reports, various years.

in most ‘transitional’ economies) will attract individuals with greatest farming skill and knowledge away from collective farming into farming on their own account. The loss of their most able farmers will threaten the economic viability of collectives. Differential access to credit will most likely generate a distribution of farm sizes. If markets prevail (especially those for land and water), farming activity in collectivized agriculture is likely to reorganize into smaller production units, from whence the model proposed here will be applicable.

The social, political and economic consequences of farm-population decline are significant. For example, in the United States, migration from farm to city during the latter half of the 20th century has undermined the economic foundations of rural communities and imposed substantial strains on urban infrastructures. Central governments have attempted to assist disadvantaged farm families by taxpayer-funded, farm-commodity price-support programs. These efforts have conferred most of the benefits upon more wealthy farm operators and land owners, and created powerful constituencies against the removal of such programs. Agricultural research and extension programs, which are operated ostensibly to assist the majority of family farmers, also appear to have benefited most those farmers who have needed assistance least, and consumers of farm products.

Because policy makers, their advisors and their constituencies will most likely exhibit urban bias (Lipton, 1977; Mellor, 1966, p. 5), they are unlikely to ignore the urban disruption which accompanies the development process but they may fail to recognize the problems associated with structural change of the farm sector. Where farm-family poverty is recognized, attempts to alleviate the problem may incorrectly focus on farm policy (as has occurred in the U.S.) rather than on policies to alleviate poverty more directly. This situation will be exacerbated where the most vocal and influential rural constituents are larger, more affluent farmers and land owners.

2. Alternative models of the decline of farming

At the risk of oversimplification, there are two groups of models to which we might look for some insight into the decline of farming: urban-wage-pull models and farm-technology-push models. In the economic development literature, models such as that of Harris and Todaro (1970) and Todaro (1969) perceive rural-urban migration as being a consequence of increasing oppor-
portunity cost of agricultural labor. Labor is attracted away from the agricultural/rural sector because the expected return to labor in the non-agricultural/urban sector exceeds its expected return when employed in agriculture.

If $V_u$ is the discounted present value of the expected income in the urban sector minus the cost of migration, and $V_a$ is the discounted present value of income earned in agriculture, then the expected income differential is given by: $(V_u - V_a)$; $V_u$ is an increasing function of education, and a decreasing function of age and migration costs (Yotopoulos and Lau, 1976); $V_a$ is determined by the marginal productivity of labor in the farm sector. Agents for whom $(V_u - V_a) > 0$ will migrate to the urban sector if they have not already done so. An implication of these models is that agents who are younger, more educated, more entrepreneurial, and who have lower relocation costs, migrate from agriculture, leaving those with opposite attributes to form the agricultural labor force. The young are generally more educated and mobile, and have a longer expected earning period over which to recoup any migration cost.

Increases in the expected nonfarm wage might have one or more of several causes including increased demand for nonfarm goods and services, improvements in manufacturing technology, increases in the capital/labor ratio in the non-farm sector, and education (= general human capital formation) of the farm population. Psychic income from access to amenities might also be factored into $V_u$ and $V_a$. Such subjective amenity income would also favor rural-urban migration by the young.

The likely income consequences for the decreasing farm population are of interest. Two cases are considered: one in which human capital and farm-labor productivity are unrelated, and the other where they are related. If human capital has no impact on labor productivity in farming (as is implied, or not considered by wage-pull-migration models) then we would expect the average and marginal product of labor in farming to increase as the labor-to-land ratio decreased. Other things equal, aggregate farm output should fall, and if farm-output demand is less than perfectly elastic, farm-output prices should increase. This analysis suggests that the income of farm labor will increase. Other things equal, the average level of human capital among the residual pool of farm labor should decrease as a consequence of rural-urban migration. If farm-labor productivity is a function of human capital (Huffman, 1985), average productivity of farm labor should decrease. This is consistent with the observed high poverty rates among farm families in the U.S.

The Harris–Todaro model is also consistent with observations that the average age of farmers in the United States is considerably greater than that of any other major occupational group, and formal education levels are lower for farmers than other major occupational group. In the U.S. in 1987, the median age of farmers was 50.1 years compared with 35.8 years for all workers and 40.6 years for skilled production workers (the most comparable group for whom data are available). In the U.S. in 1991, the percentage of farmers with less than four years of high-school education was 34.9% compared with 13.8% for all workers and 21.0% for skilled production workers.

Whereas the Harris–Todaro-type models focus attention on general education (= nonspecific human capital) as a pivotal attribute, an alternative explanation of rural-urban migration perceives specific human capital as crucial to the process. In these models, the human capital of importance is that which facilitates farm productivity. The best known of this group of models is the ‘treadmill model’ of Cochrane (1985). In the ‘treadmill model’, the existence of farming-specific human capital means that some farmers adopt new technology more quickly than others. The increased output which invariably results from such innovation causes farm-product prices to decrease. Consequent losses force noninnovat-

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ing farmers out of farming. Cochrane argues that even if farm-output demand is perfectly elastic, the additional profit earned by innovating farmers will cause land rents to increase and so noninnovating farmers will be forced to quit. The Cochrane treadmill model does not explicitly consider the opportunity wage of farm labor. We can infer that it is unimportant to the process, or at most, plays a passive role.

In the Cochrane treadmill model, the present value of expected farm income is a function of the farmer's human capital, farm-production technology, farm output price and land prices:

\[ V_a = f(\alpha, p, u) \] and \[ \alpha = g(x), f_\alpha > 0, f_p > 0, f_u < 0, \text{and } g_x > 0, \]

where \( x \) is farming-specific human capital, \( \alpha \) technology parameter, \( p \) price of farm output, and \( u \) land rent. When innovating farmers (those with higher \( x \)) adopt new technology (an increased \( \alpha \) level), aggregate farm output increases and so farm-output prices (\( p \)) will tend to fall. Land rent (\( u \)) will tend to increase if farm-output demand is elastic. Farmers who do not innovate (those with low \( x \)), will be forced or induced to quit farming, because \( (V_a - V_u) \) for them will be negative.

If demand for farm products is inelastic, and if the process of technological innovation is ongoing, then the treadmill model is consistent with a pool of poor farm families who are in transition out of farming. The pool is emptied as noninnovating farmers quit the industry, and it is replenished as the least able of those remaining face a new round of technology adoption by their more innovative neighbors. So the treadmill model provides an explanation of why we might observe higher rates of poverty among farm families than among the rest of the population. The incomes of farmers who successfully innovate are kept in check by falling output prices. However, if farm-output demand is elastic, these outcomes are less likely, despite Cochrane's claims to the contrary.

It should be noted that even though Cochrane-type models of agricultural decline are driven by improvements in agricultural technology, the technological change that is assumed to occur does not involve substitution of capital for labor. Rather, the process can be viewed as an inward shift in the unit isoquant, and if farm-output demand is less than perfectly elastic (as is usually the case), the farm sector must shed resources such as labor. If we make the reasonable assumption that farming-specific human capital is formed in a learning-by-doing process then we would expect the average age of farmers to exceed that of the labor force. This is what we do observe.

Both models outlined above are consistent with migration out of agriculture, poverty among farm families, and increasing farm size. Neither model provides an explanation of the observed size distribution of farms as the number of farms decreases nor of the widening distribution of farm incomes.

3. A general model of agricultural decline

In the model developed below, general and specific human capital are both considered as factors underlying the process of agricultural decline. We will be concerned with the consequences for the farm population of the decay process. A simple model is proposed which suggests that inequality and poverty are likely consequences of market-driven structural change in agriculture when the economy is initially based on agricultural production. The conclusions derived from the model are an inevitable consequence of the distribution of human capital characteristics among the population.

Each unit of labor is assumed to have two human capital attributes, \( x \) and \( y \). A person's \( x \) characteristic determines his/her expected productivity when engaged in farming, while his/her \( y \) characteristic determines his/her expected income when engaged in a nonfarm occupation. We can think of \( x \) as an individual's farming-specific human capital, and \( y \) as the amount of his/her general human capital.

Each farm is viewed as an organization of \( d \) units of land, \( k \) units of purchased inputs, and one farm manager who supplies human capital and labor to the farm firm. The output of a farm, managed by a farmer with specific human capital \( x \), is assumed given by: \( x \alpha [F(d, k)]^\beta \), where \( \alpha > 0, 0 < \beta < 1 \), and \( F(\cdot) \) is linear homogeneous with
The value of parameter $\beta$ implies that proportional increases in land and purchased inputs will result in a less than proportional increase in the output of the farm firm because of decreasing returns to the farm manager's inelastically supplied human capital and labor to the farm firm. A change in parameter $\alpha$ implies scale-neutral technological change.

The rental price of land, $r$, and the price of agricultural output, $p$, are assumed determined by market forces which depend on the size and composition of the farm sector. The supply of land to farming is assumed perfectly inelastic. The demand for agricultural output is a decreasing function of its own price. The market price of purchased farm inputs, $v$, is assumed independent of the size and composition of the agricultural sector.

The farm production function, $xa[F(d, k)]^{\beta}$, means that the marginal products of both land and purchased inputs are increasing functions of farming-specific human capital, $x$. From this it can be inferred that the optimal input levels of land and purchased inputs (= farm size) are increasing functions of each farmer's specific human capital. The implication is that if there exists a distribution of specific human capital (as has been assumed and as seems reasonable) then there will also exist a distribution of farm sizes (as we actually observe). Farmers with higher levels of farming-specific human capital will manage larger farms using more purchased inputs, produce more output, and earn greater farm incomes.

The nonfarm wage, $w$, is assumed to be an increasing function of the general human capital; $w'(y) > 0$. Farmers with relatively high levels of farming-specific human capital will be able to earn more as farmers than they could earn in nonfarm occupations. Therefore they will choose to work in the agricultural sector. Agents with relatively high levels of general human capital will find that their expected income from pursuing a nonfarm occupation will exceed their expected income from farming. They will seek nonfarm employment. A rigorous model with this structure is presented in the Appendix. Here we pursue a graphical analysis.

An individual with human-capital levels, $x$ and $y$, will be able to earn farm income ($FI$) of:

$$FI(x) = \text{Maximum}_{d,k} \left\{ px \alpha \left[ F(d, k) \right]^{\beta} - rd - vk \right\}$$

and his/her nonfarm opportunity wage will be $w(y)$:

- if $FI(x) > w(y)$ then he/she will choose to farm;
- if $FI(x) < w(y)$ then he/she will choose to engage in nonfarm employment; and
- if $FI(x) = w(y)$ then he/she will be indifferent between the two alternatives.

The level of $y$ for any individual is determined by his/her education and employment history as well as inherent ability. Learning-by-doing is assumed to be the primary determinant of the $x$ attribute, although formal education may also contribute to $x$. The $x$-$y$ distribution of the population is determined by the history of all individuals in the population.

We can describe the distribution of human capital levels in a population by using the positive Cartesian quadrant (see Fig. 1). An individual with zero human capital would be represented by a point at the origin. People raised in farming communities but provided with little formal education (such as farm workers in Ukraine) would have low levels of $y$, and their $x$ levels would

![Fig. 1. A graphical representation of general and specific human capital attributes with the $L(x, y)$ indifference locus.](image-url)
reflect their learned farming skills. Points a and a' in Fig. 1 would represent such people. People with farm backgrounds and with significant general education (such as farmers in New Zealand) will be characterized by moderate to high levels of both \(x\) and \(y\). In this case, points b and b' are representative in this case. People born, educated and always employed in urban environments (such as most inhabitants of Singapore) will have virtually zero levels of \(x\), and their \(y\) levels will be determined by their education and work experience. Such individuals would be represented by points such as c and c' along the \(y\)-axis in Fig. 1.

At any time the distribution of \(x\) and \(y\) is given for a population. The \(x\)-\(y\) distribution of the population will change as formal education levels increase and farming experience decreases. Diagrammatically, as the proportion of the population actively engaged in agriculture decreases over time, the representative citizen moves from near the \(x\)-axis (a-a') to near the \(y\)-axis (c-c'). For the present we will assume that occupational migration costs between farm and nonfarm employment are zero. In the positive \(x\)-\(y\) quadrant there will be a locus, \(L\), corresponding to \(F(x) = w(y)\) adjusted for appropriate migration costs, which will determine the dynamics of migration out of (or into) farming. People with \(x\)-\(y\) levels above and to the left of the indifference locus, \(L\), will have an incentive to quit farming if they have not yet done so. People below and to the right of the line will have an incentive to be farmers.

There are two dynamic processes associated with the indifference locus. Other things equal, increased levels of general education will raise people above the indifference locus. Second, with fewer farm families, there will be fewer children born into households which facilitate accumulation of farming-specific human capital. Once migration occurs, new family members will accumulate little if any farming-specific human capital. The migration process is not easily reversed because the learning-by-doing accumulation of farming-specific human capital generally requires membership of a farming household. Learning-by-doing human capital is easily lost when people stop ‘doing’.

Furthermore, as we shall see, there are economic forces which tend to make the \(F(x) = w(y)\) locus rotate and move to the right. Shifts in the indifference locus can be analyzed using a four quadrant diagram.

Fig. 2 represents the \(x\)-\(y\) distribution in the north-east quadrant. The north-west quadrant shows the expected nonfarm wage as a function of general human capital: \(w(y)\). The precise shape of the expected nonfarm-wage function is unimportant because the \(y\) represented on the vertical axis may be any increasing function of ‘true’ general human capital. An increase in the wage function over time (= a shift to the left) is likely because of technological change and/or capital formation in the nonfarm sector.

The south-east quadrant of Fig. 2 shows the expected return from farming as a function of farming-specific human capital. One possible shift is shown. The \(F(x)^0\) to \(F(x)^1\) shift would result from a costless, output-increasing, technological change when farm-output demand is elastic. (By ‘costless’ we mean that the cost of adopting the new technology is zero.) In this case the expected return to farming increases for all levels of \(x\). This result is established in the Appendix. In the south-west quadrant of Fig. 2, \(F(x)^1\) is equated with \(w(y)\), assuming the migration cost between farm and nonfarm employment is zero.

![Fig. 2. A shift in the \(L(x, y)\) locus caused by the adoption of an improved farm technology when demand for farm output is elastic.](image-url)
The indifference locii in the north-east quadrant of Fig. 2 are the \( x-y \) combinations at which \( F_l(x) = w(y) \). The indifference locus \( L_0 \) indicates all \( x-y \) points at which an individual with those levels of human capital would be indifferent between farm and nonfarm employment when the expected wage function is \( w(y) \) and the expected farm-income function is \( F_l(x)_0 \). The indifference locus \( L_1 \) indicates all \( x-y \) points at which an individual with those levels of human capital would be indifferent between farm and nonfarm employment when the expected wage function is \( w(y) \) and the expected farm-income function is \( F_l(x)_1 \). Fig. 2 indicates that any individuals with \( x-y \) attributes corresponding to shaded region A would find nonfarm employment more attractive given \( F_l(x)_0 \) and farm employment more attractive given \( F_l(x)_1 \). Such a situation would be conducive to migration from nonfarm to farm employment. This situation represents the employment options of many individuals in the United States in the 19th century.

Fig. 3 depicts a different situation. The \( F_l(x)_0 \) to \( F_l(x)_2 \) shift in the south-east quadrant would result from a costless, output-increasing technological change when farm-output demand is inelastic. In this case the expected return to farming decreases for all levels of \( x \). This result is established in the Appendix. The north-west quadrant of Fig. 3 shows a shift in the wage function, \( w(y)_0 \) to \( w(y)_2 \), which represents a proportional nonfarm-wage increase. The south-west quadrant of Fig. 3 represents the proposition that a person will be indifferent between farm and nonfarm employment if \( F_l(x) = w(y) - M \), where \( M \) is the farm-to-nonfarm occupational migration cost. (If migration in the reverse direction was being induced, then the indifference condition represented in the south-west quadrant would involve the nonfarm-to-farm migration cost. Diagrammatically this would be represented by a negative \( M \) in the south west quadrant or an \( M \) intercept on the \( F_l \)-axis.)

The indifference locus, \( L_2 \), in the north-east quadrant of Fig. 3 indicates all \( x-y \) points at which an individual with those levels of human capital would be indifferent between farm and nonfarm employment when the expected wage function is \( w(y)_2 \) and the expected farm-income function is \( F_l(x)_2 \). Both the nonfarm-wage increase, \( w(y)_0 \) to \( w(y)_2 \), and the farm-income shift, \( F_l(x)_0 \) to \( F_l(x)_2 \), will cause the indifference locus to rotate toward the \( x \)-axis. Both the nonfarm-wage increase and farm-income decrease

![Fig. 3. A shift in the L(x, y) locus caused by a simultaneous increase in the nonfarm-wage rate and the adoption of improved farm technology, given positive migration costs and inelastic demand for farm output.](image-url)
will induce occupational emigration from farming.

An important, if not crucial, aspect of this analysis is that the cost of adopting new farm technology is seldom zero. The costs may be explicit such as when new machinery or some other high-priced input must be purchased. Frequently however, new technology adoption costs are implicit, and they are sometimes inversely related to the human-capital input. This is so when learning is an integral part of the adoption process. Learning frequently involves errors and postponements due to information gathering and risk aversion. Furthermore, technology is frequently an indivisible or lumpy input in the sense that a different method of production cannot be partially adopted, and once adopted it can be applied to one or many units of output for the same cost. Generally farmers with higher levels of farming-specific human capital, who produce more output using more inputs, will find it more profitable to adopt new technology because they produce more output over which to spread the fixed adoption cost. Both of these considerations mean that farmers with higher levels of farming-specific human capital will find adoption relatively more attractive.

It is possible that farmers with little farming-specific human capital will find that the costs of adoption will outweigh the present value of future benefits arising from adoption. The more costly it is to adopt a new farm-production technology, the more likely it is that some farmers with low levels of human capital will find adoption to be unprofitable.

The important consequence of technology adoption costs is that technology-induced income increases will not be proportional to human capital levels, \( x \). If output demand is less than perfectly elastic, farmers who find adoption unprof-

Fig. 4. A shift in the \( L(x, y) \) locus caused by the adoption of an improved farm technology which involves positive adoption costs, given that demand for farm output is inelastic, and farm-to-nonfarm migration costs are positive.
itable (=those with low $x$) will experience a reduction of income due to the lower output price. Similarly, some, if not all, farmers who adopt the new technology will experience an income reduction (although less than if they had not adopted the new technology). If output demand is elastic, farmers with higher farming-specific human-capital levels, may experience an increase in income subsequent to adopting a costly new technology. Fig. 4 shows farm-income decreases, $F_1(x)_0$ to $F_1(x)_3$, subsequent to the adoption of new farm technology when output demand is inelastic and technology adoption is costly. The effect of the new technology on the indifference locus, $L$, in the north-east quadrant of Fig. 4, is that $L$ stretches to the right. For the conclusions developed here it is sufficient that only some farm technology be costly to adopt. This does not seem an unreasonable requirement.

The general conclusions of the model developed here can now be stated. If an economy has both farm and nonfarm sectors, farm-to-nonfarm occupational migration will be induced by: increased general education of the population, which enhances human capital appropriate for nonfarm employment; increases in real nonfarm wages; adoption of new farm technology when farm-output demand is inelastic; and adoption of costly new farm technology, especially when output demand is inelastic. Occupational migration from farm to nonfarm will be retarded by elastic farm-output demand, although migration by farmers with low levels of human capital will still occur if technology adoption is costly. Occupational emigration from farming is not easily reversed because of reverse-migration costs and depreciation of farming-specific human capital. Once out of farming, farming-specific human capital depreciates due to its learning-by-doing ($=$ forget-by-not-doing) nature. Farming-specific human capital has and is being lost in the United States (and elsewhere) because so few people live in farm families. The process seems inevitable.

Indifference locus shifts $L_0$ through $L_2$ in Fig. 5 are indicative of what we might expect to occur in a dynamic economy. Nonfarm-wage rates are likely to increase; new farm technology will become available, at least some of which will involve adoption costs; and most farm output is characterized by inelastic demand. People with human-capital levels consistent with region $Q$ are candidates for occupational emigration from farming. People with human capital consistent with region $R$ in Fig. 5, will not be attracted to migrate from farming, and they will not find it profitable to adopt much, if any, new farm technology. Such people are very likely to become impoverished by falling relative farm-output prices and stagnant productivity. As general education becomes universally available, we would expect there to be very few people with human capital consistent with region $S$ because individuals who have the capacity to accumulate substantial $x$-type human capital will almost certainly be able to accumulate $y$-type human capital.

In advanced stages of economic development, we would expect the farm sector to consist primarily of two types of farmers. Those with high levels of both types of human capital and those with little of each type. Consequently, we would expect poverty in the farm sector to be endemic and we would expect increasing inequality in farm-family incomes and farm size. This is exactly what we observe in the United States.
4. Policy implications of the model and conclusions

The policy implications of the model are straightforward. If low farm-family incomes are approached as a farm-productivity problem or farm-output-price problem, government actions are likely to be costly and largely ineffective unless such programs are focused on and restricted to the low income group. We should expect rent-seeking groups engaged in farming to use the existence of poor farmers as a political lever to influence farm policy which will transfer resources to the farm sector. Such rent seekers are likely to appropriate most of the transfers. Public research dollars spent developing new farm technology will benefit consumers and/or successful farmers but will unlikely help poor farmers.

Any farm technology adoption costs will likely exacerbate the low farm-income problem because the profitability of adoption is reduced. Subsidizing better farmers to adopt new technology in the hope that this will promote adoption by poorer farmers by some sort of demonstration effect (Feder and Slade, 1984), is unlikely to be successful. The price-depressing effect of the additional output (especially if output demand is inelastic), will likely reduce the incomes of the poorest farmers, and encourage poor marginal farmers to migrate from farm to nonfarm poverty.

Farm-output price supports (whether price subsidies or commodity-purchase schemes) confer most benefits on those farmers who produce most (= those with high levels of human capital). If there are participation costs (as is often the case) in price-support programs, then the inequitable distributional effect will be accentuated because smaller, poorer farmers may find it too costly to participate.

This model suggests that farm-family poverty is a problem of chronic deficiency of human capital rather than something perverse in the way farm-product markets work, or in how technological innovations operate in agriculture. This analysis parallels that of Theodore Schultz (1964, pp. 175–206) who concluded that enhanced levels of human capital are necessary to a prosperous agricultural sector. Low incomes in farming are not a transitory, arbitrary consequence of nature imposed randomly upon unlucky farmers; low farm incomes are a consequence of inadequate human capital. If there is a genuine desire to assist low-income farmers, then action should be directed at enhancing their human capital rather than intervening in the market or using subsidies to modify the impact of market forces. If farm-output demand is elastic, encouraging marginal farmers to remain in farming may be a viable option; but if farm-output demand is inelastic, inexorable farm-income decline is unavoidable. In the latter case, programs to promote general human capital improvement would seem appropriate.

Avenues for ameliorative action include a reduction in migration costs, and a reduction in farm-technology adoption costs, although simple reductions in either of these costs are unlikely to have the desired effect. Subsidizing rural-urban migration is likely to increase urban poverty by the same amount as rural poverty is reduced. The poor families will still exist but in different locations. An alternative policy would involve general education targeted on small farmers and their families, combined with policies to create rural, nonfarm-employment opportunities. Education increases the human capital of the poor, while rural-job creation will reduce occupational-migration costs. To the extent that rural-job creation reduces rural-urban migration, demands on urban infrastructures will be reduced.

Subsidizing farm-technology adoption costs will result in greater total farm output and consequently in lower farm-output prices. Farmers who do not adopt the technology will surely suffer, and if farm-output demand is inelastic all farmers, whether they adopt or not, will experience reduced farm incomes. If output demand is elastic, it is likely that the expenditure on adoption subsidies will mostly benefit farmers who do not need assistance. If output demand is elastic, technology-adoption subsidies targeted on smaller farmers will reduce farm poverty, and farm-income inequality.

The primary conclusion is that farm-family poverty which is co-incident with farm-to-nonfarm migration, should not be viewed as a farm
problem amenable to farm policy. The problem is more likely caused by deficiencies in human capital. Policies to enhance the human capital of poor farmers are appropriate.

5. Appendix

The model developed here focuses on the agricultural sector of a two-sector economy. There is a continuum of agents each of whom is endowed with one unit of labor, and two types of human capital. The first is farming-specific human capital which determines their productivity when in farm employment, and the second is general human capital which determines their expected wage if employed in a nonfarm occupation. For simplicity the population size is normalized to one. Levels of both types of human capital vary across the population. Index, \( y \), takes on one of \( n \) values, \( y_1 \) through \( y_n \), where \( y_1 \) indicates agents with lowest levels of general human capital, and \( y_n \) indicates those with highest levels of general human capital. Given \( y_i \), farming-specific human capital is represented by an index \( x \), which is drawn from a fixed distribution, \( G_i: \mathbb{R}_+ \to [0, 1] \), where \( g_i(x) \, dx = dG_i(x), \quad g_i(x) > 0 \) for all \( x > 0 \), and \( g_i'(x) \exists \) for all \( x > 0 \).

Farm production occurs when a farmer combines his/her farming-specific human capital and labor, with land and other purchased inputs. Labor is heterogeneous in that it cannot be allocated independently of its associated human capital. The farming-specific human capital with which each agent is endowed, cannot be substituted for other inputs used in farm production. Land ownership is distributed across the population. The nonfarm sector supplies all purchased farm inputs and acquires all farm output. Land, purchased inputs, and agricultural output are each assumed to be homogeneous and traded in competitive markets. A farmer’s income is the value of his/her farm output less the rental value of land used and the cost of purchased inputs. The nonfarm wage is a function of the level of general human capital with which each agent is endowed, \( w_i = w(y_i) \), \( i = 1, \ldots, n \), \( w_i' > 0 \).

Although restrictive, this specification captures some important aspects of reality usually ignored in other models of the agricultural sector, and it facilitates investigation of the firm-level and sector-level effects of having a firm-specific heterogeneous input, the existence of which has been investigated empirically by Huffman (1985), Hoch (1962), Mundlak (1961) and others.

Land rental, \( r \), and the agricultural-output price, \( p \), are assumed endogenously determined in competitive markets. Nonfarm wage rates, \( w_i \), \( i = 1, \ldots, n \), and the market price of purchased inputs, \( v \), are assumed exogenous. For simplicity, it is further assumed that all land is supplied perfectly inelastically to the agricultural sector. The economy’s endowment of land is \( D \). Finally, the inverse market demand for farm output is assumed to be \( P(Q) \), where \( P: \mathbb{R}_+ \to \mathbb{R}_+ \) is continuous and differentiable, with \( P'(Q) < 0 \). So demand for farm output is a function of its own price only.

A farm managed by a farmer with specific human capital of \( x \), with \( d \) units of land and \( k \) units of purchased inputs, produces output of \( x a[F(d, k)]^\beta \), where \( \alpha > 0, \beta > 1 \), and \( F: \mathbb{R}^2_+ \to \mathbb{R}_+ \) is linearly homogeneous, twice differentiable, increasing, and strictly concave. More detail of this process is given in Section 3 of the paper. In a competitive economy, an agent with general human capital \( y_i \), will seek nonfarm employment if his opportunity nonfarm wage, \( w_i \), exceeds his maximum potential farm income: \( f(t) = px a[F(d(x), k(x))]^\beta - r d(x) - v k(x) \).

Accordingly, there exists a set of values, \( z_i, i = 1, \ldots, n \), such that all agents with levels of human capital \( x, y_i \), will be farmers if \( x \geq z_i \), and those for whom \( x < z_i \) will seek nonfarm employment.

**Definition.** An allocation is a number, \( Q \), representing output of agricultural product in the economy; a vector \( z_i, i = 1, \ldots, n \), representing the farming-specific human capital of a marginal farmer with general human capital \( y_i \), \( i = 1, \ldots, n \); and a pair of functions, \( d(x) \) and \( k(x) \), representing the respective quantities of land and purchased inputs used by a farmer with farming-specific human capital \( x \), such that given \( y_i \),

- \( d(x) = k(x) = 0 \) for each agent with \( x < z_i \),
- \( d(x) > 0 \), \( k(x) > 0 \) for each agent with \( x \geq z_i \).
There is a continuum of agents and therefore competitive behavior is implied.

**Definition.** A competitive industry equilibrium for the agricultural sector is an allocation satisfying the following conditions:

\[ D - \sum_{x} d(x) dG_{i}(x) = 0 \]  
\[ \sum_{i} x \alpha [F(d, k)] \beta dG_{i}(x) - Q = 0 \]  
\[ P(Q) - p = 0 \]

\[ \Pi(x,y_{i}) = \text{Maximum} \left\{ px\alpha[F(d, k)]^{\beta} \right\} 
- rd - uk - w(y_{i}) \]

\[ = F_{i}(x) - w(y_{i}) \]

where \( F_{i}(x) \) is the maximum farm income of a farmer with farming talent \( x \), and in which:

\[ \Pi(x, y_{i}) > 0 \quad \text{for all} \quad x > z_{i} \]  
\[ \Pi(x, y_{i}) = 0 \quad \text{for} \quad x = z_{i} \]  
\[ \Pi(x, y_{i}) < 0 \quad \text{for all} \quad x < z_{i} \]

Eq. (1) states that the market for land clears. Eqs. (2) and (3) state that the market for agricultural output clears at a price which is consistent with the demand for agricultural output.

Eq. (4) gives the maximum rent from farming (= farm income – opportunity nonfarm wages) which could be earned by an agent with \( x \) amount of farming-specific human capital, and \( y_{i} \) amount of general human capital, and who treats all prices parametrically.

Eqs. (5a) and (5b) state that farm operators earn nonnegative managerial rents, and Eq. (5c) states that nonfarmers would earn negative managerial rents as farm managers.

This completes the definition of a competitive equilibrium. A competitive equilibrium implies the following two conditions:

**Condition A.** Given (5c), an interior solution to (4) requires that:

\[ px\alpha[F(d(x), k(x))]^{\beta-1}F_{d} - r = 0 \]  
\[ \text{for all} \quad x \geq z_{i} \quad \text{given} \quad y_{i} \]

\[ px\alpha[F(d(x), k(x))]^{\beta-1}F_{k} - v = 0 \]  
\[ \text{for all} \quad x \geq z_{i} \quad \text{given} \quad y_{i} \]

Eqs. (6) and (7) require that, for all farm managers, the marginal revenue products of land and purchased inputs are equal to their respective prices.

Eqs. (6) and (7) can be aggregated to give Eqs. (8) and (9), respectively:

\[ p \sum_{i} \int_{z_{i}}^{x} x \alpha[F(d, k)]^{\beta-1}F_{d} dG_{i}(x) \]
\[ - r \sum_{i} \int_{z_{i}}^{x} dG_{i}(x) = 0 \]  

\[ p \sum_{i} \int_{z_{i}}^{x} x \alpha[F(d, k)]^{\beta-1}F_{k} dG_{i}(x) \]
\[ - v \sum_{i} \int_{z_{i}}^{x} dG_{i}(x) = 0 \]

**Condition B.** A necessary and sufficient condition for Eqs. (5a) through (5c) is:

\[ \Pi(i, y_{i}) = 0 \quad \text{for all} \quad i = 1, \ldots, n \]

**Proof:**

\[ \Pi(x, y_{i}) = px\alpha[F(d(x), k(x))]^{\beta} \]
\[ - rd(x) - vk(x) - w(y_{i}) \]

thus

\[ \Pi(x, y_{i}) = px\alpha[F(d(x), k(x))]^{\beta} > 0 \]

where \( d(x) \) and \( k(x) \) satisfy Eqs. (6) and (7) for all \( x \). That is, \( \Pi(x, y_{i}) \) is increasing in \( x \). Therefore, \( \Pi(z_{i}, y_{i}) = 0 \) implies \( \Pi(x, y_{i}) \geq 0 \) for all \( x \geq z_{i} \), and \( \Pi(x, y_{i}) < 0 \) for all \( x < z_{i} \) for all \( i \).

Eq. (10) specifies that the marginal farmer will break even.
Any farmer with human capital levels \( (x, y) \) such that \( x > z_i \), can expect to earn positive rent in that income from farming will exceed his/her opportunity cost, \( w(y) \). This rent can be viewed as 'economic profit' because it is the excess of earnings over total opportunity costs generated by the managerial input for \( x > z_i \). Positive economic profit is earned in a competitive equilibrium in this model because there is no market for farming-specific human capital. Rent on farming-specific human capital cannot be competed away by new entrants because the latter will have less of that human capital than existing farmers. Similar positive economic profit in a competitive industry equilibrium is found in Panzar and Willig's model (1978) in which firms are endowed with a fixed, inelastically supplied, heterogeneous input.

Eqs. (1), (2), (3), (8), (9) and (10), imply a solution for the \( n + 5 \) endogenous variables: \( z_i, d(x), k(x), p, r \) and \( Q \). These equations are the first-order conditions for an interior solution to the following agricultural planner's problem:

\[
\text{Maximize } \int_{z_i}^{\infty} P(q) \, dq - \sum_i \int_{z_i}^{\infty} [v(k(x) + w(y_i))] \, dG_i(x) \tag{11}
\]

subject to:

\[
D - \sum_i \int_{z_i}^{\infty} dG_i(x) \geq 0 \tag{12}
\]

\[
\sum_i \int_{z_i}^{\infty} x \alpha [F(d(x), k(x))]^\beta \, dG_i(x) - Q \geq 0 \tag{13}
\]

Objective function (11) requires the maximization of economic surplus (= consumers’ surplus + factors’ surplus = the area under the demand function for farm output up to level \( Q \), less the opportunity cost of the resources needed to produce output of \( Q \) units). Constraint (12) prevents the allocation of more land than is available. Constraint (13) prevents the valuation of more farm output than is produced. The Lagrangian multipliers associated with constraints (12) and (13) are the shadow prices of land and agricultural output, respectively.

Let \( C(x, \alpha) \geq 0 \) be the cost of using level \( \alpha \) of technology by a farmer with farming talent \( x \), with \( C_x \leq 0 \) and \( C_\alpha \geq 0 \). One way to view this construction is to consider that \( C(x, \alpha) \) reflects learning costs associated with technology level \( \alpha \). It seems a reasonable proposition that the cost of employing technology should increase with the level of technology, and decrease with the talent of the farmer. If a technology-use cost of \( C(x, \alpha) \geq 0 \) exists, then the farm rent or profit of an optimizing farmer becomes:

\[
\Pi(x, y_i) = \text{Maximum} \left\{ px_a [F(d, k)]^\beta \right. \\
- r d - v k - C(x, \alpha) - w(y_i) \} \tag{14}
\]

\[
= px_a [F(d(x), k(x))]^\beta \\
- r d(x) - v k(x) - C(x, \alpha) - w(y_i) \]

If \( C(x, \alpha) > 0 \), then (14) would replace (4) above and the technology-use cost would have to be added into (11).

The level of technology employed, \( \alpha \), could be treated as a continuous choice variable. If this were so, more talented farmers would use higher levels of technology on larger farms, which would further widen the farm size and farm income distribution. Here we shall restrict ourselves to considering a simpler case in which an increment in \( \alpha \) is available at a nonnegative cost on a take-it-or-leave-it basis with all farmers at the same initial \( \alpha \) level.

**Proposition.** The elasticity of farm-output demand, \( \eta \), determines the directional impact of a change in farm technology on farm income.

Assume there is a technology improvement which is adequately represented by a \( d\alpha/\alpha \) percentage increase in the \( \alpha \) parameter. Initially assume that \( C(x, \alpha) = 0 \). If all farmers adopt the new technology then: \( dQ/Q = d\alpha/\alpha \), and so: \( d p/p = (1/\eta)(d\alpha/\alpha) \). Therefore:

\[
F_{\alpha} = (1 + 1/\eta) pxF(\cdot)^\beta + pabxF(\cdot)^{\beta-1}F_{\alpha} \\
- r d - v k - r_\alpha d \tag{15}
\]

The first term in (15) is the direct output effect of the \( \alpha \) change and the market price response. The
If farm output demand is unit elastic (\(| \eta | = 1\)) then the first term in (15) is zero indicating that total revenue both at the farm and market levels does not change. Consequently, in this case there will be no adjustment in farm input levels, and no changes in land rent. So \( F_{I_a} = 0 \).

If demand is elastic (\(| \eta | > 1\)) then the first term in (15) is positive. Farmers will adjust input levels in response to the increased profitability of farming and the higher land rent. Consequently terms two, three and four, \((p_x F_a - r_d \alpha - v_k \alpha )\), will be net positive (otherwise farmers would not adjust input levels, in which case they would be net zero), and the final term, \((- r_a d)\), will be negative but absolutely less than the first term. So \( F_{I_a} > 0 \). Similarly, if demand is inelastic (\(| \eta | < 1\)), \( F_{I_a} < 0 \).

In the case where \( C(x, \alpha) > 0, C_\alpha > 0 \) with \( C_x < 0 \) then:
\[
F_{I_a} = \left(1 + \frac{1}{\eta}\right) p x F(\cdot)^B + p a b x F(\cdot)^{B-1} F_a - r d_\alpha - v k_\alpha - r_a d - C_\alpha
\]

If there is technology improvement where \( C_\alpha < p x [F(\cdot)^B] \) for all \( x \), all farmers will perceive a potential gain from attempting to increase their \( \alpha \) levels. There are three cases: if farm output demand is unit elastic (\(| \eta | = 1\)), then \( F_{I_a} = - C_\alpha < 0 \); marginal farmers will exit. If farm output demand is inelastic (\(| \eta | < 1\)), then \( F_{I_a} < - C_\alpha < 0 \); marginal farmers will exit. If farm output demand is elastic (\(| \eta | > 1\)), there is some \( 1 + \epsilon > | \eta | > 1 \) such that \(- C_\alpha < F_{I_a} < 0 \). That is, when technology adoption is costly, there is some range of elastic demand which will result in a reduction in farm incomes even though adoption appears profitable when prices are viewed parametrically. In such cases marginal farmers will exit.

References


