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in Developing Country Agriculture**

By

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## INDUCED INNOVATION AND LAND DEGRADATION IN DEVELOPING COUNTRY AGRICULTURE

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### ABSTRACT

*With few exceptions, induced innovation theories give little consideration to the role of distortions or externalities as determinants of the commodity or factor biases of innovations demanded by farmers. Nor has the theory devoted much attention to the influence of technical progress, with or without distortions, on the sectoral structure of production. This analysis identifies the demand for innovations as a function of a specific policy setting which conditions and is in turn conditioned by the sectoral structure of production. In this context, when some sectors contribute more than others to land degradation and soil erosion externalities, the capacity for divergence between privately optimal and welfare-maximizing allocations of research resources - calculated at market and shadow prices respectively - is substantial. In some circumstances it may be optimal to employ research budget allocations as second-best substitutes for Pigouvian taxes.*

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## INTRODUCTION

In the theory of induced innovation, the allocation of resources to the development and dissemination of new technologies is directed by relative factor scarcity, as reflected in market prices.<sup>1</sup> It is well known, however, that market prices need not reflect the social opportunity cost of factors, for a range of reasons including missing markets and the existence of prior policy interventions. Factor price distortions may generate factor or commodity biases in the demand for innovations, relative to the set of innovations that would be demanded at undistorted prices.

In this paper I explore welfare and policy issues that arise when commodity price interventions and externalities alter the commodity or factor composition of the demand for innovations in upland agricultural regions of Southeast Asian developing economies. The primary focus is on the ways in which distortions affect the demand for innovations by altering the structure of the industries from which demand emanates. As the paper points out, some upland sectors demanding, and winning, research resources might not even exist but for the presence of distortions. Progress in R&D can then augment the commodity or factor biases that the distortions impart.

Addressing distortions and their consequences is a policy challenge. To rectify externalities is often economically infeasible, and to alter market policies may be politically costly. The challenge may be complicated by a form of ‘institutional failure’ in which different branches of government in developing countries attach their own welfare weights to different sets of prices and outcomes, and therefore disagree on the costs and benefits of alternative policies. It is common, for example, to find the Ministry of Agriculture promoting certain crops or technologies on the basis of farm-level returns, while the Ministry of the Environment struggles with problems of land degradation, deforestation and downstream siltation and water quality decline caused by the expansion of the same crops or practices. On the basis of a brief and informal Southeast Asian case study, the paper concludes by suggesting that even if distortions persist, use of a commonly agreed set of accounting prices for research resource allocation could serve as a second-best solution when social and private net returns diverge.

### **Agricultural development and land degradation in the uplands**

Upland agricultural development, driven by population growth and the opportunities presented by open-access resources at the frontier of cultivation, has been rapid in most developing nations in recent decades. The problems of agricultural development in upland regions are important because these regions have special environmental and agronomic characteristics, and are subject to the kinds of distortions referred to above.

First, soils in tropical uplands are typically shallow and fragile in structure, and due to prevailing steep slopes, easily eroded once their permanent cover is disturbed or removed. However, productivity declines are often barely noticeable until the topsoil ('A' horizon) has been eroded and the infertile subsoil exposed (Lal 1990; Hoang 1994). The difficulty of measuring inherent soil quality, often coupled with inadequate definition and/or enforcement of property rights, means that land prices at the frontier seldom reflect soil quality differences. Similarly, off-site damage (flooding, variability of water supply, siltation and water pollution) associated with soil erosion from uplands has major impacts on other upland farms as well as on the costs of providing irrigation, power generation and drinking water downstream; but because of the non-point nature of this pollution the costs of erosion are rarely capitalized into upland land values.

Second, a less widely recognized feature of upland agricultural economies is their flexibility in terms of crop and technology choice. In Asia at least, few upland agricultural regions are truly isolated from markets. In addition to the usual range of staple grains and subsistence foods, farmers take advantage of the special characteristics offered by elevation to grow not only traditional cool-climate crops such as coffee, tea, and cacao, but increasingly to supply temperate climate vegetables such as white potato, carrots, cabbage, and lettuce for sale to the burgeoning urban middle classes (Hefner 1990; TDRI 1994; Lewis 1992; Librero and Rola 1994; Scott 1987). Even in the "new tiger" economies of Southeast Asia, the actual land use shift is generally small in terms of total upland land area; nevertheless it is highly influential as a move in the most ecologically fragile areas from soil-conserving tree crops, pasture and long-fallow systems to highly intensive vegetable gardening with frequent tillage and greatly increased exposure of soils to the leaching and eroding effects of monsoon rains.

Third, the shift to vegetable cultivation (and in some countries to cereals and pulses such as corn and soybean for food and feed) is frequently provided substantial policy support, in contrast to that granted to more traditional crops. In Southeast Asia, several countries apply quantitative import restrictions on imports of temperate-climate vegetables such as potato and cabbage. Demand for these non-traditional foods grows with per capita income and urbanization. Since supply growth is limited by trade restrictions and climatic constraints, their prices have tended to rise more rapidly than the general price level, and certainly more rapidly than prices of most exportable crops and staple grains. Import restrictions or bans are arguably necessary conditions for the existence of many temperate-climate vegetable industries in tropical Asian countries; these industries in turn have generated highly focused and sometimes powerful lobby groups to defend their protected status and to press for public resources in providing infrastructure, marketing support, and research and extension services.

In summary, the economic and environmental signals all point to the highland vegetable industry as one in which private returns may exceed social profitability. In this paper I examine mechanisms by which such an industry might become established and grow, and how policy makers should respond in the allocation of agricultural research resources. I focus on both trade policies and unaccounted environmental costs and externalities as the sources of differences between market and shadow prices. These distortions are shown to be capable not only of altering the structure of upland production -- for example, making it profitable to begin cultivation of some crop -- but also of spawning demands for R&D investments that may themselves reinforce the distorted structure.

In the next section I present a simple model examining the effects of distortions and technical progress on the structure of production. In the subsequent section I speculate on the welfare and environmental implications when a distorted industry structure generates biases in the demand for new technologies. A necessary condition for these to compound the effects of the original distortions is that the supply of innovations be responsive to distorted prices, for example when public agencies responsible for agricultural R&D resource allocation fail to make use of shadow prices in deciding the socially optimal R&D portfolio.

## **PRICES, PRODUCTION AND LAND DEGRADATION**

How do commodity price interventions, factor endowment changes and technical progress alter the structure of production in a price-taking economy? How do such changes affect the endogenous depletion of a resource such as land quality? In this section I explore these questions and evaluate their welfare implications. I use a static, two-factor, two-good partial equilibrium framework to highlight the role of equilibrium conditions and to examine the role of price policy interventions and technical progress in conditioning the rate of land degradation. In this section technical progress is assumed to occur exogenously: the question of its generation is reserved for the following section.

Consider an upland agricultural economy in which two goods,  $X$  and  $Z$ , can potentially be produced using fixed endowments of land ( $K$ ) and labor ( $L$ ). Prices ( $p_x$  and  $p_z$ ) are set in an external market and these in turn determine wages ( $w$ ) and returns to land ( $r$ ).<sup>2</sup> We are particularly interested in the structure of production and how it is influenced by product prices, factor endowments, and technical progress. Figure 1 presents the basic model.<sup>3</sup> We assume non-jointness in production and constant returns to scale. Revenues in each sector are exhausted in payments to factors, so for each good produced there is a family of isoprofit curves  $Q(p_i)$ , each showing the factor

price combinations consistent with zero pure profits for given technology and output price:

$$(1) \quad Q_j = p_j y_j - wL_j + rK_j = 0, \quad j = X, Z,$$

where  $y_z = Z$  and  $y_x = X$ . The shape of an isoprofit curve indicates the value of the elasticity of factor substitution in the technology used to produce that good, and the absolute value of the slope of each curve shows the land-labor ratio consistent with zero pure profits at that point. As drawn, production consists of a land-intensive good (X) and a labor-intensive good (Z).

A ray from the origin through point A, at the intersection of  $Q_z$  and  $Q_x$ , shows the market-clearing factor price ratio,  $w/r$ . Lines tangent to each isoprofit curve at this point have slopes equal to the negative of the equilibrium land-labor ratios  $k_x$  and  $k_z$ . Both goods will be produced in equilibrium only if the aggregate land-labor ratio in this economy is of intermediate slope. An example of such a ratio is given in the diagram by the line with slope  $k$ , where  $k_x > k > k_z$ . If  $k$  lies outside this range the economy will specialize in production of either X or Z.<sup>4</sup> In this model, the representative producer's goal is to minimize costs over the domain in which profits are non-negative. This domain is defined by the area above both isoprofit curves, so given factor endowment constraints, the equilibrium is at A.

As long as markets are complete and the number of goods produced is at least as great as the number of factors employed, factor prices are determined solely by commodity prices. In figure 2, an increase in the endowment of labor relative to land is shown as a shift in the aggregate land-labor ratio from HE to H'E'. This shift reduces  $k$  but leaves factor prices unchanged, so long as the change is sufficiently small that  $k_z < k < k_x$  continues to hold. Instead, the endowment change causes a change in the sectoral structure of production. This can be seen in figure 2 by defining employment shares  $\lambda_{ij} = L_j/L$  for  $j = X, Z$  and noting that along the vertical axis  $\lambda_{ix} = GH/GI$  and  $\lambda_{iz} = HI/GI$ .<sup>5</sup> The decline in  $k$  thus reduces  $\lambda_{ix}$  and increases  $\lambda_{iz}$ ; since factor use ratios in each sector are unchanged at constant factor prices, output of Z must rise and that of X fall (the Rybczinski effect). Specialization in Z (or X) will occur in an initially diversified economy only if the change in the land endowment relative to labor is large enough that  $k \geq k_z$  (or  $k \leq k_x$ ).

A change in either commodity price displaces the relevant isoprofit curve outwards from the origin. Figure 3 shows this for a rise in  $p_z$ , which shifts the isoprofit curve for that sector to  $Q_z'$ , with a new factor market equilibrium at B. The consequent change in the structure of production can be read in the same way as for figure 2 from changes in factor employment shares. Both sectors become more land-intensive, but the shares of sector Z in employment of both capital and labor rise while

those of sector X fall. The sector whose price has risen has thus expanded, and the other contracted -- the Stolper-Samuelson result. The price change also leads to a new factor market equilibrium, in which the price of the factor used relatively intensively by the expanding sector increases relative to that of the other factor; thus at B,  $(w/r)' > (w/r)$ .

Technical progress in either sector allows producers to pay more for factors and still make zero profits; it too can therefore be represented as an upward displacement of the relevant isoprofit curve (in the special case of factor-neutral technical progress, the displacement is homothetic and thus identical to that caused by a price change and shown in figure 3). For given commodity prices, output of the sector experiencing technical progress increases and that of the lagging sector declines.

It follows from the relationships captured in figure 3 that price and technology policies play potentially important roles in determining the structure of agricultural production. Price policy or R&D resources may be deployed in ways designed to generate substantial changes in factor allocation and the output mix. In fact -- and this is a point generally obscured by the factor market focus of the induced innovation literature -- price or technology changes, by shifting the cone of diversification, can induce an economy that was specialized in production in a single sector to diversify, or conversely, induce specialization in a formerly diversified economy.

### **Structure of production and land degradation**

In upland areas of developing countries, agricultural land degradation rates depend critically on land use. Some crops and technologies cause much more rapid rates of soil nutrient depletion and erosion than others (Repetto 1990). Therefore, when land is reallocated between agricultural sectors in an upland region, the rate of change of average land quality and of the amount of erosion produced in the region is likely to be altered. We can incorporate the effects of land use on land quality in this model by measuring factor quantities in effective rather than in physical units. Thus a change in land quality is the same as a change in the effective land endowment, and the geometric analysis is exactly as was previously shown in figure 2 for an equivalent change in physical factor endowments. As before, small changes in the effective endowment are not reflected in factor prices, although the change alters the structure of production in the direction of the sector making more intensive use of the relatively more abundant factor. The difference between the two cases lies in the welfare interpretation when the effective endowment change is not given its full value -- as will be discussed below.

The next subsection builds a causal link between the structure of production and the rate of land degradation. Before formally constructing such a link, we can identify conditions under which price or technology changes have different implications for the value of output, economic welfare and policy. Relative sector size and factor intensity



are clearly important, but in addition we need to know which activity is more land-degrading on a per-hectare basis, since the more land-intensive technology need not be more land-degrading (and in fact is rarely so).

First, if a sector is relatively land-intensive (as with X in the figures), and if that sector's technology is also more land-degrading, some or all of the expansion of that sector's output (whether due to technical progress or a favorable price shift) will be canceled by the endogenous reduction in the effective land endowment as average land quality declines. The endowment shift will have the opposite effect of causing the X sector to contract. Second, if the same sector is relatively less land-degrading, then its expansion will be reinforced by the rise in the effective land-labor ratio as resources are drawn out from the more land-degrading sector. Third, if a sector is relatively labor-intensive but is more land-degrading on a per-hectare basis, its growth due to a price or technology change will be reinforced by the effective land endowment decline that its expansion brings about.

Analytically, the third case is clearly the most interesting since it embodies the greatest potential for welfare losses. Empirically, this is also the most commonly observed case in the uplands of developing countries. Grain and vegetable crop production technologies in such regions are typically far more intensive in their use of non-land inputs than are perennial crops; moreover, these crops also cause higher levels of land degradation and soil erosion when compared with perennials. As the empirical discussion later in this paper will demonstrate, this case also holds the greatest policy interest, as developing country trade, price and technology policy differences between perennials (mainly exportables) and staple grain or vegetable crops (typically importables) are often very great.

Consider the effects of a tariff or equivalent price support conferred on the labor-intensive Z sector. By figure 3, the tariff causes output of Z to expand and X to contract. The fraction of total land used in production of Z increases, and in addition both sectors become more land-intensive. Both shifts cause the average rate of land degradation to increase, giving rise to an effective endowment shift like the one shown in figure 2 -- a shift which also favors the production of the less land-intensive crop. However, for a small change in the effective land endowment there will be no change in factor prices, as figure 2 showed: in other words, the effects of land degradation will not be capitalized into land prices. In this case, therefore, both the price intervention and the unaccounted environmental damage promote an increased allocation of land and labor resources to the land-degrading sector.

### **Welfare implications of distortions and externalities.**

If increased land use for production of Z causes a decline in the effective land endowment, then a discussion of the welfare implications of policies supporting that

sector's expansion must take account of this depletion of the resource base (Dasgupta and Maler 1995). That is the task of this section, in which we assess the effects of a tariff change on real consumer expenditures by analyzing the aggregate budget constraint (sometimes called a trade expenditure function). In an economy with one initial distortion -- a tariff on good Z -- and an externality in the form of a missing market for land quality, the aggregate budget constraint may be written as:

$$(2) \quad e(\mathbf{p}, \mathbf{u}) = g(\mathbf{p}, \mathbf{v}, \tau) + t_z[(e_z(\mathbf{p}, \mathbf{u}) - g_z(\mathbf{p}, \mathbf{v}, \tau)] - s(\alpha_x K_x, \alpha_z K_z),$$

where  $e(\mathbf{p}, \mathbf{u})$  is the expenditure function of the representative consumer in prices  $\mathbf{p} = (p_x, p_z)$  and utility;  $g(\mathbf{p}, \mathbf{v}, \tau)$  is the economy's aggregate revenue function in  $\mathbf{p}$ , factor endowments  $\mathbf{v} = (K, L)$ , and technology  $\tau = (\tau_x, \tau_z)$ . By Shephard's lemma the partial derivatives of  $e(\cdot)$  and  $g(\cdot)$  with respect to  $p_z$ , denoted by  $e_z$  and  $g_z$  respectively, are functions describing domestic demand and supply for Z. The initial tariff or tariff-equivalent on Z is  $t_z = (p_z - p_z^*)$ , where  $p_z$  is the domestic price and  $p_z^*$  the foreign (border) price; and  $s(\cdot)$  is a damage function in sectoral unit damages  $\alpha_j > 0$ , and sectoral land use,  $K_j$ . Privately optimal sectoral factor demands are obtained from cost minimization as  $K_j = \partial c^j(\mathbf{w}, y_j)/\partial r$ , evaluated at  $r(\mathbf{p}, \mathbf{v}) = \partial g(\mathbf{p}, \mathbf{v})/\partial K$ ,  $w(\mathbf{p}, \mathbf{v}) = \partial g(\mathbf{p}, \mathbf{v})/\partial L$ , and  $y_j(\mathbf{p}, \mathbf{v})$  for  $j = X, Z$ . Combining these provides an expanded description of the damage function

$$(3) \quad s(\alpha_x K_x, \alpha_z K_z) = s(\alpha_z y_z c_r^z(\mathbf{w}), \alpha_x y_x c_r^x(\mathbf{w})),$$

as a function of commodity prices, the tariff, factor endowments, technical progress and sector-specific rates of land degradation.

What are the welfare implications of an increase in protection for sector Z? We can answer this question by taking the total derivative of (2) with respect to  $p_z$ , using (3), noting that  $dp_z = dp_z^* + dt_z$  and setting  $dp_z^* = 0$ . After some manipulation we have:

$$(4) \quad \gamma(du/dt_z) = t_z(e_{zz} - g_{zz}) + \partial s/\partial t_z,$$

where  $\gamma = (1 - t_z e_{zz} p_z^*) > 0$ , and  $e_{zz} < 0$ ,  $g_{zz} > 0$  are the second partial derivatives of  $e(\cdot)$  and  $g(\cdot)$  with respect to  $p_z$ . The 'pure' trade policy result ( $\partial s/\partial t_z = 0$ ) is well known: an increase in the rate of the tariff reduces welfare, exclusive of environmental effects, by inducing overproduction and underconsumption of Z relative to free trade prices (e.g. Vousden 1990; Dixit and Norman 1980).

The change in  $s(\cdot)$  is less straightforward. Taking the total differential of (3) with respect to  $p_z (= t_z)$ :

$$(5) \quad \partial s/\partial t_z = \alpha_z c_r^z(\mathbf{w})(\partial y_z/\partial p_z) + \alpha_x c_r^x(\mathbf{w})(\partial y_x/\partial p_z) \quad \dots (a)$$

$$+ \alpha_z y_z c_{rr}^z (\partial r / \partial p_z) + \alpha_x y_x c_{rr}^x (\partial r / \partial p_z) \quad \dots \text{ (b)}$$

$$+ \alpha_z y_z c_{rw}^z (\partial w / \partial p_z) + \alpha_x y_x c_{rw}^x (\partial w / \partial p_z). \quad \dots \text{ (c)}$$

The total change in the damage function has components reflecting changes in the structure of factor demand at constant prices (line (a)), and others reflecting factor substitution as the price change causes factor prices to adjust (lines (b) and (c)). We can simplify the latter by noting that  $c_i^j$  is homogeneous of degree zero in  $w$  and making use of the Euler relation:

$$w c_{rw}^j + r c_{rr}^j = 0, \quad \text{i.e.} \quad c_{rr}^j = -(w/r) c_{rw}^j,$$

to obtain:

$$(6) \quad \partial s / \partial t_z = \sum_j \alpha_j c_r^j(w) (\partial y_j / \partial p_z) - \sum_j \alpha_j y_j c_{rw}^j [(w/r) (\partial r / \partial p_z) - (\partial w / \partial p_z)] \quad (j = X, Z).$$

The first term on the right hand side of (6) confirms that when the price of one good rises in terms of the other, the output of that sector expands and that of the other sector contracts (cross-price derivatives are always negative in the two-sector model). The third term reminds us that the price change also causes a relative increase in the price of the factor used intensively in the expanding sector (in the present case, the term inside square brackets is thus positive), and this relative factor price change causes *both* sectors to become more intensive in the use of the relatively less expensive factor. Thus in figure 3, a rise in  $p_z$  causes the labor-intensive sector to expand -- drawing in more land and labor from sector X -- but also raises the factor price ratio from  $(w/r)$  to  $(w/r)'$ . At the new equilibrium, both sectors display higher land-labor ratios than at A. For a commodity price change, then, the change in the damage function depends on each sector's propensity for land degradation ( $\alpha_j$ ) as well as its relative factor intensity and the degree to which land and labor can be substituted for one another, as reflected in the cross-price derivatives  $c_{rw}^j$ .

In the case of a higher tariff for a relatively labor-intensive sector with high land degradation potential, we see that given  $(\partial r / \partial p_z) < 0$ ,  $(\partial w / \partial p_z) > 0$  and  $\alpha_z > \alpha_x$ ,  $ds/dt_z > 0$ . The expansion of the relatively land-degrading sector increases its land use at constant factor prices, but also raises  $w/r$ , causing producers in the expanding sector to substitute further towards land -- thus further increasing the extent of new land degradation.<sup>6</sup> We conclude that an increase in protection for the labor-intensive, land-degrading sector will lead to reduced aggregate welfare since the consequent increase in land degradation will augment the deadweight losses of the trade policy change.

In spite of the aggregate welfare loss, however, upland agricultural producers will benefit from the tariff increase as long as the extent of on-site land degradation is not so great as to induce specialization and thus to change factor prices. As figure 2 showed, a small change in factor endowments alters the structure of production but not

factor rewards. In these circumstances the tariff increase raises total upland factor income, as can be seen by summing equation (1) over X and Z at shadow prices  $\mathbf{p}^*$  and at distorted prices  $\mathbf{p} = (p_x^*, p_z^* + t_z)$ , then taking the difference:

$$\begin{aligned} p_x^* X + p_z^* Z &= w(\mathbf{p}^*)L + r(\mathbf{p}^*)K \\ &< p_x^* X + (p_z^* + t_z)Z \\ \Rightarrow t_z Z &= [w(\mathbf{p}) - w(\mathbf{p}^*)]L + [r(\mathbf{p}) - r(\mathbf{p}^*)]K > 0. \end{aligned}$$

The increase in protection thus confers benefits on upland producers at the expense of the rest of the economy, including those producers in sectors directly affected by increased erosion as upland agriculture becomes more intensive.

Finally in this section we consider the effects of exogenous technical progress. For simplicity we restrict our attention to the case of Hicks-neutral (product-augmenting) change.<sup>7</sup> In this form technical change has the same effect on producers as a price rise, and indeed can be analyzed by examining changes in “effective”

producer prices  $\mathbf{p}\tau$ , where  $\tau$  is an augmentation parameter with an initial value of 1.

Again starting from the equilibrium condition for a tariff-distorted economy, we consider the effects of technical progress in the Z sector. The initial equilibrium is given by:

$$(7) \quad e(\mathbf{p}, u) = g(\mathbf{p}\tau, \mathbf{v}) + t_z[(e_z(\mathbf{p}, u) - g_z(\mathbf{p}\tau, \mathbf{v})) - s(\alpha_x K_x, \alpha_z K_z)].$$

Taking the total differential of this with respect to  $\tau_z$  gives:<sup>8</sup>

$$(8) \quad \gamma(du/d\tau_z) = p_z y_z - t_z[y_z + p_z(\partial y_z / \partial p_z)] - \partial s / \partial \tau_z.$$

On the right hand side of (8), the first term is the output enhancement effect, and the second the reduction in tariff revenues attributable to the increase in Z sector productivity. The sum of these two terms is positive for all plausible tariff rates.<sup>9</sup> The third term is the effect of technical progress on the production of the externality, which is equivalent to that developed earlier:

$$(9) \quad \partial s / \partial \tau_z = \sum_j \alpha_j c_r^j(\mathbf{w})[\delta_{jz} y_j + p_j(\partial y_j / \partial p_z)] - \sum_j \alpha_j y_j c_{rw}^j [(w/r)(\partial r / \partial p_z) - (\partial w / \partial p_z)],$$

where  $\delta_{jz} = 1$  for  $j=Z$  and 0 otherwise. The first summation in (9) is positive. The second is negative as before since Z is the relatively labor-intensive good, so subtracting it has a positive effect on  $ds/d\tau_z$ .

Combining (9) and (8) we see that the overall welfare effect of technical progress in the labor-intensive, land-degrading sector is ambiguous. On one hand, productivity measured in terms of physical inputs is higher. On the other hand, the expansion of the sector is likely to lead to increased production of environmental damage and in addition, some tariff revenues are lost as domestic output growth replaces imports. However, producers in the upland agricultural sector benefit from the

technical progress, as in the tariff increase case, since they do not suffer directly as the result of either reduced tariff revenues or a small increase in land degradation. Other things equal, we would expect that in this situation private producers will press for the development of new technologies in the protected sectors even though their contribution to increases in aggregate economic welfare is not firmly established.

## **TECHNICAL PROGRESS AND THE DEMAND FOR INNOVATIONS**

Induced innovation theory explains the demand for technical progress of a particular rate and factor-saving bias in terms of shifts in factor prices or resource endowments (Hicks 1964; Ahmad 1966; Hayami and Ruttan 1985). It characterizes the supply of innovations as produced by advances in science and technology that shift out both the frontier of scientific knowledge and the “metaproduction function”, the latter defined by Binswanger and Ruttan (1978:5) as “the set of techniques that have actually been developed in the most advanced countries and that are used by the most advanced firms”. Both the demand and supply shifts are thus driven by inherently long-run phenomena. However, the theory also recognizes a shorter-run innovation supply response in which changing factor endowments or prices guide the pace and direction less of basic science than of technology transfer, screening and adaptive research. These are the primary activities of most developing-country national agricultural research institutes (Binswanger and Evenson 1978; Evenson and Pray 1991).

What has been lacking until now is a comprehensive explanation of the demand for such innovations over the same intermediate time frame: long enough for demand to be articulated and a supply response engendered, yet not so long that the influence of factor endowment trends swamps all other economic signals.<sup>10</sup> In less than the very long run, product price interventions and unaccounted externalities could well dominate factor endowment trends in shaping the demand and even the supply of technology transfer and adaptive research. In this section we explore the mechanisms and potential welfare implications of such a process.

In induced innovation theory, innovations are sought when factor price changes reflecting endowment shifts render some existing technologies unprofitable, at given output prices. In the dual formulation, factor prices are determined by product prices (as well as endowments, for large changes) and the search by producers for new technologies is directed at increasing factor returns for given output prices (this fits with the characterization of both land and labor as fixed assets: innovations, at given product prices, increase scarcity rents).

To analyze the demand for innovations we introduce a *factor price possibility frontier (FPPF)*, which by definition is the dual to the metaproduction function in factor

quantity space. For any given set of commodity prices, this frontier represents the outer boundary of possible factor price vectors achievable with a fixed research budget. The shape and slope of this frontier depends on the initial technologies ( $Q_x$  and  $Q_z$  in figures 1-3), the state of scientific knowledge, and the costs of transferring technologies to the home country or region.<sup>11</sup> The FPPF, or sections of it, can thus be shifted out not only by the generation of new technologies and/or reductions in the costs of their acquisition, but also by commodity price increases.

Suppose, for heuristic purposes, that initial innovation possibilities are neutral with respect to crops and technologies, so an equal increase in private profitability could be obtained for either crop from a given investment of research resources,  $R$ . (In this special case the shape and slope of the FPPF are determined by existing technologies, and the costs of adaptive research merely determine its distance from the origin). In figure 4 the FPPF corresponding to this assumption is drawn in as  $F_0(p, \tau, R)$ . Unlike the more general shape of the envelope typically used to represent a metaproduction function, the shape of the FPPF is a reminder that much applied and adaptive research is commodity-specific rather than directly oriented to the longer-run goal of conserving a factor that has become relatively scarce. However, the FPPF also reflects the lower cost of acquiring and adapting new technologies that use factors in similar proportions to existing technologies, since the shortest path (least cost) to the frontier from any point like A is along a ray of constant factor prices. By construction, if the entire research budget were to be devoted to factor-neutral improvements in production technology for each crop, the economy could move along a ray through the origin from its initial equilibrium to the corresponding point along  $F_0$ . A shift from A to C in figure 4 is one example. Research of value  $R$  producing technologies with different factor proportions relative to A could only buy a point somewhere closer to the origin than  $F_0$ . How will  $R$  be allocated at market prices with no value assigned to externalities, and how would it be allocated by a mechanism that took distortions into account?

In our two-sector model, technical progress that causes the Z sector to expand is accompanied by land use shifts that reduce land quality and increase environmental externalities. While upland producers' incomes are unaffected by small changes in these outcomes, aggregate economic welfare (inclusive of the costs of pollution and/or resource depletion) is a declining function of  $K_z$ , other things equal. Thus from the point of view of a social planner -- that is, taking account of the social costs of distortions and externalities -- the benefits of investing in R&D directed at the Z sector are lower than from the point of view of the owners of upland land and labor.

Since the owners of upland factors assign no value to tariff revenues or externalities, it is clear that if innovation possibilities are neutral, the optimal choice of

new technology subject to a research budget constraint  $R$  will be that which moves them as far as possible along a ray through the origin. In terms of figure 4, they will always choose to move to  $C$  from  $A$ .

The social planner (SP) must take account of distortions that drive wedges between market and shadow prices. Since in this simple model all goods are traded and their prices exogenous, the SP's optimization problem is to choose the vector  $\tau$  that maximizes the value of production at shadow (border) prices, net of the effective factor endowment effects of land degradation:

$$\max_{(\tau_x, \tau_z)} \{p_x^* X + p_z^* Z - s(\alpha_x K_x, \alpha_z K_z)\},$$

subject to  $R = \tau_x + \tau_z$ . A formal statement of the problem is given by (10):

$$(10) \quad L = \max_{\tau_x, \tau_z, \theta} \left\{ \sum_j p_j g_j(\tau \mathbf{p}, \mathbf{v}) - t_z g_z(\tau \mathbf{p}, \mathbf{v}) - s(\alpha_x K_x, \alpha_z K_z) + \theta(R - \tau_x - \tau_z) \right\},$$

where  $j = X, Z$  and  $\theta$  is the Lagrange multiplier associated with the research budget constraint. Without loss of generality let  $p_x^* = 1$ . The first-order conditions of this maximization are:

$$(11.1) \quad (\partial g_x / \partial \tau_x) + p_z (\partial g_z / \partial \tau_x) - t_z (\partial g_z / \partial \tau_x) - (\partial s / \partial \tau_x - \theta) = 0$$

$$(11.2) \quad (\partial g_x / \partial \tau_z) + p_z (\partial g_z / \partial \tau_z) - t_z (\partial g_z / \partial \tau_z) - \partial s / \partial \tau_z - \theta = 0$$

$$(11.3) \quad R - \tau_x - \tau_z = 0$$

Combining (11.1) and (11.2):

$$[(\partial g_x / \partial \tau_x) - (\partial g_x / \partial \tau_z)] + (p_z - t_z)[(\partial g_z / \partial \tau_x) - (\partial g_z / \partial \tau_z)] = (\partial s / \partial \tau_x) - (\partial s / \partial \tau_z).$$

Using (9) and the relations provided in footnote 8, multiplying by  $\tau_z$  and rearranging:<sup>12</sup>

$$\begin{aligned} & (\tau_z / \tau_x)[(y_x + (\partial y_x / \partial p_x))] - p_z[(y_z + p_z(\partial y_z / \partial p_z))] \\ & - p_z[1 - (\tau_z / \tau_x)(1 - (t_z / p_z))](\partial y_x / \partial p_z) = (\tau_z / \tau_x)(\partial s / \partial \tau_x) - (\partial s / \partial \tau_z); \end{aligned}$$

from which the optimal share of sector  $Z$  in the R&D budget can be solved as:

$$(12) \quad \frac{\tau_z^*}{R - \tau_z^*} = \frac{(p_z - t_z)[(y_z + p_z(\partial y_z / \partial p_z))] + p_z(\partial y_x / \partial p_z) - (\partial s / \partial \tau_z)}{[(y_x + (\partial y_x / \partial p_x))] + p_z[1 - (t_z / p_z)](\partial y_x / \partial p_z) - (\partial s / \partial \tau_x)}$$

where each  $\partial s / \partial \tau_j$  is evaluated in terms of price changes as in (9).

If there are no land degradation effects (e.g. if all  $\alpha_j = 0$ ) and no initial tariff distortions ( $t_z = 0$ ) then the socially optimal share of R&D expenditures on sector  $Z$  depends only on relative supply responsiveness and the effects of expansion of one sector on the output of the other -- effects captured by the first two terms of the numerator and denominator of (12). Owners of upland factors will demand a research

budget in which  $\tau_z/(R-\tau_z)$  matches this ratio, and this will also be the socially optimal research portfolio.

By contrast, if some  $\alpha_j > 0$  then the optimal ratio is reduced by the extent to which (other things equal) a transfer of resources from X to Z, or an expansion of Z, would lead to a more rapid rate of degradation - just as in the discussion of price policies and technical progress in the previous section. In the example we have been using thus far, expansion of Z reduces the effective land endowment. In figure 4, as technical progress shifts the economy closer to  $F_0$  along  $w/r$ , the slope of the aggregate factor endowment ratio  $k$  declines in proportion to the expansion of Z. Accordingly, the social planner will prefer a different portfolio of research projects to that demanded - perhaps even one specialized in sector X technologies, but in any case having a lower allocation of resources to  $\tau_z$  than will be demanded by upland farmers. Thus the SP would prefer to fund research that moves the upland economy along a ray from A of lower slope than  $(w/r)$ , reflecting the higher social opportunity cost of land measured in effective units, in the direction of a point such as D, below C and also by necessity below  $F_0$ , since to acquire new technologies having different factor proportions is more costly.

Now consider the influence of the tariff on the demand for commodity-specific research resource allocation. Suppose that producers of Z have acquired additional trade policy protection, such that their isoprofit curve is initially  $Q_z'$  rather than  $Q_z$  and the initial full-employment equilibrium is at B, where (relative to A) a greater share of land is used in the land-degrading sector and production is more land-intensive in both sectors. The tariff also moves the relevant section of the FPPF out by the same proportion by which  $Q_z$  was displaced (the new FPPF is labelled  $F_1(p+t, \tau, R)$ ).

Upland producers will now demand a research portfolio directed to achieving the maximum factor price vector at E. However, from (12), the social planner's optimum will again lie below the privately optimal point, and in fact will diverge even further from the private optimum than in the no-tariff case. Therefore, the trade policy will have generated a commodity bias in the demand for innovations augmenting that generated by the missing market for land quality, with a more negative welfare impact, and a higher relative degree of compensation to sector X in the allocation of research resources will therefore be merited.<sup>13</sup>

Of course, non-neutral technical progress opportunities would change the above analysis in predictable ways. Inherent commodity (or factor) biases in research would be reflected in the shape of the FPPF. These would then either augment or offset other influences on the sectoral structure of production. Finally, it should be noted that a sufficiently large bias in R&D resource allocation against Z may result in the upland



economy specializing in the production of X. This simply mirrors the point raised earlier, that price policy or commodity bias in the allocation of research resources could induce diversification in a previously specialized economy. If production of Z was not privately optimal before the tariff, then it is certainly possible that social welfare could be maximized by denying the sector public research resources to the point where production of Z ceases once again.

### **Induced innovation biases and research policy**

The idea that research resources should be allocated in ways that compensate for distortionary policies or for environmental externalities may seem counter-intuitive at first, but in certain policy settings it may be a useful and even powerful tool of agricultural development policy. In developing countries, the kinds of distortions dealt with in this paper -- commodity-specific trade policies and non-point pollution problems -- are frequently very difficult to address directly. Trade policies on crops grown in uplands are particularly problematic from a political economy viewpoint for several reasons. Upland communities are typically very poor and often belong to ethnic minorities, so for political and distributional reasons governments are reluctant to take steps that will hurt upland communities economically without delivering tangible benefits elsewhere. Temperate-climate vegetables -- typical candidates for our Z sector goods -- are consumed largely by relatively wealthy urbanites, so there is unlikely to be strong consumer motivation to demand reduced protection for these crops.

On the environmental side, the inherent difficulty of using first-best measures to correct non-point pollution problems are compounded in uplands of developing countries by remoteness, poorly developed infrastructure and a low degree of participation by farmers in formal sector institutions such as the tax system.

In this setting, second-best solutions to the problems of resource misallocation and environmental degradation must be sought. In choosing  $\tau$  by a shadow pricing rule rather than some market-based mechanism the social planner is using research resource allocation as a substitute for a Pigouvian tax on Z - or subsidy on X.

With few exceptions, induced innovation theories give little consideration to the role of distortions or externalities as determinants of the commodity or factor biases of the innovations demanded by farmers. Nor has the theory devoted much attention to the influence of technical progress, with or without distortions, on the sectoral structure of production. This analysis identifies the demand for innovations as a function of not only of relative factor endowments, but also of a specific policy setting which conditions and is in turn conditioned by the sectoral structure of production. In this context the capacity for divergence between privately optimal and welfare-maximizing allocations of research resources is substantial. Therefore, calculations of the internal

rate of return to agricultural research in environmentally sensitive areas, or addressing crops subject to trade or pricing policy interventions, should strive to make use of shadow prices rather than accepting market prices as representing true social values.

At the beginning of this paper I suggested that part of the problem of inappropriate research resource allocation, where it occurs, could stem from a form of 'institutional failure'. Different agencies of government are charged with different tasks and these may conflict. The Ministry of Agriculture for example, may use agricultural profitability (at prevailing, possibly distorted prices) as a criterion when deciding on R&D resource allocation, whereas an environmental agency or power generation authority might take a broader view of agricultural development priorities. Use of a commonly agreed set of shadow prices for project evaluation, including research planning, would be an important step in the direction of improved coordination or policy and programs across different agencies involved in agricultural development and natural resource management. Some of these issues are evident in the commodity case study to which we now turn.

## **A CASE STUDY**

The case of white (or Irish) potato production in the highlands of Southeast Asia provides an interesting empirical illustration of many of the analytical points made in this paper. Potato is a minor crop in the total agricultural economy of Southeast Asia, but it is of much greater significance in the relatively small highland areas where its cultivation is agronomically and climatically feasible.<sup>14</sup> In the ecologically fragile, steeply sloping upland areas where it is grown, potato is a crop that is very intensive in its use of labor and non-land inputs relative to more traditional upland crops. It is also very erosive, since effective potato cultivation requires frequent tillage and thorough weeding, with consequent high exposure of soils to rain and wind erosion.

Economically, potato production has been the target of special trade and market policies in some Southeast Asian countries (Thailand, Indonesia, the Philippines and Sri Lanka), where it continues to flourish as an industry (table 1). In these countries the volume of potato imports adds up to 1% or less of domestic production in most years, except in Thailand, where the figure is around 5%. The argument that transport and related costs afford potato a degree of 'natural' protection appears weak when we observe that in Malaysia, where potato imports are effectively untaxed, there is no discernible commercial potato cultivation in spite of the presence of a thriving vegetable industry in areas like the Cameron Highlands.<sup>15</sup>

Singapore maintains free trade in fresh potato and imports large quantities, from China, Taiwan and the Netherlands (Scott 1987). The Singapore c.i.f. price is

therefore a reasonably good indicator of regional border prices, once exchange rate differences are corrected. Scott (1987) observed that in the period 1979-84 farm gate prices in northern Thailand (the country's main production area) were approximately equal to Singapore retail prices. In the Philippines, one of the few countries in the region for which reasonably good time series of potato prices are available, the average farm gate price exceeded the Singapore c.i.f. price by 28% between 1961 and 1985 (figure 5). If we allow for approximately 30% overvaluation of the official Philippine peso during this period (Bautista et al. 1979) then prices in these two series are approximately equal. However, since domestic transport and marketing costs to Manila, the port and major market, add 50-100% or more to the Philippine farm gate price, it is difficult to imagine the domestic potato industry competing successfully against imports under free trade -- that is, at shadow prices *before* environmental factors are taken into account.<sup>16</sup> In spite of this the Philippine Department of Agriculture has identified white potato, together with a group of more traditional Philippine agricultural exports such as mango and banana, as a "high-valued crop" to receive special policy attention under the "Key commercial crops development program" (Philippine Department of Agriculture 1995).

In those countries where potato is commercially grown, production growth has exceeded population growth,<sup>17</sup> with most of the increase apparently coming from area expansion rather than from yield increases (Librero and Rola 1994; Scott 1987). Potato cultivation in the tropics is beset by pest and disease problems, to which farmers have typically responded with intensive application of chemicals. Governments, aid agencies, international organizations and some private corporations have engaged in technology transfer and adaptive research directed at improving varietal selection, seed stocks, production techniques, and pest management. Off the farm, governments and bilateral aid projects have invested in infrastructural development, marketing support, price stabilization, input subsidies and related activities (Crissman 1989; TDRI 1994).<sup>18</sup>

It is difficult to quantify the allocation of research resources to a specific crop, but the limited data available for the Philippines indicate that in that country, the agricultural R&D budget for vegetables, legumes and root crops is approximately equal to the share of these commodities in the total value of agricultural production at market prices, while that for more land-intensive plantation crops (coffee, cacao, rubber) that compete for upland land and labor resources is about one-fifth of the market value of those crops (figure 6). Another proximate measure of R&D share is provided by the volume of research output on a commodity. Again for the Philippines, Librero and Rola (1994) reviewed 182 research papers produced between 1970 and 1993 that studied production, marketing and consumption of vegetables. Of these, 38 (20%) addressed white potato in whole or in part - a ratio far exceeding the importance of this

crop among all vegetables produced in the country. Similar ratios are reported for other highland vegetable crops covered by import bans or restrictions, such as cabbage.

In Thailand, a range of foreign-funded projects and the government's Royal Project have been instrumental in channeling funds and resources to highland agricultural development. These projects have introduced new temperate climate fruit, flower and vegetable crops to highland areas, encouraging their adoption by subsidizing adaptive research, input costs and marketing (TDRI 1994). The Thai Department of Commerce (which sets trade policy) has manipulated the quantitative restriction on seed potato imports with the aim of defending domestic potato prices, restricting imports in years of high domestic production and relaxing them in bad years (Scott 1987).

Both in the Philippines and in Thailand, highland agricultural land is rarely if ever held in legal title. Most highland areas are classified as public property either by virtue of their slope, or because they form part of a protected forest or watershed area. Thus in Thailand a major impediment to socially optimal agricultural land use arises because "there is **no legal basis** supporting sustainable permanent agriculture in the highlands" (TDRI 1994; emphasis in original). In the Philippines, where all land above 18% slope is officially inalienable public land, the wholesale invasion and denudation of the Mt. Data National Park in Northern Luzon by temperate-climate vegetable farmers has been documented by Lewis (1992).<sup>19</sup> Under these property rights regimes there is little prospect that farmers can be expected to take full account of on-site land degradation problems associated with cultivation of nutrient-depleting crops, let alone to consider their off-site effects.

Finally, there is considerable evidence of 'institutional failure' of the kind that could inhibit effective policy formation for sustainable development of highland agriculture. In Thailand, TDRI (1994) has documented the fragmentation of responsibilities among different (and often competing) government organizations:

At present, agricultural research and extension work in the highlands are conducted on a piecemeal basis. Soil and water conservation research and technology are the responsibility of the Department of Land Development (DLD). Separate institutes of the Department of Agriculture carry out research on horticultural crops (fruits, flowers, vegetables) and field crops (rice, wheat, maize, soybean). Extending soil and water conservation technology and crop improvement methods to farmers are conducted independently ... The present bureaucratic division within the Ministry of Agriculture does not lend itself to the solving of complex problems (TDRI 1994:133).

In this institutional setting specialized agencies focused on particular commodity groups are more likely to compete for a larger slice of the research and extension pie than to collaborate on allocating funds in an optimal manner. Moreover, specialized

agencies are more vulnerable to 'capture' by farmer interest groups seeking to advance research and other forms of support for their own commodities.

In terms of the model presented in this paper, potato in Thailand and the Philippines represents an upland crop for which the rate of return to research valued at social prices is likely to be far below that at market prices (and may well be negative once externalities are taken into account). Cultivation is privately profitable purely by virtue of import barriers and ancilliary domestic support policies, including the devotion of public and foreign aid funds to research, technology transfer, extension and marketing support. Under current technologies potato must be grown in high-altitude areas where soils are fragile, shallow and often steeply sloping; unresolved pest and disease problems are addressed by very intensive application of agricultural chemicals, with attendant water, air and soil pollution risks, and with poorly defined property rights, there is little prospect that farmers or upland communities will internalize the full environmental costs of cultivation. At shadow prices, the optimal allocation of upland land and other resources to potato production may well be zero, implying specialization in other crops. The risk, given a high probability of institutional failure as described above, is that high private profitability, made possible by trade restrictions and domestic market supports, will translate successfully into productivity-enhancing research results that enable expansion of potato area without compensating reductions in the land-degrading properties of potato cultivation.

Potato is a relatively minor crop in Southeast Asia. However, vegetables in general as well as several cereals and pulse crops commonly grown in uplands (corn and soybean in particular) have also been the targets of trade policy protection over the past few decades. These and related interventions have contributed to major upland land use changes away from perennial crops, long-fallow systems and pasture towards increasingly intensive cultivation of relatively land-degrading, erosive crops (Hefner 1990; Lewis 1992; TDRI 1994). Insofar as the costs of soil erosion from upland areas of developing countries have been quantified, they are surprisingly large in relation to national income (Barbier and Bishop 1995).

## CONCLUSION

The factor market focus of most induced innovation theory, and its use of aggregate measures of output, have obscured some important relationships in diversified and distorted agricultural economies. First, small changes in relative factor endowments need not be reflected in factor price changes as long as the aggregate factor endowment vector remains within the economy's cone of diversification. Thus small endowment changes do not send the signal that provides the main mechanism of induced innovation in the standard theory.

Second, in practice, much or even most agricultural R&D spending is directed at commodities rather than at saving on relatively expensive factors *per se*. Commodity biases in trade or price policy may alter the structure of agricultural production, and in so doing generate their own biases in the private demand for additional innovations from factor owners seeking to maximize factor rewards valued at market prices.

Third, if the effective factor endowment is altered by agricultural growth - as when some crops deplete soils - or if agricultural growth generates off-site externalities, then less than a full valuation of the resource costs of growth will again cause factor prices to be misleading signals of relative factor scarcity. Public sector research resource allocation based on market prices of either factors or commodities in an economy characterized by distortions and externalities may redistribute income, but will not maximize social returns to scarce research resources.

In industrialized countries, the efficiency costs of biased demand for innovations are likely to be small even as a fraction of agricultural income. In developing economies, where agriculture is proportionally much larger both in terms of factor allocation and consumption expenditures, and where the total pool of resources devoted to agricultural research is relatively small, these costs could in principle be relatively large.

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## NOTES

<sup>1</sup> “... a change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind - directed to economising the use of a factor which has become relatively expensive.” (Hicks 1934). As a long-run phenomenon the theory has considerable empirical support (Hayami and Ruttan 1985; Binswanger, Ruttan and others 1978).

<sup>2</sup> The return to labor should be interpreted as a return not only to the 'raw' input (for which the long-run price could seldom be argued to be endogenous to an agricultural region, even with positive transactions costs) but rather to labor plus management inputs. In the upland setting, farms typically consist of many small plots worked mainly by family labor; their managerial input is substantial.

<sup>3</sup> This exposition uses the dual of the usual isoquant diagram in order to highlight changes in the structure of production. For earlier presentations of this dual model see Dixit and Norman 1980; Woodland 1982, and Mussa 1979.

<sup>4</sup> This conditions is the equivalent of the requirement that the endowment point lie within the 'cone of diversification', i.e. the region in which at least as many goods are produced as factors used in their production (Woodland 1982).

<sup>5</sup> Land is fully employed in production, so

$$K_x + K_z = K, \text{ from which}$$

$$\lambda_{lx} + \lambda_{lz}k_z = k,$$

but  $\lambda_{lz} = 1 - \lambda_{lx}$ ; rearranging terms:

$$\lambda_{lxX} = (k_z - k)/(k_z - k_x) = HI/GI, \text{ and } \lambda_{lz} = (k - k_x)/(k_z - k_x) = GH/GI.$$

Figure 2 shows a decline in the land-labor ratio, so  $k' < k$ : then  $\lambda_{lx}' > \lambda_{lx}$  and  $\lambda_{lz}' < \lambda_{lz}$ . Since the labor stock is fixed and factor prices are unchanged, the output of Z must have risen and that of X declined at the new land-labor ratio (proof adapted from Mussa 1979).

<sup>6</sup> If Z were land-intensive, a rise in its price would raise  $r$  and reduce  $w$ , so the term in (3) enclosed in square brackets would be positive, and the entire second line of (3) negative -- factor substitution effects would diminish the additional land degradation caused by the expansion of sector Z.

<sup>7</sup> The analysis is readily extended to non-neutral cases including factor-biased technical progress (Dixit and Norman 1980). Geometrically, a labor (land) saving bias in technical progress would rotate an isoprofit curve clockwise (anticlockwise) in addition to shifting it out from the origin.

<sup>8</sup> The derivation makes use of two relations that hold for product-augmenting technical progress:

$$\tau_i(\partial g/\partial \tau_i) = p_i(\partial g/\partial p_i), \text{ and}$$

$$\tau_i(\partial^2 g/\partial \tau_i \partial p_j) = \delta_{ij}(\partial g/\partial p_i) + p_i(\partial^2 g/\partial p_i \partial p_j),$$

where  $\delta_{ij}$  is the Kronecker delta, i.e.  $\delta_{ij} = 1$  for  $i = j$ , and 0 otherwise (Dixit and Norman 1980:138).

<sup>9</sup> In Alston and Martin (1995) the possibility of immiserizing growth from technical progress depends on the magnitude to the change in this term relative to that of the technical progress shock.

<sup>10</sup> de Janvry (1978) pointed the way for this analysis in an important paper in which structural factor market distortions associated with a bimodal farm size distribution in Argentine agriculture were identified as sources of socially suboptimal biases in the demand for new technologies.

<sup>11</sup> Binswanger and Evenson (1978, Ch.6) provide a detailed disaggregation of the costs of adaptive research.

<sup>12</sup> Full derivation is available from the author and as an appendix to the electronic form of this paper, located at <http://aae-nt.aae.wisc.edu/~coxhead/>

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<sup>13</sup> A more subtle problem arises when the nature of the policy intervention is such as to isolate domestic prices from their world market equivalents. Temperate-climate vegetables in particular are highly income-elastic foodstuffs, and since the area suitable for their cultivation in tropical countries is limited to highlands, urbanization and per capita income growth has driven up their domestic prices while the prices of competing crops, linked to the world market, have in many cases stagnated. The outcome is that the vegetable crops have come to be regarded as promising sources of future income -- "high-valued crops" deserving of public R&D support, while traditional highland agricultural products languish.

<sup>14</sup> Under current technologies potato grows best in regions where nighttime temperatures fall below 18°C. In Southeast Asia production usually starts at altitudes well above 500m.

<sup>15</sup> The FAO production yearbooks do not report potato production data for Malaysia, although the counterpart trade volumes do report imports. Studies of the Malaysian vegetable economy make no mention of potato cultivation (Dagap 1987; bin Othman 1990) and vegetable specialists working in Malaysia observe no potato production (David Midmore, pers. comm).

<sup>16</sup> A recent study estimated the tariff equivalent of the potato import ban at 40% (Philippine Department of Agriculture 1996).

<sup>17</sup> Econometric evidence on the demand for potato in tropical countries is scarce. Librero and Rola (1995, table 2.18) cite findings from a 1973 Philippine study in which the expenditure elasticity for white potato, estimated at 0.87, is by far the highest of all such elasticities in a 16-commodity study, and in fact is more than 50% higher than all but one other vegetable (Baguio beans).

<sup>18</sup> Upland farm communities are typically the poorest identifiable group in any developing country, and a case can be made on distributional and anti-poverty grounds for discriminating in their favor. However, this is not true for commercial vegetable farmers. According to Crissman (1989:9): "Potato production in the Philippines is a highly profitable activity: potato producers in Benguet [the major growing area] are among the wealthier small farmers in the country".

<sup>19</sup> According to Lewis, the park is more aptly titled the Mount Data National Cabbage Patch.

**Table 1:****Fresh vegetable and potato trade policies in some Southeast Asian countries**

Country	Year	NPR: Fresh Vegetables		Potato trade policies	Other relevant trade policies
		Range	Average <sup>1</sup>		
Indonesia	1990	0 - 50%	21% (NPR) 29% (EPR)	NPR: 29% EPR: 33%	Duty-free seed potato imports.
Malaysia	1993	0 - 5%	4.4%	None	Phytosanitary licensing; cabbage import quota.
Philippines	1992	3 - 45%	38.1%	Import ban since 1950 <sup>2</sup>	Seed potato import licensing.
Singapore	1989	0	0	None	
Thailand	1989	2.4-94.1%	52.7% <sup>*</sup>	Import ban <sup>3</sup>	Seed potato import licensing.

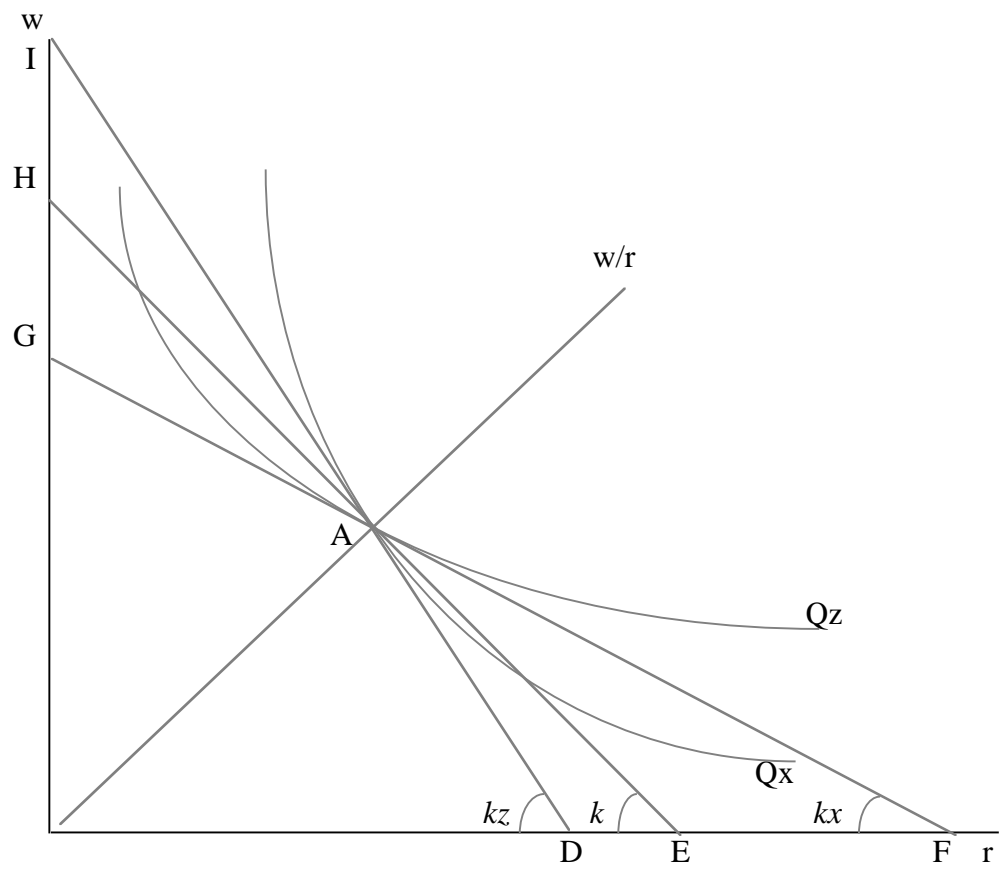
**Notes:**

1. Simple average except: <sup>\*</sup> weighted average of applied tariffs.

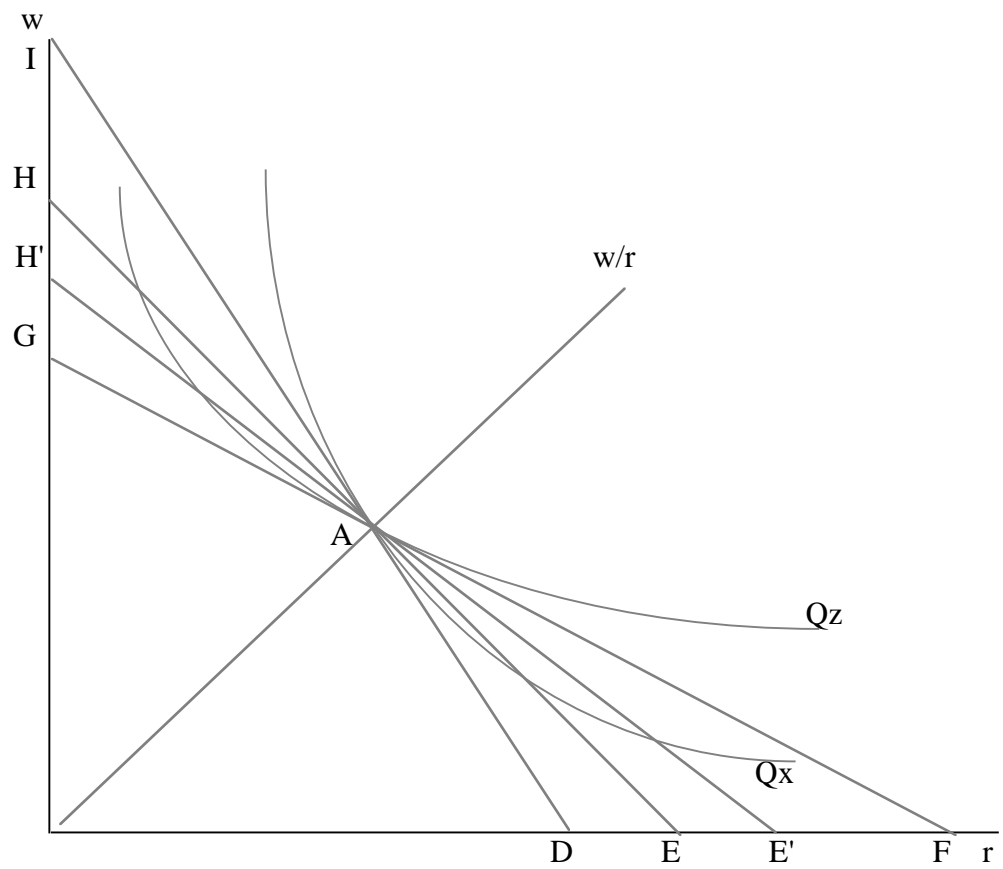
2. The 1993 Philippine law directed primarily at upland vegetable farmers and known as the “Magna Carta for Small Farmers” (RA No. 7607) reiterated the import ban on potato, cabbage and some other horticultural crops and mandated that “importation of agricultural commodities that are locally produced in sufficient quantities will not be allowed, to protect producers from unfair competition” (Philippine Department of Agriculture 1993:31).

3. Under Thai law, fresh potatoes are listed among restricted imports in the category of “imports generally not allowed” with the objectives of “protecting local production” and “to enable farmers to sell their products at reasonable prices” (GATT 1991a:259-260).

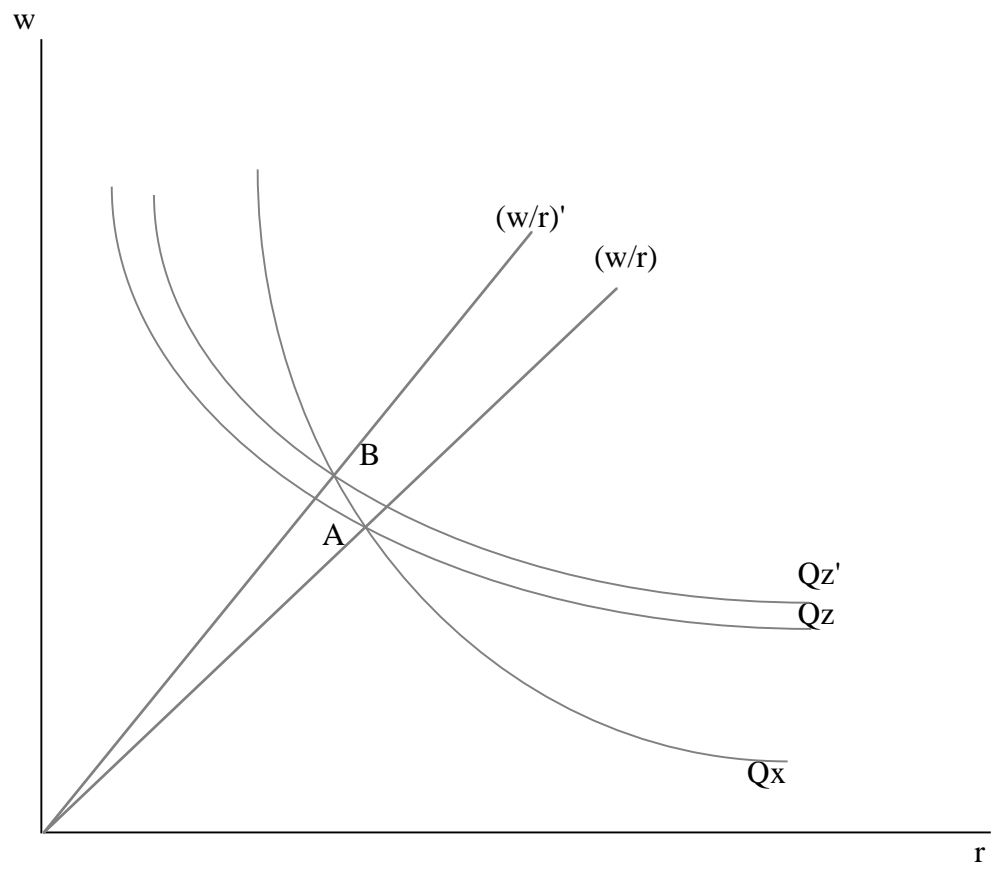
**Sources:** GATT 1991a, 1991b, 1992, 1993a, 1993b.



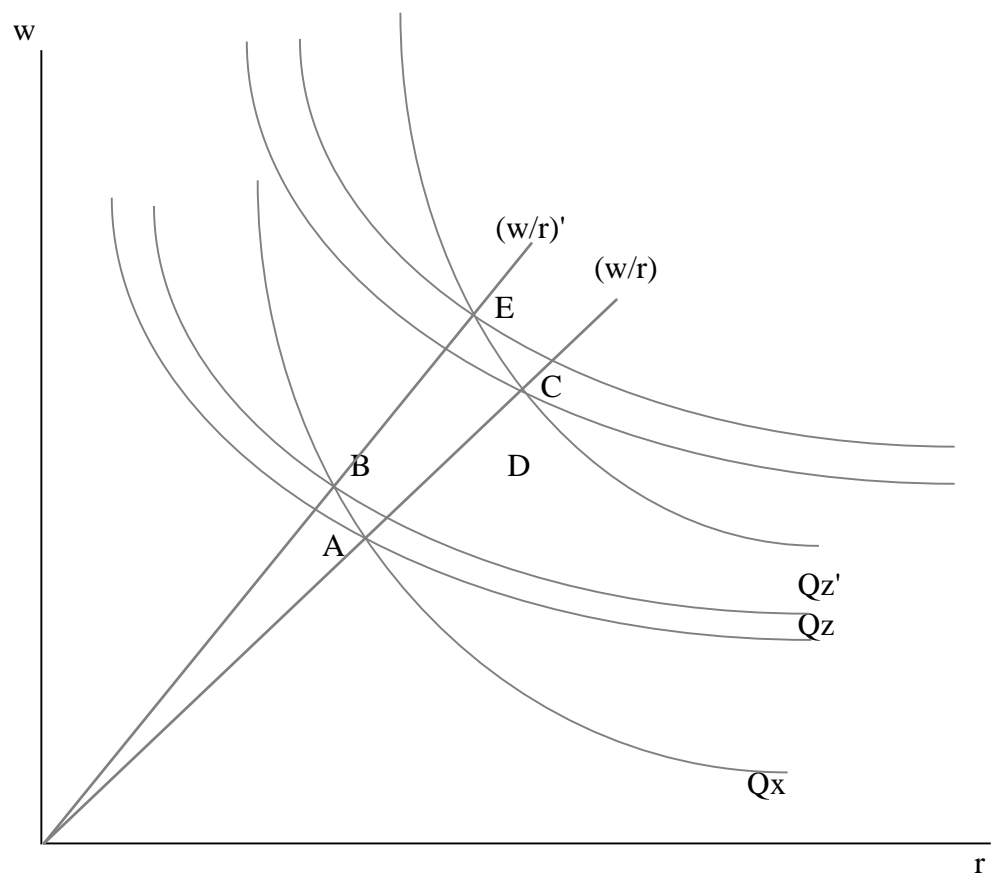
**Figure 1**



**Figure 2**

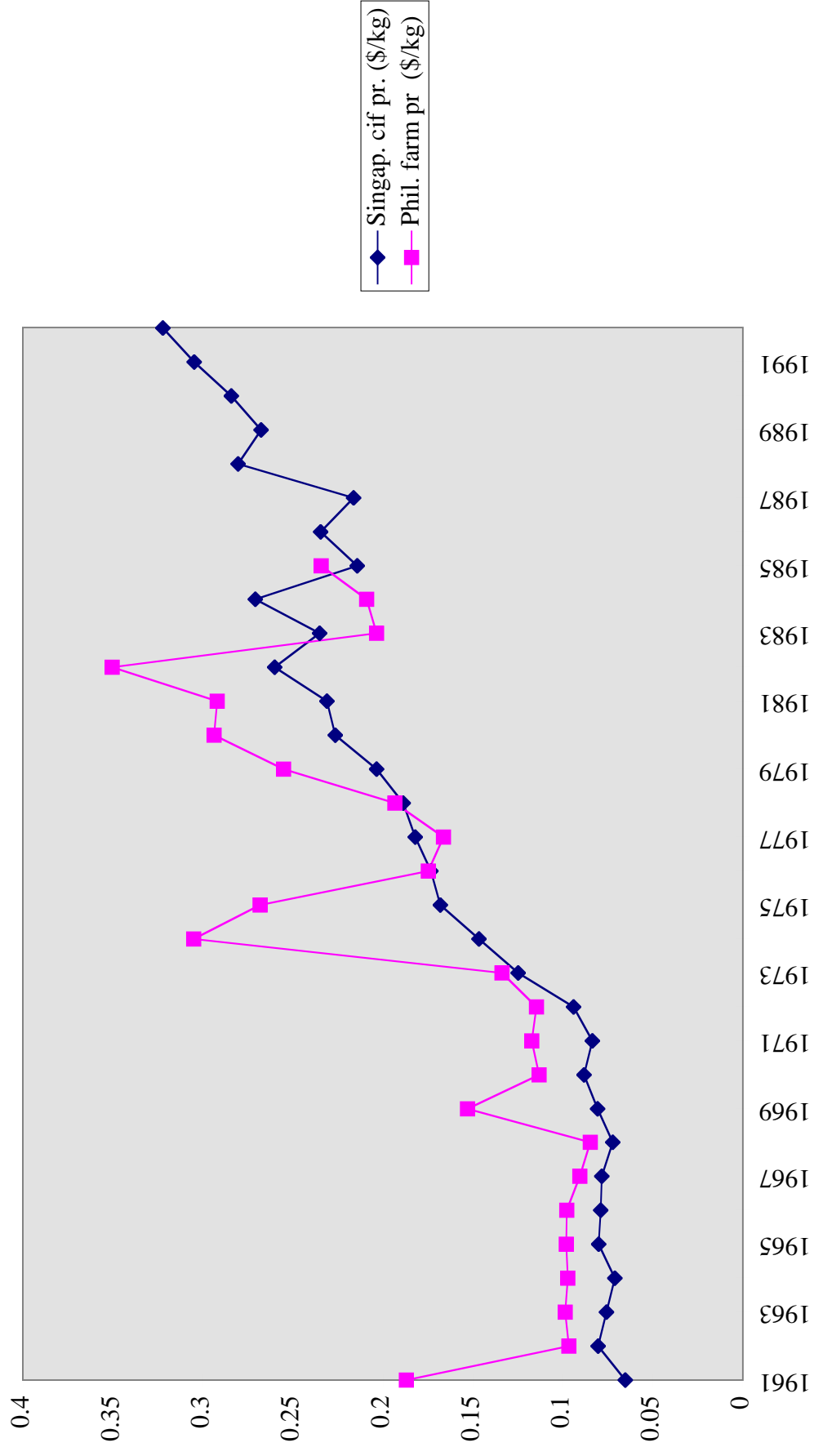


**Figure 3**



**Figure 4**

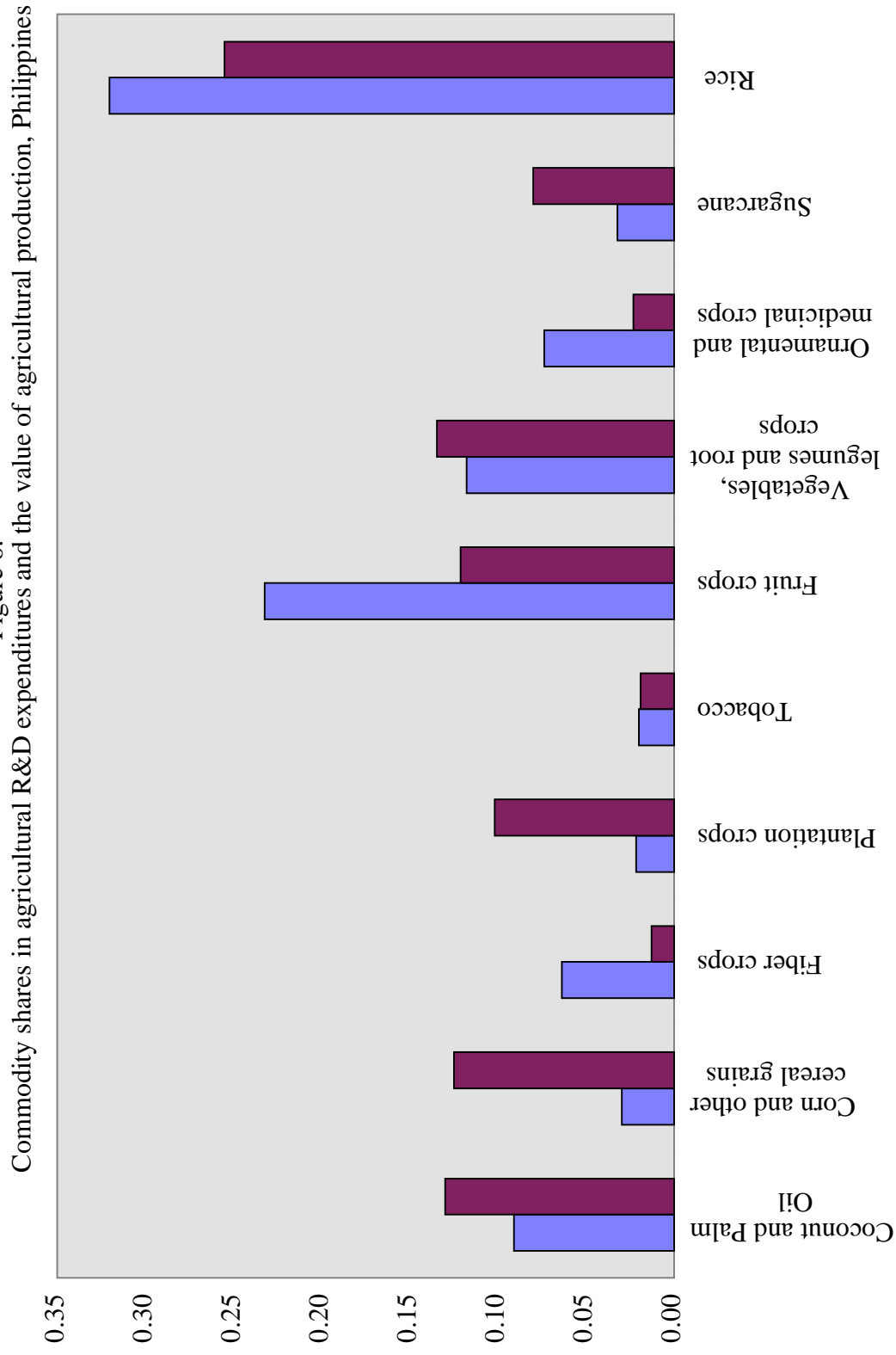
**Figure 5:**  
**Potato: Philippine farm gate and Singapore cif import prices**



Sources: Philippine prices calculated from Crissman (1987), Appendix A;  
Singapore prices calculated from FAO (various years).



Figure 6:



Sources: (R&D shares) Phil. Council for Agriculture, Forestry, and Natural Resources Research and Development; (Value shares): NCSO 1993.