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# Technology, production environment, and household income: Assessing the regional impacts of technological change

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**Abstract**

This paper clarifies the factors determining the welfare effects of improved agricultural technologies when technology diffusion is unevenly distributed across production environments. Household-level income effects are shown to depend primarily on: (a) whether the economy is open or closed with respect to world markets; (b) whether households are net consumers or net producers of the commodity for which technological change occurs; (c) whether households are adopters or non-adopters of the new technology; (d) the degree to which labor is mobile across agricultural regions; and (e) government intervention in commodity and/or factor markets. A review of recent empirical work indicates considerable variation in the relative strength of these various factors across countries, and that assumptions regarding the mechanism by which commodity prices are determined – endogenously as in a closed economy, or exogenously as in an open economy – is especially critical.

## 1. Introduction

Since the early days of the Green Revolution, social scientists have debated how agricultural technologies affect the welfare of various socioeconomic groups in countries experiencing rapid technological change. This debate has spawned a considerable (and at times contentious) literature investigating the impacts of technologies related to the production of foodgrains. The great bulk of empirical work in this area has focused on socioeconomic groups located in areas in which the new technologies were adopted, examining the impacts of technological innovations on the incomes of various types of households (large farm, small farm, landless labor) and on returns to various factors of production (land, labor, capital) [1]. In addition to analyses of direct productivity effects, other research has highlighted less immediate impacts of technological change operating through commodity and factor markets (Evenson and Flores, 1978; Scobie and Posada, 1978; Quizon and Binswanger, 1986). Still other work has analyzed the stimulus to non-agricultural sectors (both rural and urban) provided by technological change (Mellor, 1975).

Until recently, relatively little attention has been paid to the fact that the diffusion of improved production technologies such as high yielding varieties (HYVs) occurs unevenly across production environments. Historically, the bulk of productivity gains resulting from technological

[1] Lipton and Longhurst (1985) offer a comprehensive survey of this literature.


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innovations have been registered in well-watered or irrigated areas enjoying favorable topographic and agronomic conditions. In contrast, less favored or marginal environments have generally lagged in terms of adoption and the attendant impacts on productivity (CIMMYT, 1991). This has partly been the result of the inherent difficulty of developing new technologies suited to the more difficult marginal environments. In many cases it is also presumably the result of institutional strategies for maximizing the potential payoff to research activities (Renkow, 1993). Whatever the reason, distinct differences in the diffusion of improved technologies across production environments persist to this day in most developing countries.

This paper discusses key issues in analyzing the impacts of a yield-enhancing technology targeted to a particular production environment on various socioeconomic groups located in both adopting and non-adopting areas. The next section traces the direction and magnitude of welfare changes associated with differential technology adoption, as mediated through product markets and labor markets. Partial equilibrium analysis is used to isolate the key factors determining the impacts of technological change on various types of households. The third section of this paper discusses the role of government in modifying the transmission of the benefits and costs of technological change through consumer, producer, and input pricing policies. The fourth section of the paper reviews the findings of recent empirical work on the impacts of regionally differentiated technological change. Concluding remarks are found in the final section.

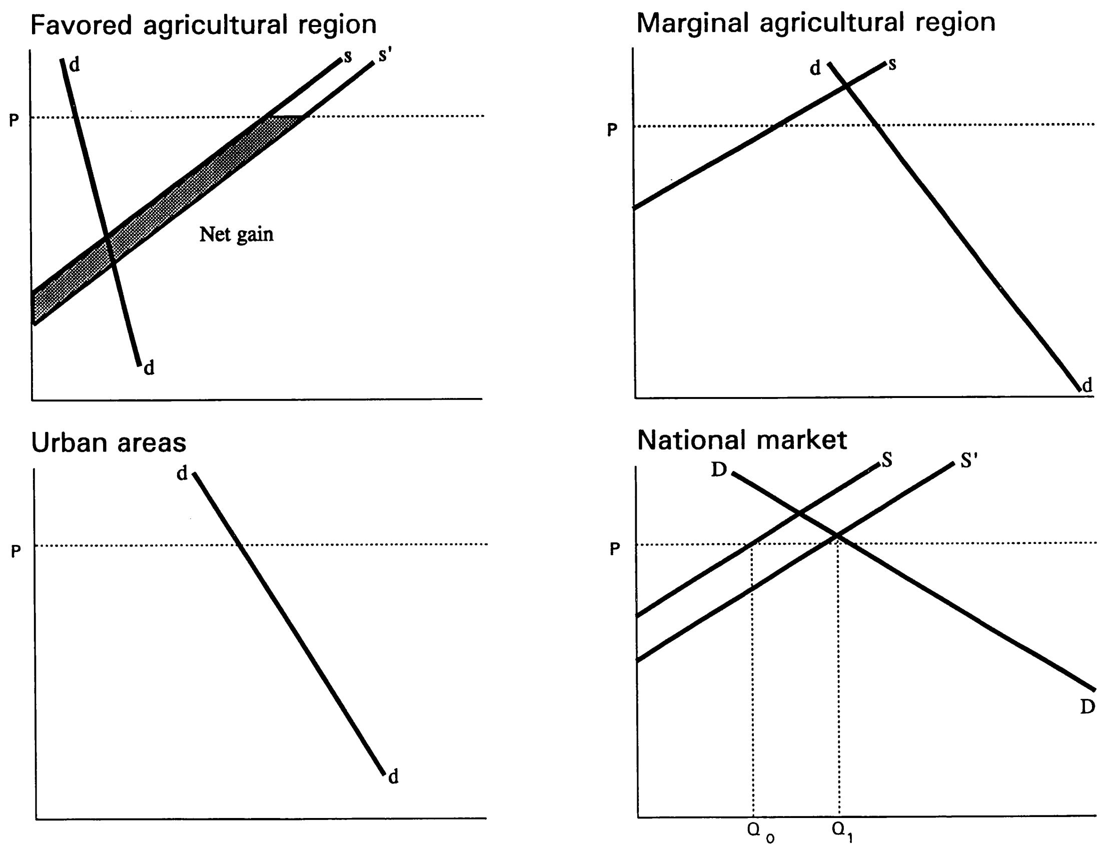


Fig. 1. Commodity market impacts of technological change: Open economy case.

## 2. Indirect effects of technological change

The two most important avenues through which the indirect effects of technological change are transmitted are commodity and labor markets. The discussion in this section considers the effects of a hypothetical yield-increasing innovation for each of these markets. For expositional ease, it is assumed that the hypothesized innovation is adopted only by farmers in one distinct ('favored') production environment, and that adoption is instantaneous and complete in this favored area. The analyses thus depict a stylized version of the process of technological change wherein the most extreme degree of regional differentiation exists. The discussion of commodity markets further assumes that (a) the country of interest is a net importer of the commodity for which technological change occurs; (b) the favored agricultural area is a net exporter of the commodity in question to other areas of the country; and (c) the other, 'marginal' agricultural area is a net importer of the commodity in question.

### 2.1. Commodity market effects

A large literature addresses the distributional impacts of various types of technological innovations due to their effects on prices in commodity markets. Early work in this area was oriented toward ascertaining social returns to agricultural research (Ayer and Schuh, 1972; Akino and Hayami, 1975). These studies emphasized the relative effects of technical change on producers and consumers using standard Marshallian surplus concepts. The basic message of these analyses is that in open economies producers reap the lion's share of the benefits from technological

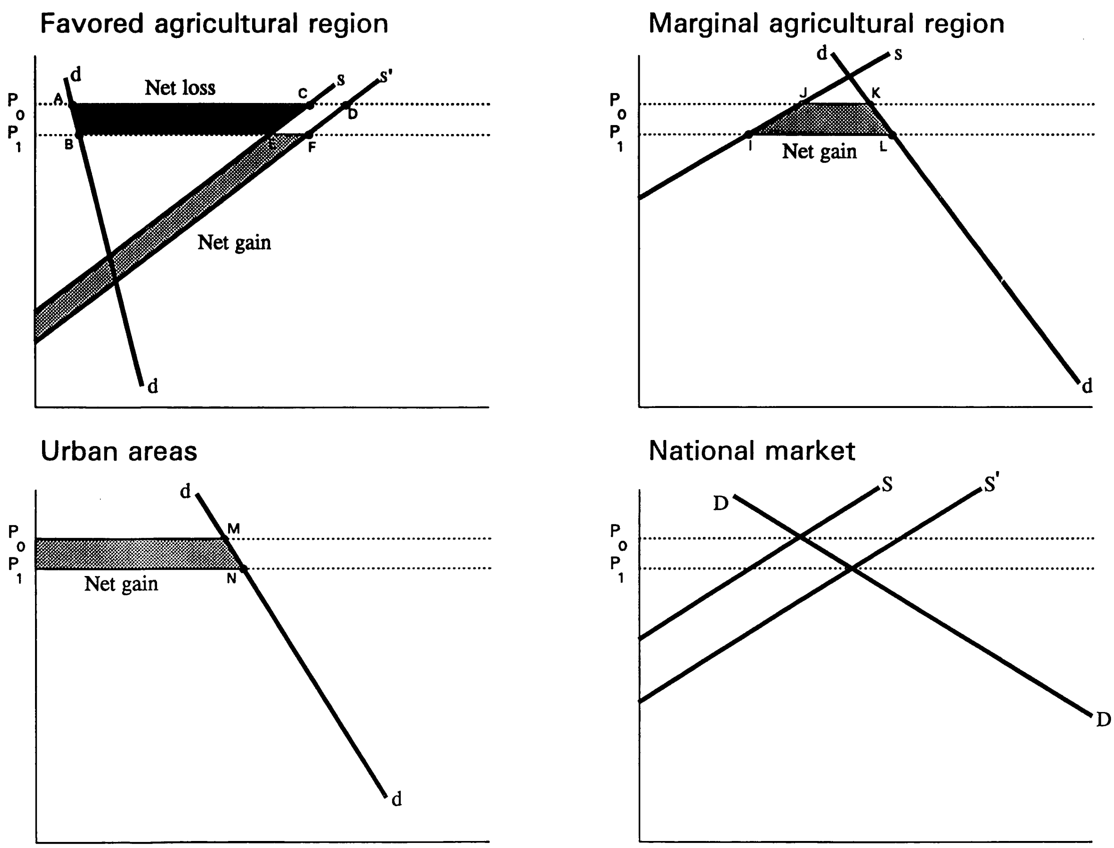


Fig. 2. Commodity market impacts of technological change: Closed economy case.

change in the form of innovators' rents, while in closed economies it is consumers who benefit most via price effects in output markets.

Expanding the analysis to include differential adoption patterns across production environments alters these conclusions somewhat for the closed economy case, and not at all for the open economy case. Figs. 1 and 2 depict the impacts of a supply shift for a particular commodity in one agricultural area on various regional markets for the affected commodity. To expedite the discussion, assume that the commodity in question is wheat.

In an open economy the price of wheat is determined exogenously – that is, by conditions on the world market and (for an importing nation) transport costs from the country of origin (Fig. 1). The shift of the supply curve in the favored region from s to s′ is thus unaccompanied by a change in the price received by producers; consequently, producers in the favored region unambiguously gain from the supply shift. In Fig. 1, the increase in producers' surplus is given by the shaded area. Since neither prices nor production change in the marginal area, there is no change in the welfare of producers or consumers there. Urban consumers are likewise unaffected by the supply shift. There is, however, a change in the level of imports necessary to meet urban demand – that is, the increased output of wheat in the favored area substitutes for wheat imports by the amount $Q_1 - Q_0$ [2].

For a closed economy in which prices are determined by the intersection of aggregate supply and demand curves, the analysis becomes more complicated (Fig. 2). With the shift in the supply of wheat in the favored region from s to s′, aggregate supply in the national market (the sum of the favored and marginal region supply curves) shifts out from S to S′, causing the price to fall from $P_0$ to $P_1$ [3]. In urban areas, consumers benefit as the fall in price leads to an unambiguous improvement in welfare (measured by the area $P_0MNP_1$).

In the marginal agricultural region, consumers similarly benefit from the drop in price. At the same time, producers – for whom there has been no alteration in production technology (by assumption) – are hurt by the lower price for their output of wheat. Moreover, at the new price less wheat is produced. Overall, there is a net increase in total surplus equal to the area IJKL – that is, the increase in consumer surplus ($P_0KLP_1$) less the decrease in producer surplus ($P_0JIP_1$). Note that total surplus would fall if the marginal region were originally a net exporter of wheat, as the decline in producer surplus would then be greater than the increase in consumer surplus.

In the favored region, the results are more ambiguous. As in the other two regions, consumers gain from the cheaper price of wheat. One cannot say unequivocally whether producers gain or lose on net, however, since the negative effect of the falling price is offset by an increase in output. The ultimate impact on producers is therefore indeterminate: it depends on the slopes of the supply and demand curves, the amount of the supply shift (i.e., the horizontal distance from s to s′), and the share of aggregate production originating in the favored region [4].

For the two agricultural areas, determining how the change in conditions in the wheat market affects the welfare of particular socioeconomic groups must account for the fact that most, if not all, wheat-producing households also consume wheat (Hayami and Herdt, 1977). For such

[2] Here it is assumed, not unrealistically, that imports are used to satisfy urban demand exclusively. There is absolutely no difference in the conclusions drawn from the analysis if instead some imports find their way into markets in the marginal area. Similarly, if the favored area is a net deficit region as well, shifting supply will reduce the inflow of wheat into that region. Finally, there is no qualitative difference if the country is a net wheat exporter to begin with. In this case, exports increase with the supply shift.

[3] This abstracts from transportation and other costs involved in moving wheat from surplus to deficit areas. Assuming that marketing margins remain unchanged (either absolutely or as a proportion of the market price), the qualitative results of the analysis remain the same.

[4] That is, a yield increase in a region producing a large share of the nation's wheat supply will give rise to greater price declines than a comparable yield increase in a region producing a small share of total wheat output.

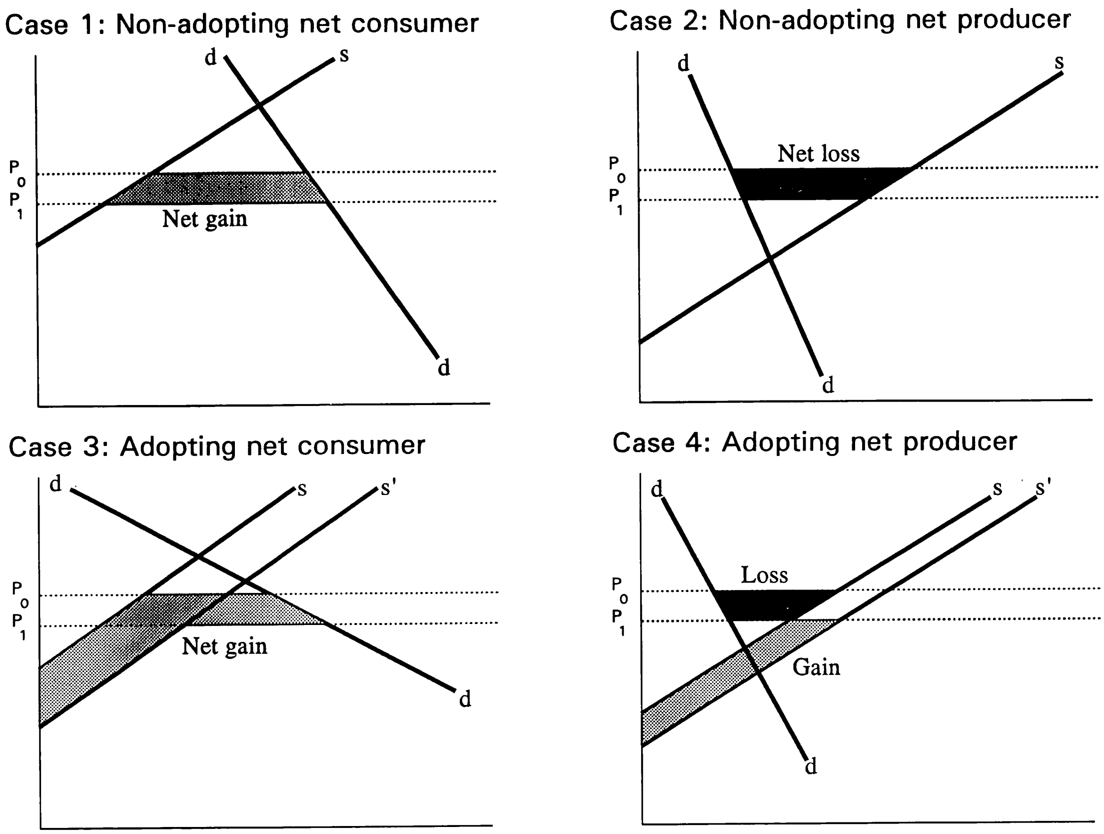


Fig. 3. Welfare effects of technological change on semisubsistence households.

semisubsistence households, a change in price (regardless of the direction of the change) has both positive and negative effects. Where a supply shift leads to a drop in price, the negative effects on farm profits are offset by the lower price of food. The critical distinction for determining the net welfare changes for a semisubsistence household is thus whether the households are net producers or net consumers of the commodity in question [5].

Fig. 3 depicts the welfare implications of technological change in a closed economy for four prototypical semisubsistence households – adopting and non-adopting net consumers, and adopting and non-adopting net producers. There it may be seen that net consuming households, adopters and non-adopters alike, unambiguously benefit from the fall in price due to the supply shift. For net producing households, the fall in price involves some welfare loss. For adopting households, this loss may or may not be fully compensated by the productivity gains due to the new technology. For non-adopting households, however, there is no offsetting change in production; hence, these households suffer losses in overall surplus [6].

[5] In many locations, net producing households may well be households with relatively large land holdings, while net consuming households correspond to smallholders.

[6] Three other, less likely possibilities involve households whose status changes from net producer to net consumer (or vice versa). For households who change from net producers to net consumers (both adopters and non-adopters), the net welfare effects are indeterminate, while adopting households transformed from net consumers to net producers by the new technology unambiguously benefit.

The above discussion leads to the following conclusions on the welfare effects of regionally differentiated technological change in a closed economy. Urban households, all of which are net consumers, unambiguously benefit from the lower price of wheat. In the marginal area, net consumers (including both non-farming households and households unable to meet their demand for wheat entirely from their own production) unambiguously gain, whereas net producing households unambiguously lose. In the favored region, net consumers unambiguously gain, while the welfare effects are indeterminate for net producers.

A number of studies have argued that a link exists between technological change in developing country agriculture and lower food prices (Akino and Hayami, 1975; Mellor, 1975; Evenson and Flores, 1978; Scobie, 1979). Additionally, there exists some empirical evidence on the distributional effects of regionally differentiated technological change, specifically the introduction of high yielding rice varieties targeted to the irrigated areas of Colombia (Pinstrup-Andersen, 1970; Scobie and Posada, 1978). These latter studies corroborate the predictions of the partial equilibrium analyses presented above, concluding that the introduction of HYV rice mainly benefited consumers (particularly those with low incomes) and adopting producers, while the incomes of net producers of non-irrigated rice were negatively affected. Because the share of food in total expenditure is typically higher for poorer households (Pinstrup-Andersen, 1985), it is often argued that the cheapening of food prices via technological progress has been the most important 'pro-poor' effect of Green Revolution-type innovations (Ruttan, 1977; Lipton and Longhurst, 1985). It is important to note, however, that this result depends on markets for the commodities involved being at least partially closed to foreign trade. It is also noteworthy that the analyses supporting this result have generally ignored the actions of government price and stabilization policies. Such policies may have profound effects on interregional and intraregional income distribution, effects likely to extend to the transmission of benefits and costs arising from technological change. These issues will be taken up again later.

### 2.2. Labor market effects

Considerable evidence indicates that the seed-fertilizer technologies of the Green Revolu-

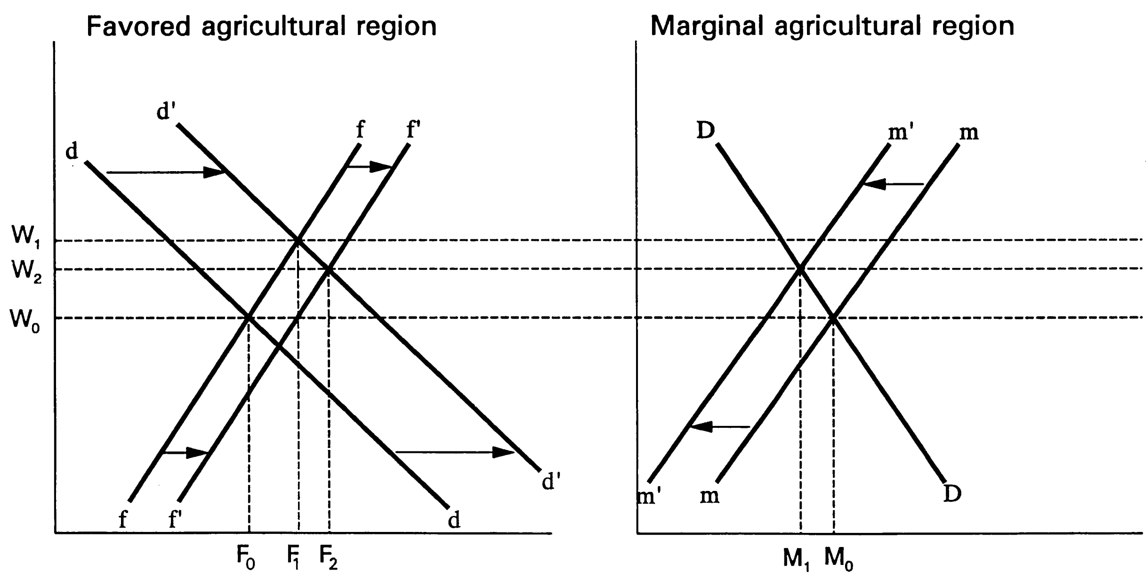

Fig. 4. Interregional labor market impacts of technological change.

tion generally led to significant increases in labor demand (Ruttan, 1977; Lipton and Longhurst, 1985; Jayasuriya and Shand, 1986). Most commonly, these have been linked to increases in harvest and threshing labor associated with higher yields, and increased cropping intensity facilitated by shorter duration varieties (Barker and Cordova, 1978). So long as labor supply is less than perfectly elastic, such changes in labor demand will put upward pressure on wage rates in local labor markets, thereby affecting the incomes of all households in adopting areas for whom agricultural labor is a source of household income (including farm households that do not sell labor to other farms, but for whom the implicit return to their on-farm labor will have changed) [7].

The impact of a new, labor-using technology on conditions in labor markets may extend outside of the area in which it is adopted if laborers in non-adopting areas are sufficiently mobile. The theory underlying such a possibility is straightforward. If real wages due to increased labor demand rise sufficiently to cover the cost of changing locations, laborers from non-adopting areas may migrate to take advantage of better employment opportunities. In addition to the transfer of some of the benefits of the new technology to migrating individuals, this will also put upward pressure on wage rates in non-adopting areas, thus benefiting laborers there as well.

This is illustrated in Fig. 4. Initially, an equilibrium wage, $W_0$, prevails in both marginal and favored agricultural regions [8]. Adoption of a labor-using technology in the favored region shifts the labor demand curve there out from dd to d′d′, driving up the prevailing wage there from $W_0$ to $W_1$. The differential between wages in the two regions induces some of the marginal region labor force to migrate to the favored region. The inflow of laborers from the marginal region shifts out the labor supply curve in the favored region (from ff to f′f′), pushing the wage rate in the favored region back down. At the same time, out-migration of laborers puts upward pressure on the prevailing wage rate in the marginal region (due to the shift in the labor supply from mm to m′m′). This process continues until a new equilibrium wage is established at $W_2$.

The potential for rural–rural migration to transfer some of the benefits of technological change to agricultural labor households in non-adopting areas (in the form of higher wages) has been widely recognized (Quizon and Binswanger, 1983; Hazell and Anderson, 1984). There is evidence from India that the rapid diffusion of wheat HYVs in the Punjab in the late 1960s induced a large influx of laborers from other provinces, and that this migration tended to equalize interregional wage dispersion (Oberai and Singh, 1980; Acharya, 1989). In the Philippines, Otsuka et al. (1990) provide evidence that differential rates of adoption of HYV rice in favorable and unfavorable production environments led to substantial interregional migration. Finally, a number of studies focusing on regional labor market impacts of modern rice varieties have recently been undertaken by economists associated with the International Rice Research Institute (Gunawan et al., 1990; Hossain and Akash, 1990; Isvilanonda et al., 1990; Upadhyaya et al., 1990). These corroborate the hypothesis that migration and subsequent wage equalization have acted to transfer a portion of the benefits from technological change in favored environments to marginal environments which did not receive as large an increment of the direct productivity benefits.

Several qualifications to the scenario depicted in Fig. 4 need be added here. First, while rising real wages might appear to be the obvious result of increased labor demand due to technological change, there is little empirical confirmation for this. Rather, available evidence indicates stagnation, or at best, small increases in real wages occurred in most areas of rapid HYV adoption

[7] This abstracts from possible spillover effects from product markets. In a closed economy, for example, output price declines accompanying supply shifts may in fact lead to a net reduction in the derived demand for labor in adopting regions in which product demand is relatively inelastic.

[8] To simplify the presentation, it is assumed here that at equilibrium wages in the two regions are identical. In reality, it is likely that an 'equilibrium' differential, equal to the transactions costs associated with migration, would exist (Harris and Todaro, 1970). Ignoring this does not alter the implications of the analysis, however.

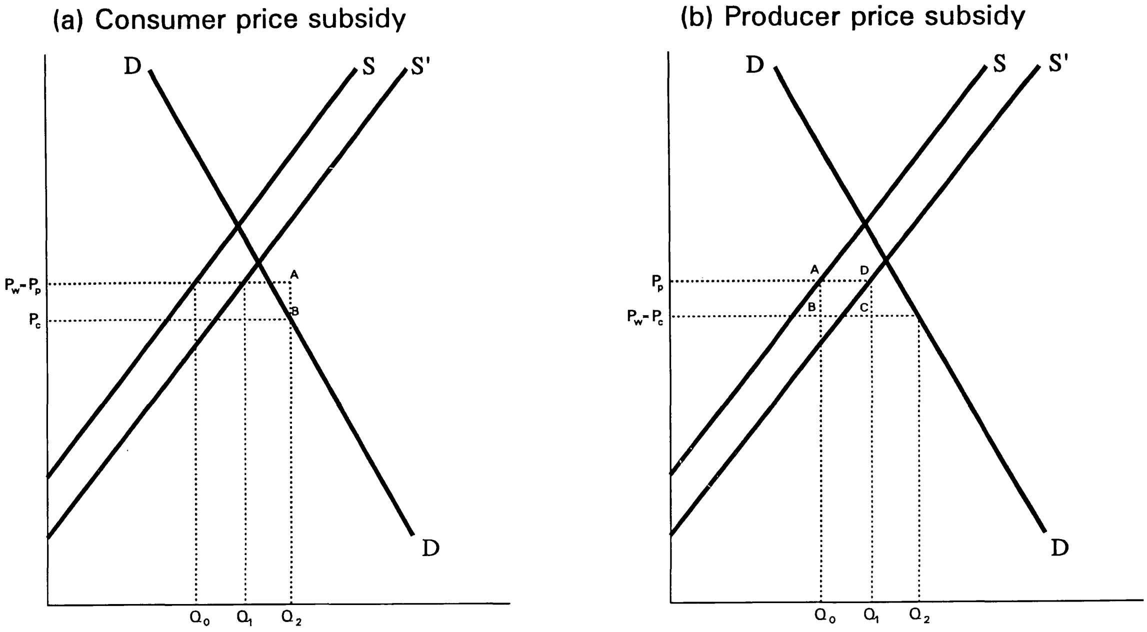


Fig. 5. Government cost of producer and consumer price subsidies.

(Lipton and Longhurst, 1985). Possible explanations for this include high levels of unemployment or under-employment in adopting areas prior to adoption, high rates of population growth, and in-migration of laborers into adopting areas. Importantly, none of these explanations contradicts the notion that remuneration of agricultural laborers was increased relative to what would have occurred in the absence of technological change.

A second qualification to the simple analysis presented above is that interregional migration is likely to take place gradually over an extended period of time, due to the substantial costs involved in migrating (even temporarily) from one geographic location to another. The dynamic nature of migration as an equilibrating mechanism renders quite difficult the task of identifying the extent to which migration contributed to the transmission of potential benefits to laborers (in the form of higher wages or greater labor demand) from adopting to non-adopting regions.

Finally, while rural–rural migration may indeed be an important force affecting the well-being of rural laboring classes, in most cases it is probably dwarfed in magnitude by migration of rural dwellers to the cities [9]. It is possible, however, that changes in conditions in rural labor markets (such as those associated with the diffusion of HYVs) may have modified rural–urban labor flows relative to what would have otherwise occurred, with higher wages and/or greater demand for labor in adopting areas rendering urban employment opportunities less attractive. Indeed, differences in rates of rural–urban migration due to differential adoption of improved technologies would generate essentially the same welfare effects as those occurring in cases where technology leads to rural–rural migration, although the dynamics of those effects (in terms of the timing of the movement of laborers) would probably be somewhat different.

[9] A large literature has examined rural–urban migration (for review, see Yap, 1977, and Rosenzweig, 1988). Generally it has been found that wage differentials (either perceived or actual) between rural and urban areas explain part, but by no means all, of observed flows of laborers to cities.

## 3. Role of government

The open- and closed-economy scenarios sketched out above are useful as a point of departure for analyzing the impacts of technological change. In reality, however, these idealized cases merely provide rough bounds within which the actual distributional consequences lie. This is because government intervention, particularly in commodity markets, is likely to alter the range of distributional outcomes resulting from a particular innovation.

Especially where staple foods such as wheat or rice are concerned, governments in developing countries regularly intervene in commodity markets in order to meet certain social and political objectives. These objectives include holding down the price of food for urban consumers, promoting national self-sufficiency ('food security'), enhancing the incomes of agricultural producers, and encouraging balanced regional development. The most common policy instruments used to meet these objectives include food subsidies for consumers and administered producer prices. Application of one or, more typically, both of these policies effectively drives a publicly financed wedge between consumer prices and producer prices (Pinstrup-Andersen, 1985).

Fig. 5 depicts the public finance costs of consumer and producer price subsidies for an importing country [10]. Frame (a) shows the case where producers are paid the world price ($P_p = P_w$) and consumer prices are subsidized. The cost to the government is given by the area $P_pABP_c$ – i.e., the quantity consumed at the subsidized price multiplied by the per-unit subsidy ($P_p - P_c$). A technological innovation that shifts supply from S to S′ does not alter this public finance cost. It does, however, lessen imports by the amount $Q_1 - Q_0$.

Frame (b) of Fig. 5 shows the case in which consumers pay the world price ($P_c = P_w$) and producers receive a price in excess of the world price. Here, the cost to the government is equal to the difference between the (subsidized) producer price and the world price multiplied by the amount produced. In this case, a shift in supply *does* have an impact on total government cost, since the per-unit subsidy is applied to a greater quantity after the shift than before. In the example shown in Fig. 5(b), this increase in public finance costs is equal to the area ABCD. In contrast, producer prices set below the world price effectively tax producers. In that case, a shift in supply increases this effective tax by an amount equal to the amount of the supply shift multiplied by the difference between the world price and producer price.

Governments commonly intervene on both sides of the market for staple foods, holding consumer prices below import parity levels and either subsidizing or taxing producers. The separate impacts of these two activities are additive. Where both producers and consumers are subsidized, a supply shift thus represents a greater drain on fiscal resources. In such cases, productivity enhancing technologies make it more difficult for a government to maintain the same level of subsidization on the different sides of the market. In contrast, where price policies subsidize consumers and tax producers, a supply shift increases the effective tax on producers, while the degree to which consumers are subsidized remains unchanged. In this situation, there is less of a drain on government fiscal resources as producers now finance an even greater share of the consumer subsidy than was the case prior to the increase in supply [11].

[10] For simplicity, the graphs in Fig. 5 abstract from differences in import parity prices to consumers and producers due to differences in transportation and marketing costs. This does not alter the conclusions drawn here.

[11] In addition to consumer and producer price policies, subsidies on inputs such as fertilizers and tractors are important examples of mechanisms through which developing country governments modify the distributional impacts of technological change or any other exogenous shock to commodity markets. Input subsidies have impacts similar to producer price supports. That is, a shift out in supply due to a lessening of per-unit input costs will lead to greater demand for a subsidized input, raising the cost to the government of that subsidy. As this cost would have to be financed from some place in the limited government budget, the supply shift thus leads to per-unit reduction of other subsidies and/or increased government debt.

The mechanism by which agricultural price commissions set producer and consumer prices for staple foods is often, to say the least, a mysterious one. Policy makers charged with this task balance the practical problem of working within budgetary limitations with the political problem of limiting imports while holding down the prices of commodities that are often the most important items of expenditure for large blocs of the population. There is no way of knowing a priori how price policy will respond to either a tightening up of the fiscal budget or a change in market conditions such as a shift in domestic supply or change in world prices. Given that urban consumers typically wield more political power than agrarian constituencies, price policy in developing countries often (but not always) tends to favor consumers over producers.

In cases where the government exercises substantial control over both producer and consumer prices – a situation that is not uncommon for basic staples in developing countries – these prices may be regarded as fixed in the short run. In the context of technology that shifts out aggregate supply, this is essentially equivalent to the open-economy scenarios described earlier: in either event prices do not respond to shifts in supply and demand.

Over time, however, prices will move, partly in response to political forces, but also in response to demand and supply conditions in both domestic and international markets and to government fiscal constraints. In a number of situations, some degree of complementarity between political and economic forces might exist. For example, where a government supports producer prices at levels exceeding the world price, a new technology that shifts out supply might put untenable pressure on government fiscal resources. A likely result of this would be for producer prices to fall in a manner similar to the closed-economy scenario sketched out earlier [12]. A similar outcome might obtain if the government faces a fixed budget in the face of rising world prices, and consumer groups are relatively stronger than producer groups in battling for (fixed) government resources. In this case, one might expect to find producer prices falling, particularly if accompanied by a technological change that would produce windfall gains to producers were producer prices fixed – again, a situation that is observationally equivalent to that of technological change in a closed economy.

Taking an even broader view, while the interventions of individual governments may serve to 'open' and 'close' markets for particular commodities at specific points in time, world markets for important traded foods such as wheat and rice *are* closed. The persistent decline in the real world prices of such commodities over time has been due in large part to continuing technological progress in production. As such, assessment of the global impact of technological change must be conducted within a closed-economy framework.

## 4. General equilibrium considerations

The partial equilibrium results presented in the preceding sections of the paper are useful in understanding isolated aspects of the process of technological change. They are, however, inadequate for assessing the overall impact of a particular innovation on various socioeconomic groups within an economy. Especially in developing countries, economic agents are not simply consumers or producers, laborers or landowners. Rather they are a combination of some or all of these, and the various economic impacts of a technological innovation may have both positive and negative consequences for a particular household. Sorting out the overall welfare effects of technological change on particular household types thus requires synthesis of partial equilibrium outcomes in a unified analytical framework.

Two recent studies have used general equilibrium models to simulate the impacts of uneven regional adoption of improved technologies on various socioeconomic groups. Coxhead and Warr (1991) developed a small computable general equilibrium model to examine the impacts of

[12] Alternatively, consumer prices might be raised in this case, in order to cover the government's increased fiscal burden. In practice, however, this has rarely been observed.

Table 1
Income effects of regionally differentiated technology adoption (% changes) [a]

| Household type | Pakistan [b] | | Philippines [c] |
|---|---|---|---|
| | Closed economy | Open economy | |
| Marginal area landless | 3.1 | 0.6 | 4.0 |
| Marginal area small farm | 1.7 | 0.3 | −0.1 |
| Marginal area large farm [d] | −4.0 | 0.1 | −4.8 |
| Favored area landless | 3.6 | 1.2 | 4.0 |
| Favored area small farm | −0.2 | 5.3 | −7.7 |
| Favored area large farm [d] | −0.8 | 5.9 | 7.5 |
| Urban poor | 2.2 | 0.0 | |
| Urban non-poor | 1.3 | 0.0 | |
| Service sector capitalists | | | 16.5 |
| Manufacturing sector capitalists | | | −10.8 |

[a] Assumed yield increases of 13.8% (Pakistan) and 10% (Philippines) for favored areas only.
[b] Source: Renkow (1991).
[c] Source: Coxhead and Warr (1991).
[d] For Philippines, these correspond to 'Landlords'.

improved rice production technologies in the Philippines. Renkow (1993) developed a multi-market model of differential diffusion of improved wheat technologies in Pakistan. As the methods employed in these two studies differed in some respects, some of the empirical results are not strictly comparable [13]. Nonetheless, the empirical findings of the two studies regarding income effects of technological change do highlight the relative importance of some of the key factors that have been discussed here.

Table 1 presents these estimates of the net income effects on various household groups of technology 'shocks' confined to favored areas [14]. In both studies, simulated income changes depend on changes in wages and profits engendered by technology adoption and the relative importance of those two components of household income. These in turn are largely determined by the kinds of technology packages considered and the underlying matrix of parameters describing the behavioral characteristics of different types of households.

Prices are exogenously determined in both the Pakistan (open economy) and Philippine cases. Comparison of the results for these two cases indicates a marked difference in the importance of real wage increases vis-à-vis changes in profits due to productivity increases. In Pakistan, profit effects were found to dominate wage effects in the overall distribution of income gains and losses. Adopting net producing households – small and large farm households in favored areas – achieve considerably greater income gains than other (net consuming) household types. In contrast, the results for the Philippines indicate a greater balance between effects mediated through product markets and labor markets; hence, households heavily dependent on labor income (particularly the landless) fare relatively much better. Possible explanations for this contrast include cross-country differences in labor demand and supply elasticities and greater mobility of laborers in the Philippines.

Comparison of the two sets of results for Pakistan indicates a sharp divergence in income effects depending on whether the market for the affected commodity is assumed to be open or closed with respect to world prices. In the closed economy case – where prices are free to adjust to shifting supply – net consuming households emerge as the major beneficiaries of technological change. Here, falling output prices are the dominant force determining the distribution of gains and losses due to technology adoption. Interestingly, adopting net producing households suffer net declines in real income following technological change. This is attributable to the fact that demand for the affected commodity is more price inelastic than supply – that is, the negative effect on farm profits of a lower output price outweighs the positive effect of the technology-induced productivity increase.

[13] The Coxhead and Warr model is short-run in nature, and focuses on the implications of technologies possessing different factor biases. Renkow's model is long run in nature, considers a more limited set of household types, and focuses on the implications of different assumptions on whether the market for the commodity affected by technological change is open or closed with respect to world markets.

[14] The magnitude of these technology shocks (given in the footnotes to Table 1) differs slightly for the two cases. For the Pakistan study, yield increases were based on experimental results for currently available technologies. For the Philippine study, 10% yield increases were assumed.

## 5. Concluding remarks

This paper has sought to clarify the factors determining the welfare effects of improved agricultural technologies when technology diffusion is unevenly distributed across production environments. Partial equilibrium analyses indicated that the net impact of regionally differentiated technological change on the well-being of different types of households depends on a number of factors: (a) the openness of the economy to world markets; (b) whether households are net producers or net consumers of the commodity for which technological change occurs; (c) whether or not households adopt the technology in question; (d) the degree to which labor is mobile across regions; and (e) government intervention in commodity and/or factor markets.

To evaluate the overall impact of a specific innovation or technology package requires an analytical framework capable of sorting out the net effect of these various partial equilibrium outcomes for different types of households. Recent empirical work assessing the net income effects of regionally differentiated technological change in a general equilibrium framework offer two important insights. First, the relative strength of effects of technological change operating through labor and product markets can vary considerably in different settings. Whereas profit effects were found to dominate wage effects in determining the overall pattern of gainers and losers from technological change in Pakistan, a much greater balance between wage effects and profit effects is evident in the Philippines. Thus, it appears that generalization of the results from one setting to others may be inappropriate.

Second, assessment of the overall welfare effects of technological change will depend importantly on assumptions regarding the mechanism by which commodity prices are determined – endogenously as in a closed economy, or exogenously as in an open economy. The evidence from Pakistan indicates that net consuming households are the major beneficiaries of technological change in a closed economy, but that net producing households will be the primary beneficiaries in an open economy. It is important to note, however, that it is nearly impossible to name a country in which international trade in important staple foods like wheat and rice does not occur. In addition, developing country governments typically play an active role in the determination of both consumer and producer prices for staples. The pervasiveness of international trade and government price controls calls into question the argument that consumers have been the major beneficiaries of technological change, at least insofar as that argument rests on a direct link between supply shifts and commodity prices.

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