Review of Economic Studies (1984) LI, 1-12
0034-6527/84/00010001$00.50

Pareto Inferior Trade

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The paper shows that between two competitive but risky economies with no insurance markets, free trade may be Pareto inferior to no trade. The model is simple enough to show clearly the role prices play in transferring and sharing risk when there is an incomplete set of markets, but rich enough to exhibit the resulting inefficiencies dramatically.

The belief that free trade is Pareto optimal is one of the few tenets of economics which, at least until recently, would have received almost universal assent. The object of this paper is to demonstrate that this belief may not be well founded. We construct a simple model which lacks a complete set of risk markets but which in all other respects satisfies the conventional assumptions of a competitive economy, and show that free trade may be Pareto inferior to no trade.

The basic idea behind our model is simple. There are two countries (regions) both of which grow a risky agricultural crop and a safe crop. The output in the two regions is perfectly negatively correlated. (The model can easily be extended to cases where the correlation is zero or even positive, so long as the correlation is not perfect.) In the absence of trade, price rises whenever output falls. If demand functions have unitary price elasticity the price variations provide perfect income insurance for the farmer. With free trade the variations in the output of the risky crop offset each other and stabilize the price, which no longer varies to offset output variations. Consequently, the revenue from the risky crop now varies and the risk faced by the farmers is increased. This induces farmers to shift production away from the risky crop, raising its average price. Since consumers have unit price elasticity and thus spend a constant amount on both crops, the mean income of the farmers remains constant with the opening of trade while its riskiness increases. Consequently, farmers welfare necessarily decreases, as shown in Figure 1.

Whereas before trade was opened, consumers bore all the risk, with free trade they bear none, and, other things being equal, this would make them better off. However, the increased riskiness of the risky crop induces farmers to shift their production to the safe crop, and the consequent rise in the average price of the risky crop can make consumers worse off. Near autarky, the risk benefit dominates this allocation effect, as shown in Figure 1, but near free trade the opposite is the case. If the change in supplies and prices is sufficiently large (which it will be if producers are sufficiently risk averse), and if the consumer risk benefits are sufficiently small (which they will be if consumers are not very risk averse), then consumers will be made worse off by opening trade. Since producers are necessarily worse off (in this model), it follows that free trade is Pareto inferior to autarky.

The reconciliation of our results with the standard theorems of Welfare Economics in which free trade is Pareto efficient is straightforward—the conventional argument

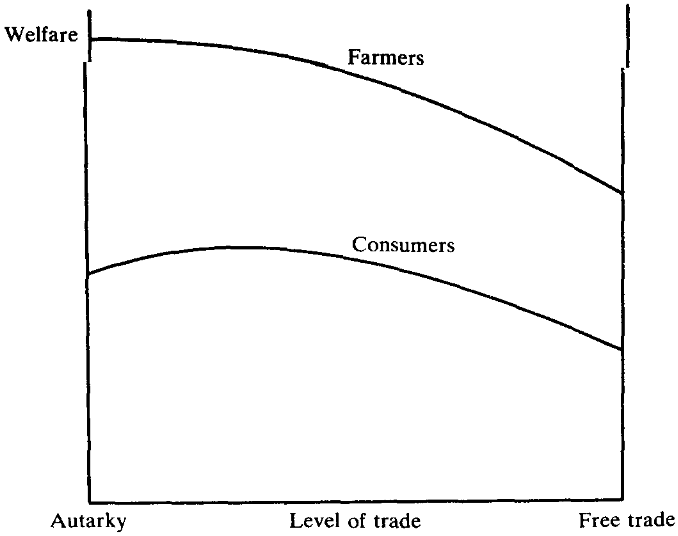

FIGURE 1
Welfare consequences of opening trade

requires not only that markets be competitive (as we assume), but also complete. In our model there must be a complete set of insurance markets enabling farmers to purchase both price and output insurance. For a variety of reasons such as moral hazard and adverse selection the set of markets is not complete. In our example autarky provides farmers with income insurance, and opening a new market (international trade in the risky commodity) has the same affect as closing these implicit insurance markets. With a complete set of markets each market provides one, and only one, marketing service, but with an incomplete set some markets may be providing several services, allocating both goods and risk. Institutional change may change the number of services provided by a particular market, and in our example such changes can make everyone worse off. Welfare analysis which assumes that each market serves only one function can be seriously misleading in these cases.

The model we shall analyze has been kept simple to make the main points as clearly as possible. In particular, we choose very special functional forms—unit price elasticity—for consumer demand which allow us to employ the concept of mean preserving changes in risk, and which thus allow a very intuitive explanation of our results. It will become clear from our model that any other specification would greatly complicate the analysis, since changes in trade will in general lead to changes in both mean income and its risk.[1] The result that free trade is Pareto inefficient is, however, quite general, and relies on three critical assumptions. First, there must be some agents who, on average, are net sellers of the risky good (in our model, the farmers) and others who are net buyers (consumers). Since these individuals must engage in trade, their welfare is affected by the price distribution.[2] Second, neither producers nor consumers can buy insurance for the risks (the variability of output of the risky crop and of its price) which they face. Changes in the level of trade change the price distribution and the risks that individuals face. If they could perfectly insure, then there would be no change in risk, and hence no adverse consequences. However, we would argue that it is more realistic to assume that individuals cannot perfectly insure themselves, and that therefore risk, and changes in risk, do matter. Third, output in the different countries cannot be perfectly correlated, for then (under our assumptions that the countries are otherwise identical) opening up trade would leave the price distribution unaffected. Thus, although we assume that outputs in the two countries are perfectly negatively correlated, all that is required is the absence of perfect positive correlation.

These three assumptions distinguish our paper from earlier studies of trade and uncertainty. These other studies have (for the most part) employed the concept of a representative consumer–producer, assumed the price distribution was given exogenously, rather than determined endogenously, assumed outputs are perfectly correlated across countries, and/or focused on the case where there are perfect risk markets, so farmers can diversify out of the risks they face.[3] The closest in spirit to the present study is the excellent work of Helpman and Razin (1978*a*, *b*) which dealt with general equilibrium effects. However, they assume a perfect equities market (a weaker assumption than a perfect risk market), perfect correlation, and they make use of the concept of a representative consumer–producer.[4]

The paper is divided into two parts. In Section 1 we develop the basic model and derive the conditions under which free trade is Pareto inferior to no trade. In Section 2 we show that the results are more robust than the simple model developed in Section 1. We discuss the critical assumptions, present an alternative interpretation of the model, and suggest extensions to the analysis.

1. COMPARISON OF AUTARKY AND FREE TRADE

We construct a simple model with two regions which are identical, except that their output of a risky agricultural commodity is perfectly negatively correlated. Each region has n identical farmers and m identical consumers. We first describe the farmers, then the consumers, and finally the market equilibria with and without trade. We then compare the two equilibria and establish conditions under which free trade is Pareto inferior to no trade.

A. *Producers*

Each of the n identical producers owns one unit of land. A typical farmer allocates a fraction x of his land to growing a risky crop, which we denote by subscript r, and the remainder, $1-x$, to the safe crop, denoted by subscript s. Output per acre of the risky crop is θ, a random variable, with mean unity and variance σ^2. The output of the safe crop is always unity. (These are just normalizations.)

Farmers are risk averse; they choose x before they know θ (the weather) to maximize the expected utility of profits:[5]

$$EU(\pi), \qquad U'>0, \qquad U''<0, \tag{1}$$

where

$$\pi = xp\theta + q(1-x) \tag{2}$$

are the profits, p is the price of the risky crop, and q is the price of the safe crop.

Farmers are assumed to know the relationship between the price and θ, but since each farmer is small, he assumes he has no effect on price (in any state of nature).[6] Our analysis thus focuses on competitive rational expectations equilibria. The expected utility maximizing choice of x is given by the solution to

$$EU'(\pi)(p\theta - q) = 0. \tag{3}$$

B. *Consumers*

It is convenient to represent the respresentative consumer by his indirect utility function $V = V(I, p, q)$ where I is income which is constant.[7] For most of the analysis we shall make use of a special parameterization of the utility function. We let

$$V = \begin{cases} \dfrac{(Ip^{-a}q^{-b})^{1-\rho}}{1-\rho} & \text{for } \rho \neq 1, \quad (4) \\ \log I - a \log p - b \log q & \text{for } \rho = 1, \quad (5) \end{cases}$$

where ρ is the coefficient of relative risk aversion. These yield aggregate demand functions for the two commodities which have unitary price and income elasticities:

$$Q_r = \frac{amI}{p}, \qquad Q_s = \frac{bmI}{q} \tag{6}$$

where Q_i is aggregate demand for commodity i (risky or safe), and mI is aggregate consumer income.

This specification of the utility function is chosen for several reasons: it greatly simplifies the calculations; it is the utility function for which consumer surplus calculations employed in conventional welfare analysis are valid;[8] and it implies that there will be no income redistribution effects in the policy changes which we shall consider,[9] and thus this specification enables a simple separation of the efficiency and distributional consequences of trade policy. Moreover, demand functions with unitary price elasticity play a critical borderline role in the analysis of risk with more than one commodity; if the elasticity of substitution between the two commodities is less than unity, the induced price variability results in farmers treating the safe commodity as if it were riskier than the risky commodity. (See Stiglitz (1972).) Finally, the utility function exhibits constant relative (income) risk aversion, ρ, and in the special case of unitary risk aversion of equation (5):

$$V_{Ip} = V_{Iq} = 0, \tag{7}$$

so changes in price do not affect the marginal utility of income.

C. *Market equilibrium without trade*

The structure of the equilibrium is simple:

(a) Producers decide on a crop allocation, x, *given* that their expectations about the relationship between price and θ is in fact the one that emerges.

(b) After the crop is harvested, the crops are marketed competitively. Market prices equate demands (given by equation (6)) to supplies (which depend on x and θ). If all farmers act alike then market clearing prices are

$$p = \frac{ay}{x\theta}, \qquad q = \frac{by}{1-x}, \tag{8}$$

where $y = mI/n$, consumer income per farmer. Equation (8) implies both crops yield perfectly safe returns, which must be identical if both crops are to be grown:

$$p\theta = q. \tag{9}$$

Equations (8) and (9) imply that

$$\frac{ay}{x} = \frac{by}{1-x}, \tag{10}$$

and give the equilibrium solution

$$x = \frac{a}{a+b}, \qquad q = (a+b)y, \qquad p = (a+b)y/\theta. \tag{11}$$

Producer profits are $\pi = q$ (using (9) and (2)) so producer welfare is simply $U\{(a+b)y\}$. The representative consumer's average welfare in the logarithmic case (5) is

$$EV = V_0 + aE \log \theta, \qquad V_0 = \log I - (a+b) \log \{(a+b)y\}, \tag{12}$$

where V_0 is the utility without risk.[10]

Note that the unit elastic consumer demands transfer all the risk from farmers to consumers. Fluctuations in the supply of the risky crop affect only its price and not that of the safe crop. Except in this special case, production risk for one commodity will spill over to generate price risk for other commodities. (Stiglitz (1972)).

D. *Market equilibrium with free trade*

Now suppose that, to the east on the other side of a mountain range there is another region, identical to the one described above in every respect save one—the weather.[11] When it rains in the West it is dry in the East, and vice versa. The output of the risky crop is perfectly negatively correlated between the two regions. Formally, let $\theta^E + \theta^W = 2$. Initially there is no trade between East and West, but there is a pass through the mountains which permits virtually costless exchange. If it is opened, there will be competitive free trade; if not, the regions will remain autarkic. Is free trade desirable?

The strong symmetry assumptions ensure there is always a symmetric equilibrium, but there may be additional asymmetric equilibria in which each country relatively specializes in one crop. If farmers are not too risk averse there will be a unique symmetric equilibrium, and for most of the paper we shall concentrate on this.

In the symmetric free trade equilibrium, each region allocates the same fraction x of land to the risky crop, $1-x$ to the safe crop, yielding total supplies:

$$Q_r = nx\theta + nx(2-\theta) = 2nx, \qquad Q_s = 2n(1-x). \tag{13}$$

Prices will be perfectly stabilized at

$$\bar{p} = \frac{ay}{x}, \qquad \bar{q} = \frac{by}{1-x}, \tag{14}$$

and so total profits are now

$$\pi = \bar{p}x\theta + (1-x)\bar{q} = (a\theta + b)y, \tag{15}$$

and farmers' income is now risky, though it has the same mean as before. The allocation of land between the two crops is given by the solution to equation (3):

$$EU'\{y(a\theta + b)\}\left(\frac{a\theta y}{x} - \frac{by}{1-x}\right) \equiv EM(\theta, x) = 0. \tag{16}$$

E. *Comparison of free trade and autarky*

Denote the equilibrium values of x, p, q, with free trade by $\{\bar{\bar{x}}, \bar{\bar{p}}, \bar{\bar{q}}\}$ and in autarky by $\{\hat{x}, \hat{p}, \hat{q}\}$. Proposition 1 compares the allocations of the equilibria in the two situations:

Proposition 1. *If farmers are risk averse, the safe crop is cheaper and the land devoted to the risky crop smaller with free trade than autarky.*

Proof. With free trade and risk averse farmers the average return to the risky crop must exceed that of the safe crop:

$$E\bar{\bar{p}}\theta = \bar{\bar{p}} > q \quad or \quad \frac{ay}{\bar{\bar{x}}} > \frac{by}{1-\bar{\bar{x}}}$$

from (14). A comparison with the autarky equilibrium (10) imples $\hat{x} > \bar{\bar{x}}$ and hence $\bar{\bar{q}} < \hat{q}$. ||

More generally, if $\Delta x = \hat{x} - \bar{\bar{x}}$ is the fall in land allocated to the risky crop in moving from autarky to free trade, then Proposition 2 identifies two of the critical parameters determining the magnitude of Δx.

Proposition 2. (a) *The more risk averse are farmers the greater is* Δx. (*Diamond and Stiglitz* (1974)); (b) *The greater the riskiness of* θ (*in the sense of Rothschild–Stiglitz* (1970)), *the greater is* Δx, *provided*
 (i) *the range of* θ *is not too great, or*
 (ii) *there is constant relative risk aversion* R *with* $R < 1$.

Either of these conditions ensure that the expression $M(\theta, x)$ is concave in θ,[12] and ensures the result.

F. *Welfare analysis*

The next result follows immediately from equation (15):

Proposition 3. *Farmers are always worse off as a result of the opening of trade. In the new equilibrium mean income is unchanged but risk is increased.*[13]

Consumers now face no risk. This makes them better off but in return there is a change in x, which makes them worse off. To see this, we ask what allocation x maximizes consumer welfare

$$V = V\left\{I\left(\frac{ay}{x}\right)^{-a}\left(\frac{by}{1-x}\right)^{-b} Z(\theta)\right\} \tag{17}$$

where $Z(\theta) > 0$ depends on trade policy. Thus under autarky $Z = \theta^a$ whilst in free trade $Z = 1$. However, for *any* $Z(\theta) > 0$, we observe that the solution is

$$x = \frac{a}{a+b} = \hat{x}, \tag{18}$$

the farmers' choice under autarky. Any other choice makes the consumer worse off. Hence, the change in consumer welfare in moving from autarky to free trade will depend on the magnitude of the resource shift, Δx, and on the consumer gain from the elimination of the risk he faces.

From Proposition 2, Δx depends on the size of the risk and the degree of farmers' risk aversion, while the consumers' benefit from risk reduction depends on the size of risk, and the degree of consumers' risk aversion.

It therefore looks as though consumers will be worse off with free trade provided farmers are sufficiently risk averse, and this is indeed true when comparing the symmetric free trade equilibrium with autarky. However, above a critical level of farmer risk aversion, the symmetric free trade equilibrium ceases to be the unique equilibrium, and multiple equilibria appear. Typically, the existence of multiple equilibria raises issues of stability, though of course stability can only be examined in the context of a particular adjustment process. Elsewhere (Newbery and Stiglitz (1982*c*)) we show that for one reasonable adjustment process the symmetric equilibrium is stable if it is the unique equilibrium, but unstable otherwise. Any particular adjustment process will doubtless appear *ad hoc* to some readers, and we shall therefore sidestep the issue by asking whether there is a critical value for the farmer's risk aversion below which the symmetric equilibrium is the unique equilibrium and for which free trade is Pareto inferior to autarky.

Since farmers are always worse off in a free trade equilibrium, free trade will be Pareto inferior to autarky if consumers are worse off under free trade, i.e., if

$$E\frac{(\bar{\bar{p}}^{-a}\bar{\bar{q}}^{-b})^{1-\rho}}{1-\rho}<E\frac{(\hat{p}^{-a}\hat{q}^{-b})^{1-\rho}}{1-\rho}. \tag{19}$$

In the symmetric equilibrium, substituting for prices, this is equivalent to

$$\frac{\bar{\bar{x}}}{\hat{x}}\frac{1-\bar{\bar{x}}^{b/a}}{1-\hat{x}}<\{E\theta^{a(1-\rho)}\}^{1/a(1-\rho)}. \tag{20}$$

The R.H.S. is a monotonically decreasing function of consumer's relative risk aversion ρ while the L.H.S. is a monotonically decreasing function of farmers' relative risk aversion R. It follows that there is a monotonically increasing critical function $R=f(\rho)$ for which consumers are indifferent between autarky and the symmetric free trade equilibrium, and it can be shown that $f(0)\equiv R_0>0$, where the value of R_0 depends on the form of the utility function, the nature of risk, and other parameters. The crucial question is whether $R_0<R^*$, the critical value at which the symmetric equilibrium ceases to be the unique equilibrium.

The values of R_0 and R^* depend on the parameters a, b, the distribution of θ, and the form of the farmer's utility function, but its value can be easily calculated for constant absolute or relative risk aversion utility functions and a two point distribution for $\theta=1\pm\sigma$.[14]

For values of $\sigma=0.9$ there is a wide range of values of a and b for which $R_0<R^*$: $0.2\leqq a\leqq 0.8$; $a+b\leqq 0.9$, for both constant absolute and relative risk aversion utility functions. R_0 increases with b, decreases with a, and is less than 3.0 for $a\geqq 0.4$. However, for $\sigma\leqq 0.8$ there are very few such configurations, and hence for free trade to be Pareto inferior to autarky, the degree of risk must be quite extreme.

These computer solutions allow us to assert

Proposition 4. *There exist sets of parameter values for which the unique free trade equilibrium is Pareto inferior to autarky.*

The simulations suggest that the range of values of (R, ρ) for which this is true increases with σ, a, and b. There is a larger range of values of (R, ρ) for which free trade is potentially Pareto inferior to autarky in the sense that though consumers would be better off with free trade, they would not be willing to pay the fixed sum needed to compensate producers for accepting free trade.

2. EXTENSIONS AND LIMITATIONS

The previous section of the paper used an extremely simple model to establish a strong result: free trade may be Pareto inferior to no trade. To what extent are the results dependent on the special parameterizations we have employed? And to what extent do they depend on the particular institutional assumptions we have made? The critical assumption in our analysis, we contend, is the absence of perfect risk markets, an assumption which, though not justified within the context of the model, seems empirically more plausible (at least in the context investigated here) than the other polar assumption conventionally employed, that risk markets are perfect.[15]

To see why this is important, let us consider briefly the nature of equilibrium under alternative assumptions.

A. *Financial markets*

First, we note that in the central case of consumers having logarithmic utility functions, there is no scope for future markets in the no trade situation; for then $V_{Ip} = 0$, the marginal utility of income is the same independent of the state of nature, and hence market equilibrium requires that if a small futures market were introduced, it be actuarially fair. But for producers, profits are constant, and they too would require an actuarially fair futures market. Hence the only equilibrium is one where there is no trade on the futures market. With perfect negative output correlation, there would be no scope for a futures market in the free trade situation either, since prices would not vary.

The consequences of opening up a market for ownership shares in farms is more serious. (We ignore all the problems of moral hazard, which are fundamental to an understanding of why such markets might not exist.) If farmers could purchase shares in each others' farms, then income of farmers would be constant; they would thus be indifferent between the opening of trade and autarky, but consumers would be unambiguously better off. Thus, the standard result that free trade is preferable to no trade is restored, if there is a complete set of securities markets.

B. *Structure of demand*

The major reason that the unit price elasticity assumption is employed is that it avoids the confusion between transfer and risk effects. If the elasticity of demand is not unity, a mean quantity preserving change in the price distribution will change the mean income of farmers. (Newbery and Stiglitz (1981).) In particular, if demand curves have constant elasticity greater than unity, farmers' revenue is a convex function of consumption, so, at each value of x, mean income is higher under autarky than with free trade. Although in autarky, producers' income is variable, it is less variable than output, and hence less variable than income under free trade. It can thus be shown that (i) a slight increase in trade from the no trade position always increases producers' welfare; (ii) provided the elasticity is not too large, a slight restriction on trade from the free trade position also increases producers' welfare.

The effect on consumers is more difficult to analyze. There are now three effects: (i) the risk effect; as before, opening trade reduces consumer risk; (ii) the transfer effect; because of the change in the distribution of prices, mean expenditure of consumers is increased, which makes them worse off; (iii) the allocation effect; because of the transfer effect, the allocation effect will be smaller, and may actually be positive rather than negative.

Similarly, if the elasticity of demand is less than unity the reduction is price variability *reduces* producers' mean income, and, if the elasticity is greater than 0.5, opening trade increases the variability of their income. Thus, producers are unambiguously worse off. Again, the effects on consumers are more complicated: now the transfer effect is positive, but the allocation effect is larger. Thus there are a large variety of possible patterns.

If the price elasticity is very small (less than 0.5), then pre-trade income variability is greater than post-trade income variability, in which case the opening of trade may be Pareto superior even without direct compensation schemes.

For elasticities of demand near unity, however, the qualitative properties remain unaffected: free trade may be Pareto inferior to no trade, provided farmers are sufficiently risk averse; if the elasticity is greater than unity, a slight liberalization of trade from the no trade position is Pareto improving; if the elasticity is less than unity, producers are strictly worse off; a slight restriction on trade from the free trade position is Pareto improving provided producers are sufficiently risk averse.

C. *Imperfectly correlated risk*

One of the three crucial assumptions which drives our model is that output in the different countries is not perfectly correlated, for otherwise opening up trade would leave the price distribution unaffected. For simplicity we took the polar alternative assumption of perfect negative correlation as this allowed us to use a single parameter, θ, to describe the state of the world. However, the results continue to hold for imperfectly correlated risk, and elsewhere (Newbery and Stiglitz (1982*c*)) we have analysed the case of symmetric risk, in which country 1 in state θ is indistinguishable from country 2 in state θ', and vice versa. This allows for imperfect output correlation whilst preserving symmetry and hence analytic tractability. With this extension it is possible to examine less extreme forms of trade policy than choosing between autarky and perfectly free trade, and to show that neither extreme is Pareto efficient.

D. *The theory of comparative advantage*

Specialists in traditional trade theory have, on a number of occasions, expressed an uneasiness with our analysis, on the grounds that it appears to ignore the principle of comparative advantage which underlies conventional trade theory. Note that this is not quite correct. Although there is no long run comparative advantage, each of the countries having precisely the same endowments and tastes, every period there is a significant comparative advantage, depending simply on the weather.

This, in fact, we would claim is one of the attractive features of our analysis: There is considerable evidence that much trade cannot be explained solely on the basis of factor endowments or tastes. It seems, accordingly, desirable to explore models in which there is trade without long run comparative advantage.[16]

We can, nonetheless, easily incorporate elements of traditional comparative advantage theory within our framework. Although we leave the formal development of such a synthesis to another occasion, let us briefly show how it may be done. Assume, for simplicity, that there are two factors, say capital and labour. Assume that the safe crop is labour intensive. For simplicity, let us assume that the two countries have the same factor endowments. Clearly, there is again no long run comparative advantage. We can ask, however, what happens as a result of the opening up to trade. Our previous analysis applies almost identically, except now farmers do not face a straight line production possibilities schedule, but face a concave production possibilities schedule. It is still true, however, that the opening up of trade will lead to an increase in the production of the safe crop (labour intensive). Assume, now, that the two countries have slightly different factor endowments. There will now be two effects: in the absence of risk, the opening up of trade will lead to the equalization of factor prices, a decrease in the price of labour in one country, and an increase in its price in the other. Now, however, there is an additional risk effect, which will tend to shift production toward the safe crop (more, presumably, in the country which has a comparative advantage in its production). This effect may outweigh the first effect, so that, still, the price of labour in both countries rises; it is even possible that factor price differentials widen.

CONCLUDING REMARKS

Free trade, which arbitrages prices in different countries, can stabilize prices. Buffer stocks, which arbitrage prices at different dates, also stabilize prices, and our analysis therefore bears on the question of the desirability of leaving commodity price stabilization to private speculators.

There is an argument, popular with economists, that if markets are competitive and agents well informed, then government intervention will lead to inefficiency. This argument has been used both to argue against restrictions on trade and against the establishment of international commodity stabilization schemes.

Our analysis questions the premises of this reasoning. We show that there is no presumption that free markets will be Pareto optimal. But our analysis is not simply negative. We have shown how to decompose the risk and allocative effects of changes in the market structure, and shown that they may conflict. A change in trade policy such as the opening of trade can have a significant effect on the risk borne by producers, who respond by changing their allocation of resources. The resulting changed pattern of output in turn affects consumers, who also experience a change in risk as a result of the trade policy. Whilst the resulting transfer of risk from consumers to producers may by itself make consumers better off, the allocative response by producers can make them worse off. Returning to the buffer stock analogy, it is possible that the opening of trade between two dates which perfectly stabilizes prices may be Pareto inferior to having no trade, and that it is thus desirable to restrict the arbitrage activities of speculators (see also Newbery and Stiglitz (1981, 1982*b*)).

Of course, it does not follow that government intervention is automatically justified by the absence of a complete set of markets, but it does suggest that simplistic arguments for free trade based on the competitive complete market paradigm are often far from persuasive.

First version received July 1981; *final version accepted October* 1983 (Eds.).

The research reported here was supported in part by the United States Agency for International Development and is an extension of Appendix E of Newbery and Stiglitz (1977). We are grateful to L. Perez and his colleagues to USAID for their comments. We are also indebted to the editor, to participants at seminars at Warwick, University of Dublin, The World Bank, Princeton and to Roy Ruffin and Robert Lindsey for their helpful comments. Financial support from the National Science Foundation, the Social Science Research Council of the U.K., and IBM are gratefully acknowledged. Revisions to the paper were completed whilst Newbery was on leave from Cambridge University at the World Bank. The view presented are those of the authors alone and do not necessarily reflect those of the World Bank or USAID. Earlier versions of this paper which include discussions of Trade Policy appeared as Economic Theory Discussion Paper No. 23, July 1979, Cambridge, England, Econometric Research Program Research Memorandum No. 281, May 1981, Princeton, and DRD Discussion Paper 50, January 1983, World Bank, Washington, DC.

NOTES

1. Elsewhere (Newbery and Stiglitz (1982*a*)) we have demonstrated the inefficiency (except under very stringent conditions) of competitive (i.e., free trade) equilibria for a more general model.

2. Thus, if individuals are all identical, the changes in price distribution which are central to our analysis have no welfare consequences.

3. For an extensive survey of the recent literature on trade and uncertainty, see Pomery (1979). Among the studies focusing on the small country case with the price distribution given exogenously are those of Batra and Russell (1974, 1975) and Ruffin (1974*a*, *b*). The Batra and Russell and Ruffin papers also assumed producers had no output variability whereas the relationship between the variability of output and prices plays a crucial role in our analysis.

4. Even when there are perfect equities markets, the assumption of identical consumers is crucial. Stiglitz (1982) has shown, for instance, that while the stock market equilibrium with multiplicative uncertainty and two commodities is always a constrained Pareto optimum with identical consumers, it essentially never is if consumers differ, either in their preferences for goods or their attitudes towards risk.

5. An inessential simplification of this analysis is that producers do not consume what they produce; their welfare depends only on what they obtain from selling their crops.

6. In our simple model, since the only source of price variability is supply variability, price will be a deterministic function of θ; in more general models, it would be a stochastic function.

7. I is the consumer's endowment of a third good (or a Hicksian composite commodity, representing all other goods), which is taken to be the numeraire.

8. See Samuelson (1942).

9. For other utility functions mean income of farmers will increase or decrease as a result of the opening of trade. See Section 2.B below.

10. The dollar value of the loss from the randomness in θ is approximately $(a/2)\sigma^2$. In the case of constant relative risk aversion not equalling unity

$$EV = E\frac{\theta^{a(1-\rho)}V_0}{1-\rho}, \qquad V_0 = \left\{\frac{n}{m(a+b)}\right\}^{(1-\rho)(a+b)} I^{(1-\rho)(1-a-b)}.$$

The dollar value of the loss from risk is then approximately $\frac{1}{2}a\{1-a(1-\rho)\}\sigma^2$ which agrees with the logarithmic case for $\rho = 1$.

11. This rules out the conventional reasons for trade and allows us to concentrate on the risk aspect alone. Regions have a comparative advantage in weather alone in this model. Obviously, this heavily qualifies any policy conclusions which might be drawn from the study. See also 2.D below.

12. Since

$$M \equiv U'[(a\theta+b)y]\left(\frac{ay}{x}\theta - \frac{by}{1-x}\right),$$

and $R \equiv -\pi U''(\pi)/U'(\pi)$,

$$\frac{\partial M}{\partial \theta} = ayU'\left\{\frac{1}{x} - \frac{R}{a\theta+b}\left(\frac{a}{x}\theta - \frac{b}{1-x}\right)\right\}$$

$$\frac{\partial^2 M}{\partial \theta^2} = \frac{Ra^2U'y}{(a\theta+b)^2}\left[-\frac{a\theta}{x} - b\left(\frac{2}{x}+\frac{1}{1-x}\right) + \left\{R - \frac{R'\pi}{R}\right\}\left(\frac{a\theta}{x} - \frac{b}{1-x}\right)\right].$$

If the range of θ is small, $(a\theta/x) - b/(1-x)$ will be small, so $\partial^2 M/\partial\theta^2 < 0$.
Alternatively, if $R' = 0$ and $R \leqq 1$, $\partial^2 M/\partial\theta^2 < 0$. Clearly, these conditions can be weakened.

13. A quantitative estimate of their welfare loss expressed as a percentage of mean income is provided by Taylor Series approximation:

$$\frac{\Delta U}{(a+b)yEU'}=\frac{U\{(a+b)y\}-EU\{(a\theta+b)y\}}{(a+b)yEU'}\approx\frac{1}{2}\left(\frac{a}{a+b}\right)^2R\sigma^2.$$

14. Details available from Newbery on request.

15. Brazilian coffee growers do not as a rule own shares in Kenyan coffee farms, or conversely Although we have not explained this absence of perfect risk markets, it would not be difficult to construct a model which is consistent with our analysis and which would at the same time have the property that there is imperfect risk sharing.

16. Of course, there are other possible models, emphasizing economies of scale and monopolistic competition; again, in such models, opening trade need not be Pareto improving. See, for instance, Arnott and Stiglitz (1981).

REFERENCES

ARNOTT, R. and STIGLITZ, J. E. (1982), "Equilibrium in Competitive Insurance Markets: The Welfare Effects of the Moral Hazard" (mimeo).

BATRA, R. N. and RUSSELL, W. R. (1974), "Gains from Trade Under Uncertainty", *American Economic Review*, **64**, (6) 1040–1048.

BATRA, R. N. (1975), "Production Uncertainty and the Heckscher–Ohlin Theorem", *Review of Economic Studies*, **42**, 259–268.

DASGUPTA, P. and STIGLITZ, J. E. (1977), "Tariffs vs. Quotas as Revenue-Raising Devices under Uncertainty", *American Economic Review*, **67**, 975–981.

DIAMOND, P. A. and STIGLITZ, J. E. (1974), "Increases in Risk and Risk Aversion", *Journal of Economic Theory*, **8**, 337–360.

FISHELSON, G. and FLATTERS, F. (1975), "The (Non-) Equivalence of Optimal Tariffs and Quotas under Uncertainty", *Journal of International Economics*, **5**, 385–393.

HELPMAN, E. and RAZIN, A. (1978*a*) "Uncertainty and International Trade in the Presence of Stock Markets", *Review of Economic Studies*, **45**(2), 239–250.

HELPMAN, E. and RAZIN, A. (1978*b*) *A Theory of International Trade Under Uncertainty* (New York).

HELPMAN, E. and RAZIN, A (1980), "Protection and Uncertainty", *American Economic Review*, **70**, (4), 716–731.

NEWBERY, D. M. G. and STIGLITZ, J. E. (1977) *The Economic Impact of Commodity Price Stabilization* (Washington, D.C.: USAID).

NEWBERY, D. M. G. and STIGLITZ, J. E. (1981) *Theory of Commodity Price Stabilization* (Oxford University Press).

NEWBERY, D. M. G. and STIGLITZ, J. E. (1982*a*), "The Choice of Techniques and the Optimality of Market Equilibrium with Rational Expectations", *Journal of Political Economy*, **90**(2), 222–246.

NEWBERY, D. M. G and STIGLITZ, J. E. (1982*b*), "Risk Aversion, Supply Response, and the Optimality of Random Prices: A Diagrammatic Analysis", *Quarterly Journal of Economics*, **97**(1), 1–26.

NEWBERY, D. M. G. and STIGLITZ, J. E. (1982*c*), "Pareto Inferior Trade and Optimal Trade Policy" (Econometric Research Program Memorandum No. 281, Princeton).

POMERY, J. (1979), "Uncertainty and International Trade", Chapter 4 of Dornbusch and Frankel (eds.) *International Economic Policy*.

ROTHSCHILD, M. and STIGLITZ, J. E. (1970), "Increasing Risk I: A Definition", *Journal of Economic Theory*, **2**, 225–243.

RUFFIN, R. J. (1974*a*), "International Trade under Uncertainty", *Journal of International Economics*, **4**, 243–259.

RUFFIN, R. J. (1974*b*), "Comparative Advantage under Uncertainty", *Journal of International Economics*, **4**, 261–273.

SAMUELSON, P. A. (1942), "Constancy of the Marginal Utility of Income", reprinted in *Collected Scientific Papers*, Vol. 1, 37–53 (M.I.T. Press).

STIGLITZ, J. E. (1972), "Taxation, Risk Taking and the Allocation of Investment in a Risky Economy", M. C. Jensen (ed.) *Studies in the Theory of Capital Markets* (New York.)

STIGLITZ, J. E. (1982), "The Inefficiency of the Stock Market Equilibrium", *Review of Economic Studies*, **49**(2), 241–261.