Commodity Price Stabilization

The Theory and Its Application

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ABSTRACT

The literature on commodity price stabilization is extensive in its coverage, diverse in its objectives, complex in its theoretical constructs, and confusing in its results. The purpose of this essay is to clarify and simplify the results of this broad body of literature in order to provide the operational economist with a better sense of the conditions under which commodity stabilization schemes will be successful and the welfare effects of such schemes.

The essay begins by introducing the early framework under which price stabilization was analyzed and then continues by relaxing the assumptions of the early model in order to demonstrate the variance of results under alternative (more realistic) situations. Topics such as storage and food security, inflation and economic development, public storage and futures markets, and non-storable goods are treated.

The more important conclusions that arise from this work are: that some countries may lose from price stabilization even though there is a net global gain; that liberalized trade reduces the need for buffer stocks; that futures markets reduce instability at a lower cost than buffer stocks; that many national price stabilization schemes are actually price support systems used to improve farmers' incomes; that good price forecasting is a prerequisite to well-managed buffer stocks; that price stability in poorer countries is not sufficient to avoid occasional food shortages; and that food is costly to store in developing countries and may not alleviate famine if an adequate transportation and distribution system is not already in place.
Abrégé

La stabilisation des prix des produits de base a fait l'objet d'une littérature tous azimuts caractérisée par des objectifs divers, des raisonnements complexes et des conclusions peu claires. Le présent exposé vise à mieux expliquer, en les simplifiant, les enseignements que l'on peut tirer de cette somme de publications, afin de donner aux économistes praticiens une meilleure idée des conditions à remplir pour que les systèmes de stabilisation des prix des produits de base soient efficaces et des effets qu'ils ont sur le bien-être social.

Il décrit tout d'abord les bases théoriques sur lesquelles s'est fondée, à l'origine, l'analyse de la stabilisation des prix. Il démontre ensuite comment, avec des hypothèses moins restrictives (plus réalistes), on obtient des résultats différents. Il traite notamment du stockage et de la sécurité alimentaire, de l'inflation et du développement économique, des stocks publics et des marchés internes ainsi que des denrées non stockables.

Les principales conclusions du présent article sont les suivantes : la stabilisation des prix peut se faire au détriment de certains pays même si, au niveau international, le bilan est positif ; la libéralisation des échanges rend moins nécessaire l'entretien de stocks régulateurs ; les caisses nationales de stabilisation des prix sont souvent, en réalité, des systèmes de soutien des prix qui servent à améliorer les revenus agricoles ; pour gérer au mieux les stocks régulateurs, il est indispensable de pouvoir disposer d'un bon système de prévision des prix ; la stabilité des prix ne suffit pas à garantir les pays pauvres de toute pénurie alimentaire ; enfin, le stockage des denrées alimentaires est coûteux pour les pays en développement et risque de n'être guère utile en cas de famine sans un réseau suffisamment développé de transport et de distribution des produits.
EXTRACTO

La literatura sobre estabilización de precios de los productos básicos es muy amplia, tiene objetivos diversos y una construcción teórica compleja y sus resultados son desconcertantes. Este ensayo tiene por objeto aclarar y simplificar los resultados de esta amplia literatura, a fin de dar al economista operacional una idea más precisa de las condiciones en que los métodos de estabilización de precios de los productos básicos resultarán satisfactorios y de los efectos de dichos métodos desde el punto de vista del bienestar.

En el ensayo se comienza por introducir el primer marco dentro del cual se analizó la estabilización de precios y luego se liberalizan los supuestos de ese primer modelo para demostrar la varianza de los resultados en distintas situaciones (más realistas). Se tratan temas como el almacenamiento y la seguridad de los alimentos, la inflación y el desarrollo económico, el almacenamiento público y los mercados de futuros, y los bienes no almacenables.

Las conclusiones más importantes que se derivan de este trabajo son las siguientes: que la estabilización de precios puede perjudicar a algunos países aun cuando el total de países se beneficie globalmente; que el comercio liberalizado reduce la necesidad de mantener existencias reguladoras; que los mercados de futuros reducen la inestabilidad a un costo menor que las existencias reguladoras; que muchos sistemas nacionales de estabilización de precios son en realidad sistemas de precios de sustentación que se usan para incrementar los ingresos de los agricultores; que el pronóstico acertado de los precios es indispensable para administrar eficientemente las existencias reguladoras; que en los países más pobres la estabilidad de los precios no basta para evitar la escasez ocasional de alimentos, y que en los países en desarrollo el almacenamiento de los alimentos es caro y quizás no permita aliviar la hambruna si no existe un sistema adecuado de transporte y distribución.
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Summary

Research on price stabilization is diverse in objectives, methods and assumptions; it ranges from highly sophisticated theoretical and empirical models to somewhat rather simplistic approaches. Because of this, it is extremely difficult to grasp the essence of this vast and somewhat confusing literature. As a result, this paper highlights the results from research on commodity price stabilization. Among the major conclusions are:

1. Many of the early theoretical developments focussed on the effects of price stabilization both in aggregate and from a distributional viewpoint. Generally price stabilization leads to a net welfare improvement especially in those cases where it is accompanied by income stabilization. A net welfare improvement implies that if there are losers from price stabilization, the gainers could easily compensate this sector such that everyone could be made better off.

2. In terms of distributional effects, the results are very sensitive to model specification. Producers can lose or gain from stabilization depending on such factors as the source of the instability and the degree of non-linearity in demand and supply curves. Producers generally prefer price instability to stability in those
cases where: (a) they are good at price forecasting, (b) the government provides price supports which prevents substantial price falls in a down market and/or (c) producers are risk takers.

3. From a trading standpoint, certain countries may actually lose from price stabilization even though the net gain to all countries taken together is positive. Thus with compensation all can be made better off with price stabilization. In terms of countries generally major exporters lose from price stabilization especially export producers.

4. The distribution issue does point to a major problem with international reserves. Some countries and hence groups within countries may actually lose from stabilization even though all countries taken together gain. Thus, why should all countries want to contribute to an international buffer stock? Theory and empirical evidence suggest that the importers of food should hold larger reserves than has traditionally been the case.

5. The gains from stabilization are generally small if risk is not an important factor. However, in cases where price stabilization schemes reduce risk and where producers are risk averse, the gains resulting because of added supply response far outweigh the gains from riskless price stabilization schemes (i.e., schemes which reduce risk but do not trigger a producer supply response).

6. Liberalized trade greatly reduces the need for buffer stocks since
trade itself has a price stabilizing effect. Hence the gains from price stabilization while positive are smaller with free trade than when trade distortions exist. The need for buffer stocks also is diminished when risk sharing can be facilitated through such means as international futures markets, efficient credit markets and international investments in securities.

7. In many cases, price stabilization schemes are introduced where price and income policies are already in effect. Some of the literature considers price stabilization jointly with such policies as price supports. Generally, the effectiveness of stabilization is reduced when other policies exist.

8. For many commodities, futures markets exist. Their existence generally reduces price instability. Where futures markets are feasible, they may be a less costly way to reduce instability than are buffer stocks. Also, where stabilization schemes are used to reduce producer risk in the presence of already functioning futures, the gain may be negligible since one of the reasons why futures markets exist is to provide a price hedge for those who want to minimize risk exposure.

9. Stocks are held by both the private and public sectors. Private holdings include storage by farmers. Generally, as government increase their size of stocks, the private sector reduces its holdings. Thus, how large an optimal government stockpile should be depends in part on how the private sector responds. If there
is a one to one substitution, government stockholding is generally not needed unless it is used, for example, to support farm incomes. At the extreme, where either stocks are entirely held privately or publically the variability in farmers' incomes will generally be greater under publically held stocks than if storage is done by the private sector.

10. Government owned reserves do not always exist as merely an instrument to bring about price stability. They generally are a result of price support policies to improve farmers' incomes. When government puts in place a price support system which prevents producer prices from falling in an abundant supply periods, the government generally ends up buying the quantity which the market can't clear at the support price (certain countries will subsidize the producers to hold part of this stock). These stocks are released in tight market situations. However, the size of the stockpiling activity is generally greater than what would be needed if the sole aim were price stabilization rather than farm income enhancement. Seldom is the role of government stockpiling solely one of price stabilization.

11. In many countries, price stabilization schemes are tied to farm income programs. Stocks are not used merely to facilitate the efficient functioning of markets. In this regard, farmer held reserves might even be larger than if government and/or private stocks were used only for price stabilizing means.
12. Certain commodities cannot be stored. In such cases governments often introduce a price stabilization scheme which is supposed to be self-financing (i.e., a deficiency payment is used in low market periods along with a producer tax during good market periods). However, generally such schemes turn out to be income enhancing for producers since the government outlay exceeds the tax.

13. From a private firm standpoint, if it has sufficient market power it will use storage in order to manufacture price instability and gain as a result. This phenomenon also applied to a food importer with market power. Also multiproduct firms may prefer price stability for the major crop produced but prefer instability in minor crops. This result is important since marketing boards are often used as marketing institutions. In cases where they aren't used to tax producers, they are often supported to market major crops but minor crops can be left to the open market.

14. Theory shows that the optimal amount of storage should allow prices to fluctuate within some band (i.e., with positive storage costs complete price stabilization is not optimal). The empirical studies are generally consistent with the theoretical developments. They show that often government stockpiling is much greater than that needed to bring about an optimal allocation of resources. It thus appears that for countries such as the U.S., storage activities have resulted in a misallocation of resources.
15. Empirical studies show that good price forecasts are needed to optimally manage buffer stocks. Also, because of the large fluctuations in prices of agricultural commodities, a storage policy should provide flexibility in both the build up and release of stocks. Generally, this flexibility has been lacking in past stock policies.

16. There is now a vast literature on food security and the role of buffer stocks to meet emergency food needs. It does not follow that price stability brought about in commercial markets through buffer stocks guarantees on adequate supply of food during extreme droughts in poor countries. Some of the early studies on this subject suggest that a buffer stock be set up specially targeted to meet the emergency needs of poor countries. These stocks would be separate from working stocks which are needed in commercial markets.

17. Recent studies on the food security issue conclude that even with price stability poor countries still experience famine when production shortfalls occur. They contend that the problem is a shortage of foreign exchange in order to purchase food. They propose the setting up of a foreign exchange reserve to be made available to poor countries so that the stocks can actually be purchased during periods of famine. The idea is to store money not food because it is not the lack of food on a worldwide basis that is the problem. The problem lies in the lack of purchasing power to buy it.
18. Food is costly to store in less developed countries. In addition, it has to be stored in places where it can be easily accessible for famine relief. Thus good transportation becomes vital to avoid famines. A good transportation system along with financial reserves would greatly reduce starvation during severe production shortfalls in less developed countries. In the past, there have been famines in poor countries even though large amounts of grain were in storage in developed countries. Thus, even though stability in commercial markets adds to food price stability to poor countries, there is no guarantee that the poor countries will receive any of the benefits from such a scheme.

19. Future research has to tie the food security issue and the price stabilization schemes for commercial markets together. The theory does not pay adequate attention to the effects of instability on poor people. The sophisticated programming models also generally lump poor and rich importing countries together. Further modelling should treat the less developed countries as a separate region.

20. Because the private sector can perform at least part of the storage function to stabilize commercial markets coupled with the fact the advanced countries over stock because of public stock-holding due to income support policies, agencies such as the World Bank might well focus only on the food security issue and develop means to implement, for example, a financial reserve mechanism. Often there are excess stocks, for example, in the U.S., and insufficient stocks in poor countries.
Introduction

The dramatic increase in commodity price instability in the 1970's brought with it a voluminous literature on its effects. Some of these studies were of a highly theoretical nature while others were quantitative and applied. However, even though most of the studies were initiated after the decade of the sixties, formal treatment of the effects of price instability was presented in 1944 by Waugh. It was this paper which laid the groundwork for the early theoretical work on price instability. However, the theoretical developments in this area since Waugh's seminal paper, have gone in many different directions as have the empirical analysis.

Because the literature on the welfare effects of price instability is so vast and in a sense does not contain any unifying theme, it is difficult for someone not dealing in this area to quickly grasp the implications of this research for economic policy analyses and implementation. Consequently, the purpose of this paper is to review the literature on price stabilization and highlight the key conclusions reached.

The Early Framework

Much of the discussion on the effects of price instability has focused on agricultural commodities where stochastic fluctuations in demand and supply can be particularly important. In 1944 Waugh analyzed the effects of price instability on consumers. This methodology was later extended by others to other sectors in the economy. The Waugh conclusion was that consumers preferred price instability to stability—a conclusion which to many is counter-
intuitive. How then, did Waugh arrive at this result?

His results are developed in Figure 1 where D represents demand and consumers face prices $p_1$ and $p_2$, each of which occurs half the time, i.e., with probability 0.5. These price variations may be caused by random fluctuations in supply between $S_1$ and $S_2$. When price is $p_1$, consumers buy $q_1$ so that consumer real income (surplus) is represented by area $a + b + c$. (The areas are bounded only by solid lines). When price is $p_2$, consumers buy $q_2$ so that consumer real income is represented by area $a$. On the other hand, if prices are stabilized by a Government policy at the average price level, $\mu p = (p_1 + p_2)/2$, then consumption takes place at $q_0$ with consumer real income represented by area $a + b$. 

**FIGURE 1**
To investigate why Waugh arrived at his result, note that half the
time consumers gain area b as price is lowered from \( p_2 \) to \( \mu P \), but the
other half of the time consumers lose area c as price is raised from
\( P_1 \) to \( \mu P \). Since \( p_2 - \mu P = \mu P - P_1 \), the loss obviously outweighs the
gain; the average loss is \( \frac{1}{2} \) (area c - area b). Thus consumers
prefer price instability if they can take advantage of it by buying
more at low prices and less at high prices.

The concept underlying the above analysis is that of "economic
surplus." Waugh used the concept of consumers' surplus while later
the notion of economic rent or producers' surplus will also be
entertained. There is a vast literature on whether or not this
concept has a legitimate use in economics (Currie, Murphy and Schmitz,
Just, Hueth and Schmitz). It forms the basis for applied welfare
economics. In the case of consumers' surplus it is the area below the
demand curve bounded by the equilibrium price line. This area is a
money measure of willingness to pay. For example, in Figure 1 the
area c represent how much a consumer is willing to pay to have the
price drop from \( \mu P \) to \( P_1 \).

Following Waugh another somewhat counterintuitive result was
presented in 1961 by Oi on producers' preferences for instability. Oi
showed that they also preferred instability to stability. To
understand his results, consider Figure 2 where supply is represented
by S and producers are confronted with two prices, \( P_1 \), and \( P_2 \), each of
which occurs with probability 0.5. These price variations may be
caused by random variation in demand between \( D_1 \) and \( D_2 \). When price is
\( P_1 \), producers will \( q_1 \) so that producer real income (surplus) is repre-
sented by area a. When price is \( P_2 \), producers sell \( q_2 \) so that real...
income is represented by area $a + b + c$. On the other hand, if prices are stabilized by some means such as Government policy at the average price level $\mu_p = (p_1 - p_2)/2$, then production is $q_0$ and producer welfare is represented by area $a + b$. Where price would otherwise be $p_1$, producers gain area $b$ and where price would otherwise be $p_2$, producers lose area $c$ with stabilization. Since $p_2 - \mu_p = \mu_p - p_1$, the latter loss is larger than the former gain; and since each occurs half the time, producers lose on average from price stabilization (unless supply is completely inelastic).

The key to the above analysis is that producers can adjust instantaneously to price changes. This implies that in Figure 2 the high price corresponds with the high quantity. One can arrive at the same result by assuming, for example, that producer's expected price and expected output at the time of planting are actually realized. In Figure 2, $p_2$ and $q_2$ can be expected price and expected quantity both of which are realized.
If the above results are correct, why do policy makers introduce policies which are aimed at price stabilization? As we shall see, this policy aim is correct since stabilization is preferred when both consumers and producers are considered jointly. Samuelson argued that in fact, an economy cannot "pull itself up by the bootstraps" by simply generating instability. The consumers gain from instability in the Waugh case because there is in essence a Santa Claus in the background who is losing. The same is true in the Oi analysis. The economic surplus to make both consumers and producers better off from instability has to come from somewhere and as Massell (1969) showed this needed surplus is nowhere to be found when consumers and producers are considered jointly.

The Massell approach is presented in Figure 3A. Consumer demand is represented by D and that stochastic supply is represented by $S_1$ and $S_2$, each of which occurs in alternating periods. Thus, equilibrium prices are $P_1$ and $P_2$, respectively. Assume that prices are stabilized at $P$, say, by means of a buffer stock authority which buys excess supply, $q_1' - q_0$, when $S_1$ occurs and sells $q_0 - q_2$ when $S_2$ occurs. In the event of $S_1$, consumers lose area $c + d$ while producers gain area $c + d + e$ for a net gain of area $e$. With $S_2$, producers lose area $a$ but consumers gain $a + b$ for a net gain of area $b$. The average overall effect of price stabilization with such a reserve policy is a gain of $1/2$ (area $b + area e$). This result implies that the loss from stabilization for consumers offsets some of the gain for producers who are benefited by stability. Furthermore, the gain for producers more than offsets the consumer loss.

The results in Figure 3B are for fluctuations in demand. With
price varying between $D_1$ and $p_1$ and $D_2$ and $p_2$, respectively, price stabilization at $\mu_p$ via a buffer stock leads to a gain of area $e$ if $D_1$ occurs or of area $c$ if $D_2$ occurs. On average, the producer loss of $1/2 \left[ \text{area } (a+b) - \text{area } (d+e) \right]$ is more than offset by a consumer gain of $1/2 \left[ \text{area } (a+b+c) - \text{area } d \right]$.  

The results suggest that society benefits by stabilizing prices of storable commodities through a reserve policy if storage costs are not excessive. However, what is equally as interesting is that even though society gains there are both gainers and losers from stabilization policies. In Figure 3A consumers lose from stability while in Figure 3B producers lose from stability. However, one group gains more from stability than what the other loses. As a result, through some form of a compensation, everyone can gain from a price stabilization policy.

At this point one doesn't find it hard to believe that society benefits from price stabilization. What's difficult to understand is why with demand shifts producers prefer price instability to stability—the result also obtained by Oi. As Figure 4 shows using the Massell framework this result need not hold. As the results show, producers are indifferent to instability vs stability and consumers gain from stability; stability is Pareto superior. In Figure 4 the right hand side of the diagram shows the model in Figure 3B—the Oi-Massell results. The new results are derived in the larger of the two diagrams. The notion of planning curves are introduced—$S$ is the

\footnote{Additional results for the vertical market case are given in Just and Salkin. Also a somewhat different approach to stabilization analysis is given in Knapp.}
planning supply curve (ex ante) and D is the planning demand curve (ex ante). If no random terms are introduced \( \hat{P} \) and \( \hat{Q} \) are both expected and realized prices and quantities. In the model a random term is introduced in the demand curve hence D is no longer an exact relationship between P and Q. Consistent with Massell’s model we assume that there is a probability of 0.5 of demand being either above or below D. (We have sketched in demand curves \( D_1 \) and \( D_2 \) to correspond with \( D_1 \) and \( D_2 \) in the right hand side of the diagram.) It is clear that even though demand is stochastic the expected price and output at planting is \( \hat{P}\hat{Q} \). Now since supply is nonrandom realized output is \( \hat{Q} \). However realized price is not \( \hat{P} \). If demand is \( D_2 \) price is \( P_2 \) and if demand is \( D_1 \) price is \( P_1 \). Prices can be stabilized by storing \( ae \) when demand is \( D_1 \) and releasing it when demand is \( D_2 \). Note now how different the results are from the Massell-Oi model. Producers there preferred price instability—now they are indifferent: 

\[
2(\hat{P}\hat{Q}) = P_2\hat{Q} + P_1\hat{Q}
\]

Consumers clearly prefer stability thus a buffer
stock scheme is Pareto Superior to no buffer stocks—the opposite to the Massell-Oi result. Also what is interesting is: (1) price variability is greater in our model, (2) storage needed to bring about stability is greater and (3) the benefits from stabilization are greater. On the last point the shaded areas are the gains in Massell-Oi's framework. This underestimates the gains by the cross-hatched area ace.

Why the different results? The difference is due to how instability is generated in the model and how much information is assumed. In the Oi-Massell model the high price corresponds to the high output and vice versa. That is, ex ante expectations and actual outcomes coincide (i.e. demand D_1 and D_2 are known with certainty at the time of planting). This assumption however is unrealistic and inconsistent with the Massell-Oi mathematical model where demand is random and where different outcomes are assigned a .5 probability. In this case, as we show, there is no output adjustment to demand fluctuations; only prices adjust if there is no storage. With complete storage however, expected price equals actual price. However, in the Massell-Oi graphical model this is not the case.

As a caveat, it is clear in the Oi-Massell framework why producers prefer price instability to stability. This is because at the high price, output is large but at the low price output is low. Generally, in reality high prices correspond to low output—not the other way around. It is easy to make money in the Oi situation because of perfect foresight just like it is to "buy low and sell high". The problem in reality however, is running the risk of "buying high and selling low". This is why in the left hand side of the diagram expected or planning price equals the realized price with storage (in
the Oi-Massell result the storage price or stabilized price is between these two expected prices).\(^2\)

**Partial Price Stabilization**

In the above discussion storage is assumed to be costless. When positive storage costs are introduced, it is no longer optimal to pursue complete price stabilization.\(^3\) Massell (1970) early introduced a partial stabilization scheme notion and it was still later elaborated on by Just and Schmitz and Turnovsky (1979). This buffer stock policy has the effect of modifying the demand curve by purchasing and selling quantities to make up the difference in actual and modified demand (Figure 5). The market demand in the absence of storage is \(D\). Producer expected price is \(\hat{P}\) and expected output is \(\hat{Q}\). Let the disturbance be due to supply fluctuations such that in one period output is \(Q_2\) and in the second period output is \(Q_1\). A modified demand curve of \(D_m\) in essence yields a price band \(P^0P^*\) since \(Q_2Q^*\) is stored in one period giving price \(P^*\) in that period; stocks are released in the high price period giving price \(P^0\).

The above model in essence uses a linear adjustment rule which ensures that a fixed proportion of the excess of any given crop over a

\(^2\) The Oi-Massell model of instability generated because of demand fluctuations has been applied by Tisdell to price stabilization schemes in the Australian wool industry. He concluded that stabilization of wool prices by the Wool Commission may reduce the average annual net income of growers and also of manufacturers of wool.

\(^3\) As Newbery and Stiglitz (1981) show, if output fluctuations are uncorrelated through time, there will come a point where with total price stabilization the stock pile will become exhausted making complete price stabilization infeasible.
normal crop is saved for times of shortage. However, not all partial stabilization schemes follow a linear adjustment rule. A non-linear adjustment rule is needed when buffer stocks alter the probability distribution of the market price in a nonsymmetric way. In practice, the most common scheme of partial price stabilization is that of a price band (i.e., the authority allows prices to fluctuate between $P^0$ and $P^\ast$ (Figure 5). However, as will be discussed later, adjusting stocks so as to operate within a specified price band may be non-optimal.

**Price vs. Income Stabilization**

An important point raised by Newbery and Stiglitz (1981) and Bigman is that in some cases stabilization of prices enhances income variability. Their proof is mathematical.\(^4\) However one can show this

\(^4\) They show that the result holds when demand elasticity $> 1/2$. 
result using the Massell framework in which it is also possible to
discuss the role of private vs. public stockholding. In Figure 6,
price fluctuations are caused by supply fluctuations. Without
storage, producer incomes over the two periods are $P_1Q_1$ and $P_2Q_2$.
Income is less than if $Q$ is sold both periods since $2(P_0Q) > (P_1Q_1 +$ $P_2Q_2)$. Storage, however, which stabilizes price need not yield stable
incomes. Suppose the government, for supply $S_1$, stores $Q^*$ and pays
producers $P_0$ in the same period $S_1$ occurs. Then in that period income
is $P_0Q^*$. In the next period, supply is $S$ and the governments release
the stocks. Producer income is now only $P_0Q_0$. The scheme is
self-financing since government outlays for stocks equals the money
received by government when stocks are released. However, now producer
income has a larger variance with government storage than if no
storage occurred since $P_0Q_0 < P_1Q_1$ and $P_0Q^* > P_2Q_2$. There are two
additional results worth noting: (1) producers still prefer price
stabilization even with government storage to price instability since:
(P_u Q_o + P_u Q*) > (P_1 Q_1 + P_2 Q_2). (2) In the absence of government storage producers privately would store in view of the price stabilization result above. Also they may have the objective of income stabilization which means they would store QQ* for sale in the following period. But now note the important result: with private storage, both income and price are stabilized since to achieve price P_u producers have to store QQ* (for which they get no payment) and sell it the following period. Thus, in the case presented, the degree of income variability generated by price stabilization depends critically on whether the public or the private does the storing.

Instability in Imperfect Markets

The above analysis is based on perfectly competitive markets. Here we show some of the results in a closed economy model where imperfectly competitive markets exist. Several cases were considered by Bieri and Schmitz (1974). Their simplest case of a producer marketing board with monopoly power is presented in Figure 7.

FIGURE 7

\[ P \]
\[ Q \]
\[ Q_1 \]
\[ Q^* \]
\[ Q_2 \]
\[ S_2 \]
\[ S_1 \]
\[ IS \]
\[ MR \]
\[ AR=\Delta MR \]
Consider a market were AR is the average revenue curve and MR is the corresponding marginal revenue schedule. For a two-period analysis, AR is also the sum of marginal revenue schedules. A monopolist marketing board will equate AR with the sum of the supply schedules \( S \) and \( S_1 \) which is denoted by \( S \). Consumer prices are stabilized at \( P^* \) as are producer prices at \( P_s \). This is brought about by storage by the board (\( Q*Q_2 \) in the surplus year to be released in the deficit year).

A more complicated case was developed by Bieri and Schmitz where a marketing firm has both monopoly and monopsony power. The analysis shows how such a firm will use storage to stabilize consumer prices but destabilize producer prices. The firm in essence buys the large quantity at a low price and buys a small quantity at a higher price. In this case the producer supply curve is downward sloping. These type of models clearly demonstrate that storage by private firms improve their economic position but at the expense of other groups. The losses are born by consumers and/or producers. Also, as these models show, price instability can be "manufactured". This is opposite to the type of price instability in the Waugh, Oi and Massell models where instability is due to natural phenomena such as weather.

Even though the manufactured price instability model was developed for a no trade environment, Schmitz et al. (Dec., 1981) in a recent book on Grain Export Cartels argue that this phenomenon might also apply to trade in wheat and feedgrains. They contend, for example, that the Soviet Union gives false price signals in the market which encourage production which is later sold at prices below the cost of production.
Recent papers have also examined storage in imperfect markets but from a different perspective. Young and Schmitz consider the case where production is controlled by a cartel which behaves as a monopolist. They allow for fluctuations in both demand and supply and consider cases where the high demand occurs during the high cost, low production period (e.g. milk). In the case of milk, it can be stored as powder and reconstituted such that the end product is indistinguishable from fresh milk. The authors, through a somewhat complicated supply and demand model, try to answer why producers have opposed the introduction of reconstituted milk into the market since at first glance it would appear that storage should increase producer profits. They show that profits can be lower with storage and uniform pricing. Also, given the magnitude of the dairy price supports, storage can be nonproftitable for a producer cartel.

Newbery rigorously derives results for the optimal stock rule for a monopolist. The optimum storage rule is nonlinear. Also he shows that: (1) a monopoly stocking rule leads to larger storage than under competition, (2) a monopolist facing a stable linear demand schedule will undertake more price stabilization through storage activities than a competitive market producing the same average supply (this result does not hold for all demand schedules) and (3) if an international buffer agency is set up and instructed to maintain prices within a bandwidth then a monopolist will be able to speculate against the agency. However under a competitive rule this would not happen. Also there would be cases when the monopolist would perform no storage.
Nichols and Zeckhauser develop a model which might be called international countervailing price stabilization. They consider large competitive consuming nations facing an export cartel. They show that it would generally pay the consuming nations to build up a strategic stockpile, whose presence would suppress price in future periods even when the supply conditions of the producing cartel were nonrandom and stationary. In the Schmitz et al. Grain Export Cartel book they contend that importers exert monopsony power through such devices as optimal tariffs and they propose pricing and storage strategies to deal with these distortions.

**International Trade Cases**

The earlier competitive models were first applied to international trade by Hueth and Schmitz. It was shown that even with trade countries taken together prefer price stability. Hueth and Schmitz clearly show this by the use of excess supply and demand curves. In Figure 8 the excess supply curve for a given good is ES (i.e. the amount exported at different prices) while the excess demand curves for both periods are ED and ED'. It follows from Figure 3 and 4 that the net gain for both the importer and exporter aggregated together is a + b. In this case the exporter loses from stability while the importer gains. However, if the instability was due to a stochastic supply system the exporter would gain from stability while the importer would lose.
This model raises the interesting issue about who should hold reserves to bring about stability. In the first case, the importer should hold the largest percentage of reserves. On the basis of this model international cooperation in setting up an international reserve pool is difficult since the countries do not share the gains equally.\(^5\)

The above framework has been used by Bieri and Schmitz (1973) to incorporate tariff policies. It was shown that in the optimal tariff case an importer no longer prefers instability even when the source of the instability is external (i.e. caused by shifts in the excess supply curve in Figure 8). In this model, the importer will impose tariffs along with positive storage.

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\(^5\) Also Hueth and Schmitz show that an importer (both producers and consumers) may prefer instability to stability when the source of the disturbances are external to the country.
In summary, in an international trade context the welfare of all countries taken together is increased by the use of storage (i.e. what the gainers gain is more than what the losers lose). However, even though this is true some countries may actually lose from stability due to storage. In these type of models the distributional effects critically depend on such factors as the source of the instability (i.e. whether it is generated from without or within a country) and the height of the tariffs.

The Hueth-Schmitz model was empirically tested for the wheat and feedgrain sectors of the United States. Konandreas and Schmitz found that U.S. producers and consumers taken together benefit from policies which would stabilize feed grain prices but instability was preferred in the wheat sector. The model upon which this conclusion rests specifies a U.S. domestic demand relationship for food and feed use, stock relationship and a foreign demand sector.

A version of the Bieri-Schmitz optimal tariff model was tested by Carter and Schmitz for U.S. and Canada wheat exports to the EEC and Japan. It was found that those importing nations do in fact pursue a tariff policy that is welfare improving for importers. The optimal tariff model was also tested by Sampson and Snape but for feedgrains was well as wheat. Also instability created by tariffs and storage was explicitly introduced. Their results show that a substantial income transfer from the major grain exporters to the EEC occurs as a

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6 See Bale and Lutz and Lutz and Bale for welfare consequences with price distortions. Also see papers by Shei and Thompson and Toshihisa.
result of the combined tariffs and instability. These studies are reviewed in detail in Schmitz et al. (1981).

What is often overlooked in the literature is that the degree of trade liberalization can affect the magnitude of price instability and hence the need for buffer stocks. As Newbery and Stiglitz (1981) show, international trade by reducing price instability has similar effects to a buffer stock scheme and may be a cheaper substitute; although, as shown earlier, storage can yield added gains to the free trade no storage model. The proposition that freer trade results in greater price stability was also shown by Sarris and Taylor (1978) and Bigman. One of Bigman's results is given in Figure 9. For example, free trade has associated with it much less price instability than has no trade.

FIGURE 9

Source: Bigman, p. 325.
The effects of buffer stocks also critically depend on the degree and type of market distortions present. As Newbery and Stiglitz (1981) show, if non-linear trade policies are used such as quotas, price stabilization will generally yield larger benefits than if such trade distortions are absent.

Nonlinearity and Multiplicative Disturbances

The above framework is based on linear supply and demand relationships and additive disturbances (i.e., parallel shifts in supply and demand schedules). We relax first the linearity assumption. To see the implications of nonlinearity, consider Figure 10 where the demand curve D is nonlinear and supply alternates between $S_1$ and $S_2$. Now suppose price is stabilized by purchases when supply is high and sales from buffer stocks when supply is low. For such a buffer stock to operate for a long period of time, the increase in stocks when supply is high must be the same as the decrease in stocks when supply is low. Otherwise, the buffer stock would either tend to accumulate until some of the stock would require disposal or stocks would tend to run out so that the stable price could not be realized. (This was also assumed in the linear case). With this requirement, excess supply, $q_1 - q_0$, at $S_1$ is equal to excess demand $q_0 - q_2$, at $S_2$ so the buffer stock's sales in a short supply period are the same as their purchases in a long supply period; thus, the net welfare effect is zero on average with complete price stabilization (excluding storage and transactions costs).

The stable price $\bar{p}$ in Figure 10 must be chosen so that the horizontal distance between $S_1$ and D is the same as between $S_2$ and D.
Hence, if demand is upward bending (convex) as in Figure 10, then the stabilized price is lower than the average destabilized price; if demand is downward bending (concave), then stabilized price is above the average destabilized price. The welfare gains and losses for producers and consumers in terms of areas a, b, c, d, and e in Figure 10 are exactly the same as in Figure 3A, except that areas a and b are now relatively large and areas c, d, and e are relatively small. As a result, an average net gain of $1/2 (\text{area } b + \text{area } e)$ is still possible, but now the average consumer effect of $1/2 [\text{area } (a+b) - \text{area } (c+d)]$ may be positive rather than negative (with sufficient nonlinearity) because the stabilized price is lower than the average destabilized price. Also, the average producer effect of $1/2 [\text{area } (c+d+e) - \text{area } a]$ can possibly become negative, thus obtaining exactly the opposite qualitative impacts on producers and consumers then was suggested by Figure 3A.
A similar generalization of the analysis for the case of upward-bending (convex) supply also shows that sufficient non-linearity in supply can reverse the qualitative effects of price stabilization when instability is due to fluctuations in demand. However, as before, the net effect of price stabilization considering both sectors is positive.

The above conclusions were suggested in a paper by Hillman, Johnson and Gray prepared for the Food and Agricultural Organization. They state "A demand curve grown steeper at higher prices and shallower at lower prices enhances the consumer stake while diminishing the producer stake in reserves. This calls for a dramatic reversal from policies which accumulate reserves ostensibly in the producer's interests, away from the notion that stocks acquisitions benefit producers, toward explicit recognition of the overriding consumer interest." (p. 8)

Another important issue in the stabilization literature is the form of the disturbance as to whether it is additive or multiplicative. Up to now, additive disturbances have been assumed. Additive means that if supply or demand is written with quantity q as a function of price p, say f(p), then the actual demand or supply curves correspond to q = f(p) + E where E is a random disturbance with the same variance regardless of price level, E(E) = 0. One alternative form of disturbance defended, for example, by Turnovsky (1976) is the multiplicative specification q = f(P)E, E(E) = 1.

To demonstrate the implications of multiplicative disturbances graphically in Figure 11, suppose demand is stable at D but supply is unstable with multiplicative variation represented by fluctuations
between $S_1$ and $S_2$ in alternating periods. For buffer stocks to be self-liquidating, prices must be stabilized at $p$ where $q_2 - q_0 = q_0 - q_1$ rather than at the average destabilized price, $\mu_p = (p_1 + p_2)/2$.

Again, the welfare effects in Figure 11 are the same as in Figure 3A in terms of areas $a$, $b$, $c$, $d$, and $e$; but, again, as with nonlinearity, areas $c$, $d$, and $e$ are smaller than areas $a$ and $b$. As supplies $S_1$ and $S_2$ diverge (as the slope of $S_1$ falls), these results are accentuated until area $c + d + e = 0$. Hence, with sufficiently strong multiplicative disturbances, net overall gains of $1/2$ (area $b + e$) are still possible; but, again, even the qualitative implications for individuals or groups may switch. Producers may lose [if area $(c+d+e) - area a < 0]$ and consumers may gain [if area $(a+b) - area (c+d) > 0$].

Results similar to those in Figure 11 can also be developed for the case of multiplicative disturbances in demand in which case the
qualitative implications can possibly be just opposite of those in Figure 3B where demand disturbances are additive.

As a caveat, a recent study by Dunn and Heien quantitatively determined both whether consumers preferred price instability and the magnitude of the gains. They used Monte Carlo techniques to generate random prices and then used a translog expenditure function to measure the benefits. They conducted a large number of experiments and found for the realistic case that the gains from price instability were quiet small. The average benefit was $1.14 out of $20,000 expenditure, or .0057 percent.

The analysis incorporating both non-linear demand relationships and multiplicative disturbances was carried out in a free trade context by Just et al. (1978) and in a trade distorted world by Just et al. (1977). Unlike in the early trade results by Hueth and Schmitz, the source of the price instability in terms of whether it is generated within a country or externally no longer plays a key role. This is clear from Figure 12. Suppose ED is the excess demand by an importer and ES_1 and ES_2 are fluctuating excess supply curves. If ED were linear the importer would gain from instability. However, this is no longer true. Using the analysis developed to this point, it is clear that a stabilization policy which results in p is preferable for the importer over fluctuating prices P_1 and P_2.

The interesting result in both of the papers by Just et al. is that producers in exporting countries prefer instability but consumers in importing countries gain from stabilization. It was found that exporting countries generally are worse off and importing countries better off with stabilization. However, as with all of the studies
surveyed to this point, with appropriate compensation the world as a whole can actually gain from stabilization. As already pointed out, these results were found to be the case for wheat in the study by Konondreassa and Schmitz using the Hueth-Schmitz linear framework. Interestingly, the degree of curvature of the excess demand curve in a sense substitutes for the source of the instability as a major determinant of the distributional effects of price stabilization.

Table 1 presents some of the results from the effects of price instability in a trading context when non-linearity and multiplicative disturbances are considered. Note that the strong conclusion is supported which is that importers prefer price stability and exporters generally do not. Also, although some of the results are inconclusive, an interesting distributional effect is apparent. Producers in both importing and exporting countries prefer instability while
Table 1: International Price Stabilization: Who Gains and Who Loses in Polar Cases of Nonlinearity

<table>
<thead>
<tr>
<th>Impact Group</th>
<th>Country 1 (exporter)</th>
<th>Country 2 (importer)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Extreme Nonlinearity</td>
<td>Linearity</td>
</tr>
<tr>
<td></td>
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<tr>
<td>Country 1</td>
<td></td>
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<td>Producers</td>
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<td>?</td>
</tr>
<tr>
<td>Consumers</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
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<tr>
<td>Country 2</td>
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<td>Producers</td>
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<tr>
<td>Country</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>World</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Supply Fluctuations in Country 1

<table>
<thead>
<tr>
<th>Impact Group</th>
<th>Extreme Nonlinearity</th>
<th>Linearity</th>
</tr>
</thead>
<tbody>
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<td>Country 1</td>
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<td></td>
</tr>
<tr>
<td>Producers</td>
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<td>?</td>
</tr>
<tr>
<td>Consumers</td>
<td>+</td>
<td>?</td>
</tr>
<tr>
<td>Country</td>
<td>-</td>
<td>?</td>
</tr>
<tr>
<td>Country 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Producers</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Consumers</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
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<td>+</td>
</tr>
<tr>
<td>World</td>
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<td>+</td>
</tr>
</tbody>
</table>

Supply Fluctuations in Country 2

<table>
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<th>Impact Group</th>
<th>Extreme Nonlinearity</th>
<th>Linearity</th>
</tr>
</thead>
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<tr>
<td>Country 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Producers</td>
<td>-</td>
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<td>Consumers</td>
<td>+</td>
<td>?</td>
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<td>Country</td>
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<td>?</td>
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<tr>
<td>Country 2</td>
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<tr>
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<td>Country</td>
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<td>+</td>
</tr>
<tr>
<td>World</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

a + indicates a gain; - indicates a loss; 0 indicates no impact; and ? indicates uncertain.

b Country 1 is the exporter and Country 2 is the importer.

consumers in both prefer stability. In this regard, the preference for stability by consumers in importing countries is stronger than for consumers in exporting countries.

A Utility-Maximizing Approach

The Waugh and Oi analysis outlined earlier have been generalized by Hanoch to a multicommodity situation. In generalizing the Waugh approach, the benefits are included in terms of a concave (or convex) utility function, rather than in terms of consumers' surplus. Turnovsky, Shalit and Schmitz, also using the indirect utility approach, show under what conditions the Waugh proposition holds. They derive the following expression:

$$\text{sgn} \left( \frac{\partial^2 V}{\partial P_1^2} \right) = \text{sgn} [s_1 (n-r) - e]$$

(1)

where $P_1 =$ random selling price of good 1

$V =$ indirect utility function

$r = \frac{\partial^2 V}{\partial V/\partial M} = \text{coefficient of relative risk aversion}$

$s_1 = P_1 C_1 / M =$ share of consumer's budget allocated to good 1

$e =$ own uncompensated price elasticity of demand for good 1

$n =$ income elasticity of demand for good 1.

It follows that the desirability of price instability depends on the share of the consumer's budget allocated to the commodity. Also, the desirability of price stability decreases with the magnitude of the price and income elasticities but increases with the coefficient of relative risk aversion. While it is possible for $\frac{\partial^2 V}{\partial P_1^2} < 0$ (in which case Waugh's proposition does not hold), Turnovsky et al. use empirical evidence to suggest that $\frac{\partial^2 V}{\partial P_1^2} > 0$ in which case the Waugh
proposition holds true. (Note that Dunn and Heien also found this to be true in the translog approach).

Schmitz, Shalit and Turnovsky also applied the above framework to a multi product firm case in which they express producer's utility in terms of the prevailing input and output prices. They develop the following criterion.

$$\text{sgn} \left( \frac{\partial^2 V}{\partial P^2_j} \right) = \text{sgn} \left( \left( \frac{\mu}{1+r} \right) \frac{\varepsilon_j}{a_j} - r \right),$$  \hspace{1cm} (2)

where $\varepsilon_j = \frac{\partial Y_j}{\partial P_j} \frac{P_j}{Y_j}$, price elasticity of supply

$\gamma = -\frac{\pi u''}{u'}$, Arrow-Pratt measure of relative risk aversion

$\mu = \text{profit margin as measured by profit to cost ratio}$

$a_j = \text{total revenue contributed by good } j$.

In the single product case (not shown in (2), $a_j$ not present), if firms are risk-neutral $\frac{\partial^2 V}{\partial P^2_j}$ depends solely on the slope of the supply curve. As long as it is positive, Oi's result holds. This result that producers prefer price instability will, of course, continue to hold if firms are risk-takers ($r < 0$). However, if $r > 0$ the result may cease to apply. As the degree of relative risk aversion increases, so does the firm's preferences for stability-over instability.

For the multiproduct firm (2) applies since unlike for the single produce case the term $a_j$ is added. Whether or not a firm prefers price instability with respect to a single good of the many it produces depends in addition to the determinants in the single good case the total revenue contributed by this good. A risk-averse firm may prefer instability in some of the markets for its products and not
in others. However, as (2) shows the firm is likely to prefer price instability in those goods that contribute relatively little to its total revenue.

In a different framework Newbery and Stiglitz (1981) also discuss the implications of price stabilization when more than one product is considered. They argue that price stabilization for one of the products may increase income risk. "If the farmer is widely diversified and the income variability from the crop were uncorrelated with his other sources of income, then the variability in this source of income has a negligible effect on the welfare of the individual... For crops whose return is negatively correlated with income from all sources in the aggregate, the reduction in income variability would actually increase total income risk and hence have a deleterious effect on welfare." p. 27

Formation of Expectations

The above models generally assume that producers ex ante price and quantity expectations are actually realized. This essentially assumes that they have perfect foresight. Turnovsky (1974) relaxed this assumption and analyzed this effects of price stabilization for two different price expectation formulations: Adaptation Expectations and Rational Expectations.7

7 Consumers are still assumed to make their decisions on the basis of actual prices. These models are spelled out in more detail in Turnovsky (1978), pp. 119-48.
(a) **Adaptive Expectations**

In the adaptive expectations framework supply decisions are based on anticipated prices as follows:

\[ S(P_t^*) = B + bP_t^* + V_t \quad b \geq 0 \]  

where \( P_t^* \) denotes the selling price producers expect at time \( t \). With adaptive expectations the equation becomes:

\[ P_t^* - P_{t-1}^* = \gamma (P_{t-1} + P_{t-1}) \quad 0 \leq \gamma \leq 1 \]  

The change in expectations equals some fraction of the previous periods forecast error, where \( \gamma \) describes the rate of adaptation.

The expected gains for producers from stabilization (\( G_p \)) are given by the expression:

\[ E(G_p) = E[(P_s - P_t^*)[S(P_s) - S(P_t^*)]] - E[(P_t - P_s)S(P_t^*)] \]  

Turnovsky has shown that as with the previous models overall welfare is increased with stabilization even though one group may be hurt. However, the Oi conclusions that producers prefer price instability due to demand fluctuations no longer holds. Whether they prefer price stability depends on the relative slopes of the demand and supply schedules, on the auto-regressive properties of the random disturbance, and on the length of lag in the formation of expectations. However the Waugh proposition that consumers are hurt by having prices stabilized in the face of supply fluctuations still applies.

(b) **Rational Expectations**

The hypothesis of rational price expectations can be stated as:

\[ P_t^* = E_{t-l} (P_t^*) \]  

where \( E \) denotes conditional expectations at time \( (t-l) \).
Equation (6) asserts that the forecaster's predicted price for period $t$ should equal the price predicted conditional on all the information at time $(t-1)$ when the forecast is made. From the formulation Turnovsky derived qualitative conclusions similar to the Massell's perfect flexibility model.

1. The total gains from price stability are always positive.
2. Consumers lose from price stabilization if the source of the instability is due to supply shifts.
3. Producers lose from price stabilization if the source of the instability is random shifts in demand provided that these random disturbances are autocorrelated.

From the above, it is clear that whether or not the Oi proposition extends to firms that base their supply decisions on expected prices depends critically on how their forecasts are generated. Also the total gains from stabilization which is based on a model that assumes rational expectations are at least is great as those obtained when the firm has perfect flexibility. However, one cannot deduce anything definite about the comparative gains under rational versus adaptation expectation schemes.

Also using a rational expectations framework Subotnik and Houck compared the benefits from mean price stabilization to those of alternative schemes that stabilize production and consumption at their respective means. Depending on certain parameters, the expected total gains from supply stabilization may be greater or less than those from price stabilization. In either case, the gains exceed those from demand stabilization. Also they consider the variance of changes in government stocks associated with each of three different schemes.
The larger the variance in stocks the more the government must hold in order to operate the buffer stock. For each scheme the variance of the change in government stocks is proportional to expected social gains. Subotnik and Houck show that the storage costs involved can be ranked in the same order as the expected gains from the various stabilization schemes. Thus the more beneficial the scheme the higher is the cost.

**Price Instability, Storage and Food Security**

The studies surveyed to this point do not explicitly deal with food security or the impacts of instability and storage on vulnerable groups in the world's population. The following studies focus on grain reserves as a means to assure global or food security by less developed countries.\(^8\)

A set of papers on this issue were conducted by economists at M.I.T. Sarris and Taylor (1976) argue that conceptually the emergency

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\(^8\) The Waugh theorem is highly questionable for people who are poor and spend a large share of their income on food. If at the low price in the model people could only buy sufficient food to meet nutritional needs what happens at the high price? In terms of purchasing power at this price malnutrition has to result. Waugh was clear that his model doesn't necessarily apply to the poverty and malnutrition cases since his theorem is true only if the consumer can adjust his expenditure among the n periods. Also using consumer surplus is a measure of rising price on demand and hence malnutrition can create problems if not done carefully. As Bigman notes: "In a more relativistic world there is no way for us to measure the total welfare losses caused in times of supply shortfalls and high prices, because there is no way for us to measure the damage caused by malnutrition or the loss of human life caused by starvation", p. 78. Willingness to pay measures of which consumer surplus is an approximation may be difficult to obtain when there is a wide discrepancy between willingness to pay and what a consumer can actually pay.
and food aid problems must be separated from price stabilization. Based on net cereal imports, an annual food aid commitment of 5 million tons would help maintain nutritional standards but an annual flow of 10 million tons of critical aid would be more realistic. This commitment should be made in physical and not value terms. They argue that quantities allocated for emergencies or food aid are net drains on the resources of a reserve while buffer stocks for price stabilization are released in shortfall periods but replenished in surplus times.

Taylor, Sarris and Abbott evaluate price-stabilizing buffer stocks through foreign exchange gains and losses from stabilization. They show that the U.S.S.R. could save $1 to $2 billion in foreign exchange from stabilized prices while the major exporters would lose. Most wheat importing countries, especially less developed ones, would also gain. They also show how a grain buffer stocks could provide order and effectiveness to international efforts for famine relief. The actual magnitude of required relief efforts is small and this would only have a minimal impact on the grain buffer stocks or the world market in general. They suggest a guaranteed flow of funds to a relief agency which would use the world market, shipping facilities and the storage from a price-stabilizing grain reserve. Grain reserves must be viewed as supporting food aid, but aid of a special kind: its destinations will vary from region to region and from time to time.

The work by Sarris, Abbot and Taylor draws partly on the above two

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9 Additional material on this subject is contained in Huddleston et al. *International Finances for Food Security.*
studies. They distinguish between "food aid", "emergency relief" and "stabilization". They conduct a simulation analysis for wheat and for feed grains. As an example, one of their figures shows how foreign exchange earnings are a function of the width of the price band. They also calculate the effect of a buffer stock on consumer and producer surpluses. An example for feedgrains is given in Table 2.

<table>
<thead>
<tr>
<th></th>
<th>Change in Consumer Surplus ($ billions)</th>
<th>Standard Deviation</th>
<th>Change in Producer Surplus ($ billions)</th>
<th>Standard Deviation</th>
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<td>-0.000</td>
<td>0.002</td>
<td>0.001</td>
<td>0.003</td>
</tr>
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</table>

Note: Estimates of surpluses and standard deviations are calculated across 200 Monte Carlo simulation runs. The buffer stock capacity is 10 mmt, and the price band is (93.1, 130.0).

Source: Sarris, Abbott and Taylor.

10 Various stock rules have been worked out by Newbery and Stiglitz (1981) including one for famile relief (p. 416). They specify a famine utility function and postulate optimal storage strategies.
They go on to incorporate emergency relief and argue that it should be viewed as a flow not a stock. They suggest a famine relief fund and its purchasing power would increase with the existence of a stabilization reserve. In addition, part of the stabilization reserve itself could be purchased at low prices by the famine relief authorities. An international price-stabilizing reserve could make famine relief a much more orderly and effective operation. Emergency stocks have to be viewed as a special kind of food aid. They show that the yearly magnitude of a reserve for emergencies is extremely small relative to world production and trade. They also provide an excellent discussion of the interrelationships of food aid, emergency relief, and a price-stabilization buffer stock. Also they examine in detail the food security proposals which followed the 1972-74 grain crisis. They discuss the economic and political obstacles to agreement on food aid emergency relief and price stabilization. The gainers and losers from price stabilization have been shown in the previous section. They conclude by showing the needed reserves for price stabilization, emergency relief and food aid. The wheat reserve could be less than 15 million metric tons while the emergency relief would be much smaller—one million metric tons per year. In general, they argue that food aid should be phased out and replaced by general economic assistance.11

In a World Bank study, Reutlinger (1976) used a simulation model for evaluating worldwide buffer stocks of wheat where food aid requirements were explicitly considered. Reutlinger contends that a

11 The interested reader should also refer to works by Taylor (1978) and Sarris (1980, 1981).
policy which aims at assuring food aid at a given level when needed and at the least possible cost would not separate food aid stocks from other stocks. With such a food aid objective the holding of large stocks is desirable and the value of these stocks would be higher. He shows the additional gains and losses from storage attributable to the change in the demand function resulting from food aid. The additional economic benefits are sufficient to turn a net loss from storage (without food aid) at almost any level to a net gain for as much as 30 million tons of storage capacity. Also there is a large effect of storage on consumer gains and producer losses. Without storage the added demand generated by food aid during shortages causes steep price rises; consumers (in the commercial market) register large losses while producers make large gains from the added demand for food aid. In essence storage reduces the cost of food aid.\textsuperscript{12}

Studies by the International Food Policy Research Institute have also addressed the issue of food security for LDC's. A food insurance scheme was analyzed using an economic simulation model by Konandreas, Huddleston, and Ramangjura. The scheme was designed to stabilize consumption and grain import costs for LDC's. The scheme could operate as an international financing program or as a combined financing and grain reserve program. Large reserves increase the probability that LDC's can obtain grain when needed to keep supplies from

\textsuperscript{12} The book edited by A.H. Chisholm and R. Tyers, Food Security: Theory, Policy, and Perspectives from Asia and the Pacific Rim contains many interesting chapters on food security, some of which are not reviewed here. Those who are especially interested in food security issues for specific regions should read this volume. To give the readers some scope of the regions covered, Ederisinghe deals with Sri Lanka, Dixon and Tyers with India's food security and Yamada focuses on food security in Japan.
falling below 95 percent of their trend production. A 20 million ton reserve is recommended to be combined with a compensatory financing program.

Recently, Valdés strengthens the argument put forward by Reutlinger (1977) that the problem of instability for LDC's is the resulting fluctuation in real income within the country. Clearly food prices abroad could be stabilized even though internally domestic incomes could be depressed by droughts or whatever which reduces their purchasing power even though world prices may not have risen. The standard solution is to hold assets in the form of food stocks themselves. Valdés argues as did Reutlinger that an alternative and generally less costly strategy is to hold foreign exchange reserves to import more food in the lean periods. The foreign exchange available to import food appears to be the most critical factor to stabilize food consumption. Valdés presents data (Table 3 below) on food imports and balance of payments (i.e. the average ratio of the food import bill to total export revenues from goods and services). The higher the food import bill relative to the supply of foreign exchange the more severe the food import problem is. Table 2 shows that for 10 of the 18 countries the mean ratio is high suggesting a "severe constraint."

Valdés presents data (Table 4 below) also on the foreign exchange cost of the "excess food import bill" relative to the supply of foreign exchange. Note that the extra cost represents 10 percent and sometimes as high as 20-30 percent of the supply of foreign exchange. This is over and above the trend value of cereal imports in those years and represents a short-run unexpected excess demand for foreign exchange. Valdés uses these and other data to show that world price
Table 3: Ratio of Gross Food Imports to Total Export Revenues

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<tr>
<td></td>
<td>(Percent)</td>
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<tr>
<td>ASIA</td>
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<tr>
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<td>n.a.</td>
<td>67.0</td>
<td>104.9 (1975)</td>
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<tr>
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<td>36.9</td>
<td>40.4</td>
<td>39.4</td>
<td>57.4 (1975)</td>
</tr>
<tr>
<td>India</td>
<td>40.2</td>
<td>12.7</td>
<td>19.4</td>
<td>43.4 (1967)</td>
</tr>
<tr>
<td>Indonesia</td>
<td>7.6</td>
<td>14.9</td>
<td>7.6</td>
<td>18.5 (1970)</td>
</tr>
<tr>
<td>Philippines</td>
<td>10.4</td>
<td>8.6</td>
<td>6.0</td>
<td>12.9 (1967)</td>
</tr>
<tr>
<td>NORTH AFRICA/MIDDLE EAST</td>
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<tr>
<td>Somalia</td>
<td>n.a.</td>
<td>24.4</td>
<td>52.1</td>
<td>67.0 (1977)</td>
</tr>
<tr>
<td>Egypt</td>
<td>n.a.</td>
<td>19.3</td>
<td>34.1</td>
<td>46.0 (1975)</td>
</tr>
<tr>
<td>Jordan</td>
<td>n.a.</td>
<td>43.7</td>
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<td>n.a.</td>
<td>25.4</td>
<td>16.7</td>
<td>34.3 (1971)</td>
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<tr>
<td>SUB-SAHARAN AFRICA</td>
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<td>Mali</td>
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<td>21.0</td>
<td>27.9</td>
<td>112.7 (1974)</td>
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<tr>
<td>Senegal</td>
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<td>21.2</td>
<td>17.1</td>
<td>33.5 (1973)</td>
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<tr>
<td>Upper Volta</td>
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<td>11.1</td>
<td>13.8</td>
<td>23.5 (1974)</td>
</tr>
<tr>
<td>Tanzania</td>
<td>n.a.</td>
<td>7.1</td>
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<td>29.3 (1974)</td>
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<tr>
<td>LATIN AMERICA</td>
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<tr>
<td>Haiti</td>
<td>16.9</td>
<td>15.1</td>
<td>29.8</td>
<td>33.9 (1979)</td>
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<td>18.3 (1975)</td>
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<td>Chile</td>
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<td>11.8</td>
<td>11.7</td>
<td>24.1 (1974)</td>
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<td>Brazil</td>
<td>11.6</td>
<td>6.2</td>
<td>5.7</td>
<td>13.5 (1967)</td>
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</table>

Note: Gross food defined to include cereals, meats, dairy products, fruits and vegetables, sugar, pulses, root crops, oilseeds and vegetable oils, cocoa beans and derivatives. Total exports defined to include total merchandise and service exports plus net private unrequited transfers.

Source: Valdés (1982).
Table 4: The Foreign Exchange Cost of the Excess Food Import Bill  
(expressed as a percentage of the supply of foreign exchange*)

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<td>23.7</td>
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<td>17.0</td>
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<td>17.0 (1975)</td>
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<td>1.8</td>
<td>3.0</td>
<td>1.7</td>
<td>0.9</td>
<td>3.4 (1974)</td>
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<td>Upper Volta</td>
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<td>10.4</td>
<td>12.2</td>
<td>5.0</td>
<td>12.4 (1974)</td>
</tr>
</tbody>
</table>

* The supply of foreign exchange is defined to include total export receipts plus private unrequited transfers and plus net capital inflow. Food defined to include cereals, meats, dairy products, fruits and vegetables, sugar, pulses, root crops, oilseeds and vegetable oils, cocoa beans and derivatives.

Source: Valdés (1982).
stabilization schemes can help mitigate food insecurity but alone it is insufficient.

On the issue of food aid it is often unresponsive to widespread production shortfalls. The volume is often reduced in years of higher world prices when aid is most needed. Valdés contends that what is needed is a financial facility which provides foreign exchange on years when food imports exceed their trend level.\textsuperscript{13}

Reutlinger's (1982) argument runs along lines similar to those put forward by Valdés.\textsuperscript{14} Food-grain consumption in developing countries was unstable in the 1950's and 1960's in spite of relatively stable world-market prices. Hence a stable world price provided little insurance against food insecurity. In this context Reutlinger contends that: "The major cause of consumption instability was instability of production in the developing countries and not unstable external supplies or prices. Imports were not used more aggressively to compensate for the inherent instability in production of individual countries probably for the following good reasons: balance-of-payments problems, instability in demand caused by instability in consumers' incomes, inadequately flexible distribution

\textsuperscript{13} In a study, McIntire compares the cost and benefits for seven countries in the Sahel from three policy systems: variable levies on grain imports, security stocks of grain, and foreign exchange assistance. The study shows that the three policy instruments are complementary thus the cost of providing food security to the Sahel can be greatly reduced through a combination of policies. Also an important finding is that the foreign exchange costs of relying solely on grain reserves are far higher than the costs of financial assistance schemes.

\textsuperscript{14} There are several other papers on this subject. See; Reutlinger (1978), Rojko, Sanderson 91975, 1977). Reutlinger et al. (1976, 1981), Bigman et al. (1978, 1979) and Pistrup. Anderson et al.
channels and transportation and port handling facilities." p. 23 He concludes through the use of a simulation model, that the removal of trade and market-demand constraints are likely to be more effective and less costly than buffer stocks for eliminating temporary and periodic shortfalls in consumption. In addition financial insurance schemes would greatly reduce the effect of unstable food import bill, by less dependent countries.

The impact of trade policy itself on food insecurity has been determined by Bigman (Figure 13). This work first started with Bigman and Reutlinger (AJAE, 1979, AER, 1979). It is clear that more liberalized trade leads to greater food security than does protectionism. Thus trade liberalization itself can reduce the need for holding strategic reserves.

FIGURE 13

Source: Bigman (1982).
Instability, Inflation and Economic Development

A shortcoming of the standard price stabilization models is that they do not analyze the impact price increases may have on inflation. As Adams and Behrman state: "A boom may add to aggregate-demand inflationary pressure, add to cost-push wage pressures by permitting more easy pace setting wage increases in the primary production sector, and reduce cost-push or structural devaluation inflation by increasing the availability of foreign exchange." p. 28 Clearly, a bust would tend to work in the opposite direction. In terms of examples, clearly the oil and grain price boom in the early 1970's added to the existing inflation which generated many interesting changes. As an example raising grain prices and the rising inflation triggered off a phenomenal rise in the real price of farmland in the North American region the effects of which have not been fully analyzed.

The recent book by Adams and Behrman adds an additional important aspect to the price stabilization literature. They explore in depth the relation between primary commodity markets and economic goal attainment in developing countries. The empirical part of the book assesses the impact of fluctuating coffee and copper prices on nine quite different developing countries. This is due for both price fluctuations and secular price movements. The attainment goals specified are: (1) increases in per capita income, (2) distribution of income wealth and economic power, (3) utilization of production capacity and cyclical stability in real output, (4) price or nominal

---

15 The reader interested in the impact of price stabilization on export earnings should read the papers by Nguyen (1979 and 1980).
stability and (5) international economic position.

The authors develop an integrated econometric approach to the commodity problem and economic development. They develop first a macro econometric model for nine countries and embed in each of these a primary commodity sector micro model for coffee and copper. These combined models are then integrated with econometric models of internationally traded goods specifically copper and coffee. An analysis is then made of the impact of fluctuating copper and coffee prices on the five goals outlined earlier. They show how the instability effects are spread over several years and demonstrate intracyclical dynamics. Whether instability is good or bad depends on the weights attached to various economic goals in the appropriate welfare function. The authors also show the dynamic effects resulting from a sustained price increase or decrease in copper and coffee prices. The impacts are found to be more complex than for mere price fluctuations. Various impacts cannot be considered independently of the producer country's policy responses. These include tax rate changes, buffer stocks programs and export tax schemes.

Public Storage, Private Storage and Futures Markets

In the previous models, who actually holds the stocks to bring about price stabilization is not spelled out explicitly although it is generally implicit that governments do the actual storing. However, Gustafson, Sarris, Gardner (1979), Newbery and Stiglitz (1981) and Lutz point to a finding that has significant implications for public policy. This finding is that a private storage industry with many traders could carry socially optimal stocks and that in the presence
of such private storage public stocking intervention will be completely ineffective. Only in the presence of a less than one-to-one trade off in private for public stocks can the case for public intervention be made. A related issue as to how the private trade reacts to government stockpiling appears to be unresolved (Stein et al.). But if the private trade reduces carry-over stocks by as much as the public authorities' stockpile, then there is no extra price stability induced by government intervention.\(^{16}\)

Recently Peck uses the "supply-of-storage" theory developed by Working (1948, 1949) and later by Brennan to test the trade-off between public and private stockholding. This theory postulates a positive relationship between the price of storage (a discounted, expected future price minus the current price) and the quantity stored. Peck shows that the substitutability between private and public stocks is much less than one to one.\(^{17}\) In a different but related study, Sharples and Holland used the supply-of-storage theory to determine the impact of the U.S. farmer owned reserve on privately owned wheat stocks. They hypothesized that wheat held in the farm held reserve substituted for wheat which would have been otherwise held privately by farmers. They separate pipeline stocks (stocks held

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\(^{16}\) It was shown earlier that which of the agents hold stocks can have a markedly different effect on income variability even though their effect on price stabilization may be the same, an important point which seems to have been neglected in the literature. Private stockholding by producers will tend to bring about both price and producer income stability while government stockholding by itself will bring about price stability but income instability can result which can be greater than if no storage was undertaken by the public and/or private.

\(^{17}\) Peck found a negative coefficient of only \(-.12\) between U.S. private owned wheat stocks and government owned year-end stocks.
by processors and traders that are normally hedged on the futures market) and speculative stocks. Most of the latter appear to be unhedged stocks owned by wheat producers. Sharples and Holland found the interesting result that the farmer held reserve did not substitute for otherwise private stockholding. They found that the two can be complementary in that an increase in the demand for private stockholding can be positively related to the increase in the demand by the farmer held reserve.

Sarris attempts to answer why there is not a one-to-one tradeoff between public and private stockholding and why private stockholding only can yield non optimal results. Some of the factors are different private discount rates, different marginal variable storage costs, risk aversion and different information sets. Sarris derives the following important propositions:

(1) If private storage firms are large in number and have information equivalent to that available to society then aggregate private carry-over is equal to the socially optimal one.

(2) In the presence of a risk-averse private storage industry the trade-off between public and private storage is less than one. It follows that if the storage industry consists of many traders public stockpiling with a known role will have no effect upon total carry-over.18

(3) When the public storage is less than socially optimum then the aggregate stocks are less than the socially optimum. Unless the public sector takes over all of the storage the mixed performance

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18 Sarris shows that if public stocks are larger then the socially optimal land, the private trade carries no stocks.
of private and public sectors together is less than optimal.

(4) In the presence of a public policy rule that is uncertain rather than certain, to achieve the same level of total stocks requires a larger public carry-over (i.e. if government policy is unpredictable at most denote more resources to achieve the same level of optimality).

Helmberger and Weaver also develop a model where private storage activities are incorporated. In their model production and storage decisions respond to rational expectations of uncertain prices. They assume a competitive storage industry and show how benefits and costs to various groups are affected by alternative programs. To find the competitive level of storage they derive a supply and demand function for storage (Competition pushes storage to the level where expected profit is driven to zero). They find that: (1) a competitive storage industry does not prevent large swings in grain prices, (2) differences between expected and actual prices are much greater in the absence of competitive storage, (3) producers can gain from the existence of a competitive storage industry though not necessarily so, (4) buyers may or may not gain from competitive storage.19

Helmberger and Weaver show the effects of three different government stabilization programs: (1) complete price stabilization, (2) partial price stabilization, and (3) stabilization of quantity purchased. In comparing complete price stabilization by government versus competitive storage they show that the transfer to producers from buyers under the former can be quite significant. For partial

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19 Points (3) and (4) are within reference to zero storage levels.
stabilization producers gain, consumers lose and economic efficiency is decreased. They also show that quantity stabilization schemes may not be feasible in a free market economy. They conclude that competitive storage leads to the maximization of net benefits. But competitive storage is consistent with wide price fluctuations and significant differences between expected and realized prices. They contend that market failure might provide a rationale for government intervention to stabilize prices. However, they point out that this argument had not been used by others to justify a price stabilization policy. For example, Cochrane and Danin appear to accept price stabilization as an ultimate policy goal requiring no further analysis of the linkages between the degree of price stability and the welfare consequences.

For many commodities futures markets exists. Therefore, their role in stabilizing prices has to be taken into account. A deficiency of the stabilization literature is that it focuses on spot prices and ignores the role of futures markets. Turnovsky (IPE 1978) addresses this issue and assumes that the futures price equals the statistical expectation of the spot price which will prevail at the maturity of the contract. If futures market do indeed stabilize spot prices significantly (a highly debatable subject), then the introduction of futures markets may be an effective and certainly cheaper alternative to buffer stocks stabilization. Turnovsky demonstrates the following: (1) the introduction of futures trading tends to stabilize spot prices where no private storage takes place. (2) the choice will generally be true even in the presence of private storage.
(3) producers gain from futures, consumers lose and there are overall society benefits.20

(4) A conventional buffer stock stabilization scheme will generally yield a larger increase in surplus gains than will a futures market which provides only partial price stabilization. However, given the relative costs of the two, futures markets may be preferred.

(5) the introduction of private storage in the presence of an already existing futures market improves the overall welfare of society although the benefits to the various groups is indeterminate.

(6) information is an important stabilizing device and thus efficient futures are stabilizing. Thus, for futures versus government stabilization by some intervention rule, if the authorities have to operate on the basis of past information, their intervention will never improve upon the performance of an efficient futures market.

Sarris (1982) extended the Turnovsky analysis and concluded that:

(1) futures trading coordinates and facilitates the carrying of speculative stocks across different production periods, (2) with rational expectations futures market tend to stabilize cash prices and (3) the use of futures prices by producers for planning production is always stabilizing.21

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20 This is the Massell result when instability is due to supply fluctuations.

21 For additional excellent studies on the implications of futures markets in the presence of buffer stocks, see Peck, McKinnon and Newbery and Stiglitz (1981).
Supply Response and Risk Preferences

In the standard surplus models reviewed the assumption of risk neutrality is made. However, what if producers are risk averse and they face uncertainty? It is argued that if price stability can be attained generally risk can be greatly reduced. As risk is reduced, risk-responsive producers may increase supply; as a result, both producer and consumer welfare may increase by more than the standard Massell risk-neutrality assumptions would indicate. Once risk is taken into account, estimates of gains from stabilization may be seriously biased and any efforts to determine an optimal stabilization policy—for example, a normal price about which to stabilize—may be in vain when risk preferences and responses are not considered.

The topic of welfare measurement for producers operating with risk has been addressed in the context of stabilization policy by Just (1975) and by Just and Hallam. Changes in welfare are adequately reflected by changes in the area above the supply curve and below price if a producer's economic welfare depends linearly on expected profits and the variance of profits. With risk, however, the relevant supply curve depends on expected price (possibly a function of lagged prices) and the subjective variance of price (also possibly determined by previous experience). Specifically, consider the risk-neutral supply curve or certainty supply curve S in Figure 14. Now suppose

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22 Or, alternatively in the case of grain supply, acreage can be specified as depending on the subjective mean and variance of returns per acre. Such a specification automatically corrects for any correlation between prices and yields which may otherwise have differing implications for income stability when price is stabilized. That is, due to negative correlation between price and average yield, price stability may actually destabilize income; if so, this would be appropriately reflected by returns per acre.
that the introduction of a given amount of price risk causes the producer to contract production so that supply shifts to $S^*$. The results by Just and Hallam show that the appropriate curve to use in measuring economic welfare effects for the producer is the curve $S^*$ which holds the amount of risk constant. Thus, the surplus area which reflects economic welfare under risk is area $a + c$ at expected price $p'$. Under risk neutrality or certainty at $p'$, the supply curve $S$ would imply real income of area $a + b + c + d + e$ so the real income loss associated with price uncertainty is area $b + d + e$. Of course, if the risk response from $q$ to $q'$ associated with price stabilization is ignored, then the associated real income benefits of area $b + d + e$ would be ignored. Thus, Just and Hallam argue that the identification of significant risk preferences as evidenced by risk-responsive decision may be crucial in justifying a price-stabilization policy.
The issue of price stabilization under uncertainty has also been dealt with by Berck and Schmitz. They show explicitly that, if producers are risk averse and they operate under conditions of uncertainty, the standard Massell-Turnovsky result, does not hold. The reduction of uncertainty triggers a net positive supply response which has to be taken into account in managing a buffer stock.\textsuperscript{23}

An excellent book on the subject, \textit{The Theory of Commodity Price Stabilization: A Study in the Economics of Risk} has been recently published by Newbery and Stiglitz.\textsuperscript{24} Some of their results have already been referred to. They find generally that if price stabilization is to have a significant impact, it has to be on its effects through risk reduction. That is, the efficiency gains from stabilization because of supply response far more than outweighs the distributional and net effects modelled by Massell. This is also supported by Bigman. In the cases where price stabilization does not reduce risk or producers are risk takers, its net welfare effect can be relatively small and even negative.

\textbf{Multiple Policy Instruments and Goals}

Often price stabilization through storage is not undertaken merely

\textsuperscript{23} The issue of instability with uncertainty has also been dealt with by Just, Huet and Schmitz in the case where attitudes toward risk are not explicitly considered. Producers determine quantity before price is known. They show that expected quasi-rent under instability is exactly the same as if prices were stabilized at their mean. However, expected welfare quantities are generally not the ones actually realized.

\textsuperscript{24} Newbery and Stiglitz (1979) also present an excellent discussion on commodity price stabilization rules. Also see Hazell and Scandizzo for optimal price policies under risky production.
for the purpose of stabilizing prices or producer's income. As Gardner (1979) points out: "The inherent difficulty of operating a buffer-stock regime can be amplified by a tendency to tailor price bands to goals other than stabilization, such as farm-income support (leading to upper limits on stocks which are too large coupled with acquisition prices which are too high) or minimizing budget costs (which leads to a preference for production controls over the costs of carrying large stocks over a period of years)." p. 158 Gardner's simulations show that: "even when production deviations and random demand shifts are serially independent, it is not uncommon to find runs of several years during which carryover stocks are continually above the mean stock level." p. 158

A model which incorporated at least two policy instruments together was developed by Bieri and Schmitz (1973) in the context of trade where an importer pursued optimal tariff policies in conjunction with storage. Storage added gains on to those already achieved through tariffs. Also Bigman in a recent book has examined the role of buffer stocks when internal price policies are already in place. "The presence of internal price policies dramatically changes the role and effects of buffer stocks. When, for instance, a procurement program is in operation, most of the storage activities are automatically carried out through it. A storage facility is then only an instrument of the procurement policy, and the stock policy is meaningful only to the extent that it changes rules of intervention defined by the price band." pp 246-247. In addition Bigman shows that "the larger the independent stabilizing effect of the support program the smaller will be the added stability achieved through buffer stocks
and the more rapid will be the decline in the marginal productivity (expressed in terms of the stabilizing effects) of additional storage units." p. 216

The welfare implications of a combined stocks and price support system have been shown by Berck and Schmitz. Several models are developed along the lines of the one which follows. In Figure 15 price fluctuations, in the absence of storage and government price supports, are $P_1$ and $P_2$. With storage, a stable price $\bar{P}$ could be obtained. It is easy to see why from the model producers can prefer price instability to stability through storage if in fact the government uses price supports to prevent producer prices from falling to $P_1$ in the abundant supply period. Clearly if government for example sets the support price at $P_s$ for producers and allowed the market to clear by charging price $P_1$ to consumers, producers would prefer price instability to stability. This is opposite to the result one would derive using the Massell model. However, in the Massell model the only policy instrument is storage. In Figure 15 to this point the comparison is between storage versus no storage and price supports.

FIGURE 15
One can combine price supports and storage in this type of model. These two generally go hand in hand. That is, to deal only with storage excluding price supports, and/or loan rates is unrealistic in some cases. For example the U.S. Food and Agriculture Act of 1977 has as its cornerstone a "loan rate" coupled with a "farmer-owned reserve". The latter is basically a subsidy program for on-farm storage. To illustrate the combined effects of price supports and farmer held reserves, a government storage subsidy for producers of the cross-hatched area \( Q_1Q_s \) is introduced. This storage will be released by producers in period 2 and will cause prices to be \( P_2^{1} \) instead of \( P_2 \) in that period. Because of the inelastic demand total revenue will decrease when the stocks are released. However, if the price support \( P_s \) is maintained even though it is on a smaller output \( Q \) it is apparent why producers prefer price instability along with price supports, and farmer held reserves to stability brought about only with reserves. In the model this result holds since:

\[
2(P_2^{1}Q_2^{1} + P_sQ_s) + T(Q_sQ_1) \]

Apart from many other implications which can be drawn from the above model it is apparent why farm groups generally prefer price instability to stability—opposite to the Massell result. This is because price supports or some such device are used along with storage to enhance farmers income—not merely stabilize it. As Figure 15 shows, price supports, in essence chop off the part of the price distribution containing the low prices.

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25 Clearly producers are worse off with farmer held reserves and a support price \( P_s \) on output \( Q_s \) than if \( P_s \) applied to \( Q_1 \) where farmer held reserves are absent.
Nonstorable Goods

The major emphasis in the stabilization literature is on storable commodities. However, stabilization schemes also exist in various parts of the world for nonstorable goods. Price stabilization schemes exist, for example, in the production of beef, pork and mutton. Unfortunately detailed studies are not available which have analyzed the purpose of these schemes, how they are managed and their effect on producer response through the reduction of risk. Figure 16 is presented to highlight what such a scheme might do and how it can run into difficulty. The model also supports the contention by Newbery and Stiglitz that if efficient risk sharing apparatus are available along with properly functioning credit markets, the need for stabilization programs is greatly reduced.

The example used in Figure 16 applies to a now storable good such as beef cattle. Suppose actual market prices move above and below some price $p$ and because of this instability producers pressure government into enacting a "beef stabilization scheme". Suppose the board in charge determines that such a program can be made actuarially sound by using a cost of production formulae. In the model the program is actually sound if price $\bar{p}$ which is received by the producers covers the cost of production; at price $\bar{p}$ the net pay out by the government for running the program is zero since over time the government payout $a + c$ is equal to the tax on producers $b + d$. However, what happens if cattle prices fail to rise but production costs rise. Suppose the rise in costs has the board set $p^1$ to producers. Clearly in this case the beef producers are never taxed
and the government runs a deficit in supporting the beef stabilization program (i.e. the program is no longer actually sound).

The model in Figure 16 raises some interesting points. If the program is actuarially sound in that the net government outlay for the program is zero why would producers want it? In a different context as Newbery and Stiglitz point out, if active futures and credit markets exist the need for such a scheme is greatly reduced if the intent of stabilization is to reduce income variability of producers and hence consumption variability. In the example, without the stabilization scheme producers could borrow in a and repay in b and so on. However, even if means are available to spread risk producers are still likely to opt for a stabilization scheme if by various means the board in charge can use it as a means to enhance farmers income—not merely reduce variability in incomes. In Figure 16 price $P_1$ is a price support but unlike in the previous model it is not accompanied by storage.
In particular cases if the stabilization program is not actuarially sound how long the government is willing to subsidize it through covering producer costs depends on many factors including the lobbying power of the group involved. Of course, one way that the government could make the programs self financing at price $P_1$ is to use supply management techniques so that market prices rise to cover costs of production. In many countries such as Canada supply management is common. It would be interesting to know how many supply management schemes were a result of price stabilization schemes which at their inception were deemed to be self-financing without supply management.

It is clear why if producers received price $P_1$ through a stabilization scheme they would prefer this to a free market situation. This is because price stabilization is accompanied by an income support.

Instability, Storage and the Pure Theory of Trade

An important and growing literature has devoted attention to the more general incorporation of uncertainty into gains from trade theorizing and how to optimally deal with the uncertainty. Ruffin has investigated the case of a small trading country experiencing large fluctuations in the terms of trade as a result of uncertain transaction costs and/or of erratic movements in spot exchange rates. The following nonautarky theorem was derived: Given trade uncertainty (and excluding "pathological" distortions), autarky will not be

26 A more detailed summary is contained in John M. Letiche, R.G. Chambers and A. Schmitz "The Development of Gains from Trade Theory: Classical to Modern Literature".
optimal regardless of variations in the terms of trade. Similarly, by introducing forward markets into the analysis, it was shown that in the long run autarky cannot be optimal regardless of the variations in terms of trade and whatever the level of forward prices.

Batra and Russell considered the effects of increasing uncertainty of world prices on the social welfare of a trading nation and demonstrated that it would bring about a reduction of expected utility. Under conditions of uncertainty, therefore, free trade may not be an optimal policy. To reduce the effects of uncertainty, and to increase the potential gains from trade, the authors considered various governmental policies designed to minimize the cost to consumers resulting from variations in actual as compared with expected terms of trade. Among the policies considered was the use of buffer stocks.

Batra further examined the effects of uncertainty by introducing a random variable in the production function and by assuming that the expected utility of the producers is to be maximized. Although the theorems derived are narrow in scope, they provide insights for the application of gains from trade theory, especially in regard to the "commodity problem" and the stabilization of terms of trade.

In effect, the introduction of uncertainty is shown to have important consequences for standard trade theory. Contrary to the standard Heckscher-Ohlin conclusion, given constant commodity prices and the customary assumptions regarding homogeneity—with uncertainty, changes in factor endowments do affect relative factor prices. Still, the following related theorems remain in tact: (1) the Stopler-Samuelson theorem, which demonstrates that a tariff increases the
return to factors used intensively in the import-competing industry, (2) the Samuelson theorem on the one-to-one correspondence between international commodity-price ratios and factor-price ratios; and (3) the celebrated Rybczynski theorem: At constant commodity prices, accumulation of a factor increases the output of the commodity that uses that factor intensively and reduces the output of the other commodity. Even the Heckscher-Ohlin theorem, it is shown, can be valid for conditions of uncertainty if we define factor abundance in physical terms. However, under certain specifications of risk aversion, complete factor-price equalization is ruled out. But the weak factor-equalization theorem, i.e., the existence of a tendency toward factor-price equalization, remains. However, the volume of trade and the gains from trade, it is conclusively demonstrated, are smaller under uncertainty than under certainty.

The Ricardian model also has been reworked to include uncertainty and this conclusion reached: Expected gains from trade for a risk-averse country which, under certainty, would wish to trade may, under postulated assumptions with price uncertainty, become negative, causing it to cease trading. Several authors have formulated a trading model in which both price uncertainty and storage activities were included. Fedder, Just and Schmitz, for example, showed that with nonincreasing risk aversion but increased price uncertainty, both importers and exporters of the stored commodity tend to reduce the volume of their trade and, at the limit, would be better off not trading. Also, an uncertainty increases, importers store relatively more of the uncertain good. A framework has been developed for the analysis of trade under conditions of substantial fluctuations in
prices, given alternative specifications of risk by the governments of respective trading partners.

Theoretically, the presence of uncertainty in the foreign trade of goods and assets can, to a degree, be treated as an additional or joint "commodity", denoted as "risk." In the absence of satisfactory, or feasible, risk-sharing arrangements—reflected by the fact that this "commodity" is not internationally traded—the prices of these risk elements in production and distribution are manifestly different in different countries. As a consequence, some of the basic properties of international trade theory may not hold. Without such minimal risk-sharing arrangements, analysis of the effects of substantial uncertainty on the basic properties of trade theory (e.g., comparative advantage) has little predictive value for international specialization in the pattern of trade. Nevertheless, studies which have considered a planning model in which a social welfare function (expected utility) is maximized subject to the country's technological constraint, can be interpreted as models which include domestic stock markets and/or domestic Arrow-Debreu contingent commodity markets. For effective gains-from-trade analysis under uncertainty, the incorporation into these models of international trade in firms' equities and/or other national and international risk-sharing arrangements appears to be a primary requisite.

The role of trade in affecting uncertainty in price instability has been also emphasized by writers such as Newbery and Stiglitz and Bigman. They contend that liberalized trade smooths out price

\[\text{See for example E. Helpman and A. Razin}\]
fluctuations and in a sense free trade has similar effects to a buffer stock scheme and may be a cheaper substitute.\(^\text{28}\) Also the work by Newbery and Stiglitz support the findings by economists such as Helpman and Razin that the need for price stabilization schemes is greatly reduced if adequate credit markets exist and there are means available to share risks. International futures markets, and trade in a firm's equities are certainly such means.\(^\text{29}\)

**Empirical Results**\(^\text{30}\)

As a concluding section to this paper, some additional empirical studies are presented. The following studies largely focus on optimal stockpiling from the U.S. point of view. According to Gardner (1979) "optimal stockpiling is holding quantities back from current consumption such that expected welfare, as measured by an objective function, is maximized given the current state of the world. An optimal stockpiling policy is a set of rules which specifies optimal stocks for every possible state of the world, p. 3". To arrive at optimal stockpiling rules, Gustafson more than 20 years ago treated

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\(^{28}\) Although, as shown by Hueth and Schmitz, a buffer stock scheme can yield welfare improvements over a situation of free trade and no stocks.

\(^{29}\) To highlight risk sharing activities the Japanese experience provides a good example. In the purchase of grain from abroad they actively use the Chicago futures markets as a hedging means. Also they have invested in the U.S. in local elevators and terminal in order to be near the source of supply; thus they do not have to rely solely on purchases from export marketing boards and non-Japanese multinational grain firms.

\(^{30}\) Some of the studies reviewed here are also discussed in Houck and Ryan.
grain stockpiling as an optimal inventory problem.\textsuperscript{31} Gustafson considered production per acre as a random variable with fixed mean and shows given a value (welfare) function for grain, storage costs, and a discount rate how an optimal carryover policy would be specified. He derived an optimal storage rule which determines each year's carryover as a function of the year's beginning supply. Among the important applications, extensions and improvements on this work are reported in Johnson and Summer (1976, 1978), Cochrane and Danin, Arzac, Talpaz and Taylor, Taylor and Talpaz, and Burt, Koo and Dudley.

Among the most sophisticated storage models is that developed by Burt, Koo and Dudley of the U.S. wheat economy. They first develop an econometric model of the U.S. wheat sector which incorporates the dynamics of supply response then they use these results to develop a stochastic dynamic programming model to estimate optimal stockpiling strategies for the U.S. They used two separate criterion functions: domestic and world welfare. They used as the domestic criterion the sum of domestic consumers' and producers' surpluses minus storage costs (consistent with the Massell framework). The world welfare criterion also contained consumers' surplus associated with the export demand equation.\textsuperscript{32}

In their stochastic storage model, the decision variable is quantity of wheat exported that indirectly controls year to year

\textsuperscript{31} The study by Gislason C. is also of interest as an early model of grain storage.

\textsuperscript{32} In computing the annual expected net benefit function they replaced the random variables by their mean values in the demand and supply equations.
carryover. The disturbance term in their econometrically estimated export price equation is unknown at the time a storage policy decision is made. Thus, a specific level of exports does not determine price but only the probability distribution. In their model the probability distributions for price and the disturbances in supply and demand in conjunction with the state variables determine the distribution of domestic consumption, production and ending carryover for the ensuring crop year.

They state the general recursive equation of dynamic programming as:

$$V_n(Y) = \max_{x} \left( g_n(x, y) + \alpha E[V_{n-1}(T_n(x, y))] \right),$$  \hspace{1cm} (7)

where $y$ and $x$ are vectors of state and decision variables, respectively, and $E[.]$ is the expectation operator. In the wheat storage problem $V_n(y)$ is the present value of expected net benefits over an $n$-year planning period when following an optimal storage policy and given that the initial state vector is $y$; $\alpha$ is the discount factor with $0 < \alpha < 1$. The function $g_n(x, y)$ is expected annual net benefits from the first year of $n$ future years, while $T_n(x, y)$ is the transformed vector of state variables at the beginning of a planning horizon of $n-1$ years. Actually $T_n(x, y)$ is a random variable and the function notation is used to show that $x$ and $y$ enter as parameters in the multivariate distribution function of the vector of state variables. The subscript $n$ on $T_n(x, y)$ implies that the probability distribution is permitted to change from stage to stage in the decision process.

Since in their wheat model they have a total of fifteen state variables they use an approximation method for arriving at a
solution. They use a variance of the method suggested by Arrow. The approximation discussed by Arrow is to replace $V_{n-1}(.)$ in (11) by an estimate of some kind. The usual computational method of dynamic programming calculates the function $V_n(.)$ recursively starting with $V_0(.)$ as a given function. But now we are considering some a priori estimate of $V_{n-1}(.)$ in order to estimate the optimal decision rule for stage $n$ only. It is seen from (11) that if $V_{n-1}(.)$ were a known function, the optimal decision for stage $n$ could be obtained from a static optimization algorithm.

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is the maximization of the expected present value of a perpetual stream of consumers' and producers' surpluses less storage costs. Their basic framework is the first order certainty equivalence principle. The classical certainty equivalence theorem states that the optimal decision in a risky situation is the same as in some associated riskless situation.\textsuperscript{34}

They denote the objective function in general form as:

$$W^* = \sum_{t=1}^{T} W_t(P_t, P_{t-1}, S_t, S_{t-1}) r^t$$  \hspace{1cm} (8)

$$= \sum_{t=1}^{T} r^t[f_t(P_t) - g_t(P_{t-1}) - cS_t],$$

where $P_t$ is price (dollars per bushel); $S_t$, total stocks (million bushels); $f_t(P_t)$, area under the demand curve as a function of $P_t$; $g_t(P_{t-1})$, area under the supply functions at time $t$ as related to $P_{t-1}$ and $t$; $c$, annual storage cost (dollars per bushel); $r$, discount rate; and $T$, length of planning horizon (years). From this expression they derive an equation for determining optimal level of stocks through simulation trials.

Their results show that U.S. stock levels beginning in 1976/77 have been too high. Also the use of a certainty equivalence rule to manage stocks increased welfare by $199$ million per year in the U.S. compared to the current system. However, price variability doubled. In terms of distributional affects domestic producers become worse off.

\textsuperscript{34} Their model is less complicated than that used by Burt et al. since exports are estimated as a function of world price with the random disturbance reflecting variations in exports for a given price. Thus in the Taylor-Talpaz model price or at least a target price is the decision variable.
by $236 million annually, while domestic consumers gain about $414 million. Also, under the certainty equivalent rule foreign consumers' surplus increases by about $70 million.

Gardner (1979) also calculated the optimal U.S. wheat storage policy using simulation techniques. His results are consistent with other studies on this subject with respect to the amounts of grain the U.S. actually stores. He concludes that generally U.S. stock levels are too high — mean socially optimal U.S. wheat stocks should be put at 550 to 600 million bushels. Gardner also calculates optimal stock levels for different interest rates and varying levels of private stockholding combined with public stockholding.

The Cochrane and Danin study specifies a world model of wheat, coarse grains, rice and all grains and a U.S. model for wheat to evaluate several stock decision rules. The focus is on stock size relative to price stabilization associated with a specific probability of success. The optimal rule generates stock changes to minimize price instability. They conclude that a world stock reserve of 38 to 57 million metric tons of all grains would keep prices within 10 percent of the target price level four years out of five. Also, reducing variation by more than that provided by a 10 percent price band governing stock activity requires very large stocks.

Analysis by Johnson and Sumner (1976, 1978) show that grain reserves are desirable chiefly because there is no free trade in grains. Trade clearly reduces optimal stock sizes. As an example, in the Far East region for a given year, stocks would be 7.5 million metric tons under free trade. This compares to 22.5 million tons with no intraregional trade and each nation doing its own stockpiling.
The models by Zwart and Meilke estimated an econometric model of the Canadian and rest of the world wheat economies. They tested several variations of three grain reserve storage rules by simulation experiments. The storage rules tested differed more in their impact on price stability and consumer welfare than on producer welfare. For the model as a whole producer reserves are stabilized more by a price-stabilizing storage scheme than by a quantity stabilizing scheme. However, the most stability for consumers comes from storage rules that combine price and quantity triggers. They conclude that mixed rules seem to yield the best overall results.

The above papers give some of the typical findings concerning stockpiling. There are many other studies also on this general topic but the general conclusions are similar. These are listed below. The two exceptions are studies by Gardner and Just for the U.S. General Accounting Office on farmer held reserves. They generally conclude that these reserves have been ineffective in meeting their stated objectives. Some of the other studies on the general topic of stabilization are: (1) Adams et al. (1977) "A Welfare Analysis of Long-Term Forest Products Price Stabilization", (2) Alaouze "Australian Wheat Storage: A Dynamic Programming Approach", (3) Bailey et al. Grain Stock Issues and Alternatives, (4) Brandow "Grain Reserves and the U.S. Economy: A Policy Perspective", (5) Brzozowski "Grain Sales and Production Cycles - A Computer Simulation Study", (6) Casley et al. "Instability of Production and Its Impact on Stock Requirements", (7) Chaipravat "International Rice Buffer Stock Operations, A Simulation Study", (8) Eaton et al. "The Joseph Problem: How Large a Grain Reserve?", (9) Ericksen "Farm Programs
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