

The Impact of Technical Progress in Milk Production

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Introduction

Advances in biotechnology research soon will become applicable to milk production. The gene responsible for production of the bovine Growth Hormone (bGH) has been isolated and transferred to ordinary bacteria cells by applying gene splicing techniques (Miller et al. 1980). The hormone is a naturally occurring protein produced by dairy cattle that regulates the volume of milk production. Although the functioning of bGH is not fully understood, injecting supplemental quantities into dairy cows results in additional milk production. Laboratory research has achieved production increases of up to 40 percent (Bauman et al. 1982). Response time following the injection is relatively short: production responses typically occur within two to three days.

Given the strong potential for a substantial increase in dairy cow productivity, private firms are preparing for commercial production of bGH. Marketing this hormone, however, usually requires approval by the regulating agencies responsible for food safety. Since the hormone occurs naturally in dairy cattle, regulatory approval of bGH should not be difficult. It is expected that the hormone will be available for commercial use in the United States by 1989.

Although official approval for use in commercial markets will be given, undoubtedly, the hormone is not yet a viable product. A study by Kalter et al. (1985) investigated the commercial viability of bGH. One of their conclusions was that "even if farm milk prices deteriorated sharply, a substantial incentive would exist for adoption at bGH prices ranging from two to four times raw production costs." In other words, even if bGH manufacturers were to charge the dairy sector for use of their product, it would still be profitable for farmers to apply the hormone at even lower milk prices. The authors also stated that if prices became very unfavorable it would not be profitable to produce milk regardless of whether bGH was used or not. Kalter et al. (1985) also calculated production cost for bGH to be between two to four dollars per gram at 1984 prices, depending on the scale of production.

At this stage, the extent to which commercial bGH producers attempt to market their product abroad can only be the subject of speculation. However, with present prices it is very profitable to introduce the hormone. Hence, there exists a strong incentive for commercial firms to enter foreign markets as well. Biotech firms in foreign countries also may obtain a license to produce bGH and sell it in their domestic market.

Although the rate of return for using bGH may not be as high in all countries as that calculated by Kalter, et al. (1985), it is probable that bGH will find global use. There are, however, two factors that delimit talk about its level of global acceptance. One is the necessity of official admission of bGH as a feed component. The second is the rate of adoption, especially in developing countries. New products typically are adopted slowly at first, and there is no reason to believe that the situation will differ for bGH. Kalter et al. (1985) found through a survey that, after one year of availability, 66 percent of all dairy farmers questioned in the state of New York would use the hormone on a trial basis; 76 percent would use it after three years of availability. Thirteen percent of the farmers surveyed indicated they would never use the hormone.

Since bGH application requires the development of new skills and techniques, it is likely that farmers in developing countries will have a much slower rate of adoption. One of the critical factors determining rate of adoption is the availability of a mechanism for slow release of the hormone in the body of the dairy cow. If new application techniques were to be made available, the rate of adoption might be much higher if bGH did not have to be injected daily. For instance, if the hormone could be released continuously without new injections over a certain period, perhaps two weeks, the adoption rate probably would improve.

Objective of the Study and Specification of Scenarios

The purpose of this study is to analyze the impact of bGH on global agriculture, especially on the dairy sector. The

world market for dairy products is one of the most distorted agricultural markets. World prices for dairy products are suppressed by excessive export restitutions paid by major exporting countries like those of the European Community. In addition, only a relatively small portion of global production is traded internationally (approximately 5 percent).

It can be expected that applying bGH will lower the marginal cost of milk production and, hence, shift the supply curve of milk outward. It is of interest to study how the application of bGH will affect the comparative advantage of milk production in various countries. Of course, shifts in comparative advantage can be offset by government policies designed to protect dairy producers, as has occurred in the past. Consequently, it is important to determine the most likely reaction of world market prices to the introduction of bGH. In addition, it is important to understand how these changes will be transmitted to domestic markets and what the resulting impact on the global dairy sector is likely to be.

Previous studies analyzing the economic impact of bGH have been conducted at the farm level (Kalter et al. 1985) and the regional level (Magrath and Tauer 1986a,b). Although these studies provide an in-depth analysis of changes in farming practices and farm income, they fail to fully integrate the market response to shifts in supply functions. They also do not take into account any cross commodity effects.

This paper analyzes the impact of bovine Growth Hormone under two policy assumptions. In the first scenario, it is assumed that past policies--especially those pertaining to the dairy sector--are continued after the adoption of bGH injection techniques. This assumption is relaxed in the second scenario. In that scenario, a reduction in protection of the dairy sector is assumed to be followed by all countries. This scenario is specified so that there is no border protection in the trading of dairy products after the introduction of bGH.

The impact of the new technology on milk production is investigated using the Basic Link System developed by the Food and Agriculture Program of IIASA (Fischer et al. 1988). For purposes of this study, it is assumed that annual milk production per cow increases by 10.5 percent in all countries. A productivity increase of that magnitude seems realistic in

that it represents the lower end of all results achieved in laboratory trials to date. It is, however, assumed that the technology is not adopted at the same rate and at the same time in all producing countries. The assumption is made that dairy farmers in the United States start to adopt the new technology in 1988, and that bGH will be available in all other countries beginning 1989.

The rate of adoption is assumed to vary, with developing countries having an adoption rate half that of developed countries. Developed countries are assumed to adopt this new technology over a period of three years. Hence, the new technology will reach its maximum level of adoption in developing countries after six years.

The new technology, as introduced in the models, also is assumed to increase consumption of feed concentrates by the same percentage. In other words, the milk response function to feed concentrates is shifted outward so that, at the given ratios of milk to feed prices, both yield and intake of feed concentrates are increased by 10.5 percent. However, some nutrients required for milk production are supplied by roughage, which is not explicitly included in the models, so the specification chosen also implies a gain in feed efficiency. It is difficult to assess the size of this efficiency gain, but it is believed that this assumption is realistic. The increase in feed efficiency is assumed to be due to lower maintenance requirements.¹

Application of the hormone also requires additional labor. The simplifying assumption is made that labor use increases by 2 percent when the technology is used. This proportional increase of the labor requirement implies more work in developing countries than in developed countries and reflects the additional expertise needed to apply bGH successfully. Capital requirements are not affected.

Thus, the decline in the marginal cost of milk production is assumed to be caused by several factors: higher feed efficiency, higher capital productivity, and higher labor productivity. the increase in capital productivity exceeds that of labor.

This specification implies that, due to a faster adoption rate, the comparative advantage in milk production shifts in

favor of the developed countries. However, little is known about the interaction between bGH and yield level. It is conceivable that yield response to the hormone depends on yield level, with low-yielding dairy cows showing a higher response. This could reverse the shift in comparative advantage.

The model results are compared to a base-run scenario that, by and large, assumes that recent conditions will continue to prevail.¹ The impact of bGH is simulated over a 13-year period. Discussion of the results focuses largely on the last year of the simulation period, a year in which, it is believed, adjustment to the new technology will be fully carried out. The dairy industry can, therefore, be regarded as having reached a new steady state by that year.

Impact of bGH Assuming a Continuation of Past Policy

It is important to understand the assumptions made about dairy policies in the major producing and trading countries. For the United States it is assumed that dairy policy, as stipulated in the 1985 Farm Bill, will continue until the year 2000. Thus, the support price U.S. dairy farmers receive will be substantially above world market prices. This support price is not constant over time; it varies with stocks of dairy products held by the government. Greater government intervention will result in a lower domestic support price for milk, helping to avoid excessive stock levels. The United States continues to have an effective import quota for dairy products.

The European Community is assumed to tighten its dairy quota. The effective quota is set at 7 percent above Community-wide disappearance of all milk products. No superlevy is used in the model. The intervention price, however, varies with the world market price for dairy products. The elasticity transmitting the variations of world price for dairy products is rather small, between 0.10 and 0.15. According to this policy, the European Community increases its exports of dairy products in the reference run only marginally over the period 1988-2000.

Canada also pursues a policy of supply management, as do both the European Community and the United States, but it imposes a much stricter quota on production. Canada imposes a production quota that equals total disappearance, thus eliminating any possibility of participating in world trade with dairy products.

New Zealand is assumed to pursue a nonprotectionist dairy policy. Hence, changes in world dairy prices are fully transmitted to the New Zealand market.

Australia is assumed to pursue a dairy policy slightly more aggressive than that of New Zealand, but it will not approach the degree of protectionism found in Canada, the United States, or the European Community. World market price variations are partially transmitted to the domestic market.

Changes in relative world market prices, production, and net exports due to the introduction of bGH, and assuming a continuation of past policies, are reported in Table 1. These changes compare to the reference run and are presented for the world market. Results given for the year 1990 reflect an immediate global response to preliminary adoption of the new technology. By year 2000, world agriculture will have achieved a new long-term stationary equilibrium path. As reported in the table, world market prices for dairy products decrease strongly in 1990 and less strongly in the year 2000.³ Recall that, by assumption, in 1990 most countries have not yet fully adopted the new technology. Likewise, production increases by a meager 2 percent in 1990 and by slightly more than 3 percent in 2000. A relatively strong decline in world dairy prices corresponds with a very small increase in global production, reflecting the lack of transmission of changes in world market prices to the respective domestic levels. This transmission is, of course, even lower for consumer or retail prices than for prices received by producers.

The most noticeable change occurs in the volume traded. A rather small increase in trade occurs immediately after the new technology is introduced. However, a 35 percent increase in net trade of dairy products can be observed by 2000. This is due to shifting production patterns that, in turn, reflect

Table 1. Changes in relative world market prices, production, and net exports in 1990 and 2000: Advances in dairy technology assuming no change in policies compared to reference run (in percent)

| | Relative World | | | | | |
|------------------------------------|----------------|------|------------|------|-------------|------|
| | Market Prices | | Production | | Net Exports | |
| | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 |
| Wheat | 2 | 2 | +0 | 1 | +0 | 3 |
| Rice | -1 | -1 | +0 | -0 | +0 | 1 |
| Coarse grain | 2 | 2 | +0 | 1 | +0 | 3 |
| Bovine & ovine meat | -5 | -6 | +0 | 1 | 1 | 6 |
| Dairy products | -31 | -28 | 2 | 3 | 3 | 35 |
| Other animal products ^a | +0 | +0 | +0 | -0 | +0 | +0 |
| Protein food | 2 | +0 | +0 | +0 | -0 | +0 |
| Other food ^b | -1 | -0 | +0 | -0 | -0 | 1 |
| Nonfood agriculture ^c | -3 | -6 | +0 | +0 | -0 | -4 |
| Total agriculture | -3 | -3 | | | | |
| Nonagriculture ^d | | | +0 | +0 | -1 | -3 |

Note: A "+0" indicates a small positive change; a "-0" indicates a small negative change.

^aPork, poultry, eggs, and fish.

^bMainly fruits, vegetables, sugar, fats and oils, and beverages.

^cAll nonfood agricultural products.

^dAll nonagricultural activities.

changes in comparative advantage caused by introduction of bGH use.

Some of the resources freed from dairy production, such as grassland, are used to produce bovine and ovine meat, leading to small production increases. The demand for bovine and ovine meat is inelastic with regard to world market prices, as can be observed from the changes of those prices. These prices decline by approximately 5 percent, while production increases negligibly.

In general, relatively small cross commodity effects are observed in the international market. Most of those occur at levels that are beyond the precision obtainable with a model like the Basic Linked System. One noticeable exception, however, is the increase in grain prices at the world level. This is due to a shift in production patterns that results in more grain being used as feed in livestock rations.

A selected set of individual country results for the dairy sector is reported for the year 2000 in Table 2. The new technology has different impacts on the various countries, but, to a large extent, these differential effects are due to different domestic policies. For example, Canada and the European Community indicate no change in production. This is because there is virtually no change in consumption of dairy products, which, in turn, is a result of only marginal changes in retail prices and an insignificant increase in income. Although production is not changed in either Canada or the European Community, a change in the value of the production quota is indicative of shifts in the competitiveness of the dairy sector. In Canada for the year 2000, the ratio of the quota value to milk price increases 32 percent, from 0.27 in the reference run to 0.35 after adopting the new technology. The corresponding numbers for the European Community--0.19 and 0.31--represent a 63 percent increase.

In contrast to these results, is the impact observed in New Zealand. Here the decline in world dairy price is fully transmitted to the domestic market, which in turn leads to a lower profitability of milk production. The result is an 8 percent decline in milk output and a 13 percent reduction in export volume.

Table 2. Changes in the dairy sector: Production, demand, trade, prices, and net return in 2000 for selected advances in dairy technology without changes in policy specification compared to reference run (in percent)

| | Production | Demand | Net Export ^a | Relative Producers ^b | Prices Retail | Net Return ^c |
|--------------------|------------|--------|-------------------------|---------------------------------|---------------|-------------------------|
| Argentina | 3 | 1 | 56(E) | -19 | -13 | -12 |
| Australia | 1 | -2 | 18(E) | -19 | -18 | -14 |
| Canada | +0 | +0 | +0 | -6 | -3 | 1 |
| European Community | +0 | -0 | 6(E) | -10 | +0 | 1 |
| India | 1 | 4 | 233(M) | -22 | -6 | na. |
| New Zealand | -8 | +0 | -13(E) | -28 | -17 | na. |
| United States | 8 | 9 | 35(M) | -27 | -30 | na. |

Note: A "+0" indicates a small positive change; a "-0" indicates a small negative change.

^a"E" indicates export and "M" indicates import in the reference run.

^bSupport price for the United States.

^cGross receipts minus feed cost.

Among all the countries listed in Table 2, the United States has one of the most responsive domestic demands for dairy products with respect to changes in retail dairy prices. A decline in retail prices of 30 percent leads to a 9 percent increase in consumption. Demand price responsiveness seems to be higher than that of supply in the United States. To keep stocks from growing excessively, the U.S. government has to reduce the support price by 27 percent. Yet dairy herd size hardly declines, since production increases almost by the full amount by which yield increases. The model indicates an increase of 35 percent in imports of dairy products by the United States.

There is little impact on the dairy sectors of Argentina and Australia. The increase in yield is more than offset by a decrease in producer prices, leading to a decline in net revenue per animal unit. However, bovine and ovine meat production also becomes less profitable relative to crop production. This explains why there is not much decline in the number of dairy cows. In other words, there is almost a zero opportunity cost for roughage land in these countries.

In general, the results of this simulation indicate that the policies protecting the dairy sector to a large extent offset the advantage of the new technology. Consumers also do not benefit from the lower cost of production that results from the new technology. This is indicated by the fact that equivalent income, a consumer welfare measure, increases by less than 0.5 percent. (This measure was calculated for all countries but is not reported in detail here.)

The comparative advantage, which could change dramatically due to the new technology, is affected little by the protectionist policies. Developing countries gain only marginally from the technology because most of them import dairy products and hence enjoy an improvement of their terms of trade. This is also reflected in the number of hungry people, which declines marginally--a decrease that is not sufficient to claim any success. The centrally planned economies, which also are assumed to introduce the new technology, do not change their trade pattern but use the increased production for domestic consumption.

It is likely that policies protecting the dairy sector from necessary adjustments will not be sustainable when bGH use is adopted. Since in many countries producer prices for dairy products decline less than does the world market price, the relative protection enjoyed by the global dairy sector increases.

Impact of bGH Assuming Removal of Border Protection

It is of interest to see how the world agricultural sector might adjust if the protectionist policies pursued by many developed countries were relaxed. Since it is not known to what extent those policies will be relaxed after bGH use has been adopted, the simplifying assumption was made that border protection for the dairy sector is abolished. This means that variations in the world market price are fully transmitted to the domestic level and that the relative domestic price for dairy products equals that of the world market level. In addition, Canada and the European Community are assumed to abolish their milk production quota. In the United States, farmers are not paid the support price any more; instead, they are paid the market clearing price for milk.

Changes in world market conditions for this scenario are reported in Table 3. Observe that dairy prices initially decrease by 23 percent but then increase by 7 percent by the year 2000. This is a substantially different result than the one discussed for the first scenario, in which the world dairy price declined by 28 percent by the year 2000. Although the new technology has been adopted and the marginal cost of dairy production has declined, world dairy prices actually increase due to the removal of subsidies by the major exporting countries of dairy products. This is another indication of distortions in the world market price caused by current policy.

Most prices for other agricultural products also decline in this scenario. The only exception, besides dairy products, is the price for protein feed, which increases 3 percent by the year 2000. The decline of the aggregate agricultural price index by 8 percent is due primarily to the shift of resources used in the reference run for dairy production to other

Table 3. Changes in relative world market prices, production, and net export in 1990 and 2000: Advances in dairy technology with a simultaneous removal of border protection for dairy products compared to reference run (in percent)

| | Relative World | | | | | |
|------------------------------------|----------------|------|------------|------|------------|------|
| | Market Prices | | Production | | Net Export | |
| | 1990 | 2000 | 1990 | 2000 | 1990 | 2000 |
| Wheat | 3 | -2 | +0 | 1 | +0 | -2 |
| Rice | -9 | -9 | +0 | 1 | 1 | -1 |
| Coarse grain | 3 | -2 | +0 | 1 | -1 | -2 |
| Bovine & ovine meat | -4 | -4 | +0 | 2 | 5 | 13 |
| Dairy products | -23 | 7 | 3 | 5 | 52 | 143 |
| Other animal products ^a | -3 | -5 | 0 | 1 | -1 | 4 |
| Protein food | 4 | 3 | -0 | -2 | -0 | -5 |
| Other food ^b | -5 | -12 | +0 | 1 | 3 | 18 |
| Nonfood agriculture ^c | -6 | -17 | 1 | 1 | -1 | -7 |
| Total agriculture | 6 | -8 | | | | |
| Nonagriculture ^d | | | +0 | +0 | -1 | 5 |

Note: A "+0" indicates a small positive change; and a "-0" indicates a small negative change.

^aPork, poultry, eggs, and fish.

^bMainly fruits, vegetables, sugar, fats and oils, and beverages.

^cAll nonfood agricultural products.

^dAll nonagricultural activities.

enterprises. Yet, as noted in Table 3, global production of most agricultural commodities does not increase substantially. This, too, reflects the low response of global demand to changes in world prices. Dairy production, however, increases by 3 percent initially (in 1990) and by 5 percent by 2000. Although this does not represent a strong increase in production at the global level, changes at the country level are much more pronounced. This can be seen from the changes in net exports, which increase 50 percent initially and 140 percent by year 2000. This implies more than doubling the share of global trade on global production for dairy products. Trade in bovine and ovine meat and in the aggregate other food category (fruits, vegetables, sugar, fats and oils, and beverages) increases by 13 percent and 18 percent, respectively. The main change in the trade pattern of other food occurs between developed and developing countries. Developing countries are able to increase their exports substantially while, as a whole, developed countries open their markets for these products.

Table 4 lists dairy sector changes for the same group of countries described in the previous section. With the exception of Japan, all countries increase their production in this scenario, as does the European Community. The strongest increase occurs in Australia, whose approximately 40 percent increase in milk production can be explained by a substantial rise in producer prices (27 percent) and a yield increase that goes beyond that induced by the new technology. Net revenue per dairy cow (gross revenue minus feed cost) increases in Australia by approximately 50 percent. Australia's producer price increases dramatically because dairy exports are taxed in the reference run.

Canada also increases milk production substantially, in spite of a 14 percent decline in the dairy price. The reason is that the quota is removed in this scenario, so output increases to the extent that the marginal cost of production equals the price received by farmers. The rent Canadian dairy farmers receive from the quota is about one-third of the dairy price in the reference run. In other words, the marginal cost of milk production is only two-thirds of the price dairy farmers receive.

Table 4. Changes in dairy sector: Production, demand, trade, prices, and net return in 2000 for a selected set of countries' advances in dairy technology with a simultaneous removal of border protection for dairy products compared to reference run (in percent)

| | Production | Demand | Net Export ^a | Relative Producers ^b | Prices Retail | Net Return ^c |
|--------------------|------------|--------|-------------------------|---------------------------------|---------------|-------------------------|
| Argentina | 12 | +0 | 247 (E) | 9 | 4 | 16 |
| Australia | 39 | 2 | 218 (E) | 27 | 19 | 54 |
| Canada | 20 | -2 | ^d | -14 | -5 | -5 |
| European Community | 6 | -0 | 168 (E) | -20 | -9 | -12 |
| India | 2 | 1 | -25 (M) | -11 | -4 | -- |
| Japan | -18 | 5 | 526 (M) | -51 | -16 | -43 |
| New Zealand | 12 | 2 | 17 (E) | 7 | 11 | -- |
| United States | 5 | 15 | 735 (M) | -17 | -43 | -- |

Note: A "+0" indicates a small positive change; a "-0" indicates a small negative change.

^a"E" indicates export and "M" indicates import in the reference run.

^bComparison between market price in the technology run and support price in the reference run for the United States.

^cGross receipts minus feed cost.

^dCanada exports approximately 2 million metric tons by 2000, which is equivalent to a 5 percent market share.

A similar argument can be used to explain production increases in the European Community, where an even larger decline in the producer milk price is observed. Rent for the milk production quota is approximately 20 percent of the dairy price or, in economic terms, the marginal cost of milk production is 80 percent of the price dairy farmers receive in the European Community. Again, this does not include the superlevy. Production increases in the European Community by 6 percent and, since there is no change in the demand for dairy products, the additional output is entirely exported. Net exports increase by 170 percent.

In this scenario, New Zealand's dairy farmers increase dairy production by 12 percent. This increased production is almost entirely exported since demand increases by a relatively small amount. Nevertheless, New Zealand is not able to maintain its position as the largest exporter of dairy products, a ranking it holds in the reference run. The top slot is taken over by the European Community and New Zealand falls to second.

Retail prices for dairy products fall by 43 percent in the United States, leading to a 15 percent increase in demand. Producer prices also fall, cushioning but not offsetting the incentive from bGH use to increase production. The end result is that production increases by about 5 percent. Increased milk output per dairy cow is also beyond the productivity gains attributed to the new technology, offsetting a substantial part of the price decline leading to increased production. In addition, grassland has only limited alternative uses, and hence it has almost zero opportunity cost.

The larger increase in demand relative to production leads to a strong rise in U.S. dairy imports (73.5 percent). The self-sufficiency ratio drops from 99 percent in the reference run to 92 percent in the current scenario.

Removing protection of the Japanese dairy sector makes its dairy farmers decrease milk output. Net revenue declines sharply (40 percent), so that milk output contracts by 18 percent. Since there is a simultaneous increase in the demand for milk products, Japan increases its imports of these commodities substantially.

In the reference run, India imports 3 percent of all globally traded dairy products by the year 2000. Under the current scenario, India is able to reduce its dependency on the world market. In spite of a decline in producer prices, India is able to increase output slightly more than demand. Due to improved dairy sector productivity and its spillover effects, welfare rises slightly in India.

Similar conditions can be found for most of the developing countries. In general, this scenario shows that this group of countries enjoys a slightly higher welfare gain from the adoption of bGH use when it is accompanied by a reduction in protectionism. However, there are a few instances under the current scenario in which welfare suffers in comparison to the previous scenario. These are for countries where consumers are protected at the expense of the agricultural sector; that is, where agricultural exports are taxed and imports are subsidized. Argentina is one such country. Its welfare declines by roughly two-thirds of one percent in this scenario, whereas it improves by approximately one-third of a percent in the previous scenario.

It is also assumed in this scenario that the centrally planned economies will not adjust their trading pattern because of the new technology. Instead, they will use the increase in output to increase domestic consumption. It is not clear whether these countries will pursue such a policy in reality. Instead, they might reduce imports of dairy products and import more grains, as the terms of trade would suggest.

Summary and Conclusion

These findings on the impacts of the bovine Growth Hormone on the food and agricultural system, as obtained with the Basic Linked System, indicate that this new technology leads to welfare gains. On the global scale the gains are relatively high, given that bGH technology leads to a relatively small increase in the productivity of inputs used in milk production. Gains on the global scale far outweigh the cost.

These results have been obtained under the assumption that the new technology will be adopted everywhere, although at

different rates. One interesting aspect of the findings is that use of bGH does not necessarily give producers in the country for which it was originally developed a comparative advantage when all protectionist policies are removed. Instead, the results seem to point out that, since the technology is fully transferrable, farmers in other countries might enjoy a higher benefit than farmers for whom the technology originally was invented. The end result is that bGH use shifts the production possibility frontiers differently in various countries, giving some other countries a comparative advantage.

Endnotes

1. It is debatable whether the nutrient density of the feed ration has to be increased, as assumed here. Experimental evidence has been found to support both an increase in density and the sufficiency of voluntary increase in intake. The fact that the hormone is not applied during the first third of the lactation period suggests that the second conclusion is correct.
2. All prices reported in this study are relative to the observed price in the nonagricultural sector.
3. A discussion of the reference run can be found in Parikh et al. (1988).

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