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Farmers as Price Takers: How Farm Returns are Established

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Abstract

This paper shows that the market price received by farmers is determined by aggregate supply and demand forces. Yield increases, on-farm cost savings and improvements in transportation and storage lead to an outward shift of the aggregate supply curve. Since the outward shift in this curve has been greater than the outward shift in demand, agricultural prices have generally fallen over the last 50 to 100 hundred years. Despite this falling price, some agricultural producers are able to earn a positive economic profit due to their relatively low costs of production. Since these producers generally establish the values in the land market, the higher cost agricultural producers typically earn little or no economic profit when land is evaluated at market values. These producers may also find it difficult to adopt technologies that will allow them to remain cost competitive. Investments in one region (whether by producers, governments or agribusiness firms) to lower costs and increase yield typically result in lower price–cost margins in other regions, which then typically respond by undertaking their own investment. This investment game is one of the reasons for the continued shift out of the aggregate supply curve and the falling price of agricultural commodities.

1 Introduction

During most of the 20th century, agricultural prices have fallen, in large part because of a substantial investment into research and development by both public (e.g., government) and private (e.g., agri-business firms) players. The reasons for this historical long-term price decline (as well as the sometimes large short-term price variations) are reasonably well understood. However, the past is not necessarily a predictor of the future; as a result, the question emerges of what is likely to happen to agricultural prices in the future. This question is particularly important given that the emergence of lower cost export suppliers such as Brazil are likely to put additional downward pressure on the long-run price of agricultural commodities. The ability of higher cost suppliers to continue to operate within the industry will be determined by the degree to which they can adopt strategies to remain competitive.

To address these questions, this research paper provides the following: (1) A review of the basic conceptual framework used to understand how agricultural prices are determined; (2) A review of historical prices for the major agricultural commodities. Included in this review is an examination of whether the patterns observed are mostly for field crops, or whether they also apply to meat production. This section also examines whether the historical decline in prices is likely to continue (e.g., while there is some evidence that yields may not be rising as quickly as they once did, the presence of potential new exporters with productive capacity that has not been fully exploited is likely to lead to continued supply increases and falling prices); (3) A reformulation of the conceptual model of how agricultural prices are determined to include a focus on different cost structures within and among different regions and the implications of these cost structures for price determination; and (4) An exploration of some of the policy implications of the findings developed in the paper (e.g., the strategies that are open to farmers, agri-business firms and government to deal with the falling price).

2 The Determination of Agricultural Prices: The Basic Model

Agricultural prices are determined – both in the short run and the long run – by supply and demand forces. The basic elements of the supply and demand framework that has been constructed to understand agricultural prices are: (1) demand is highly inelastic; (2) supply is highly inelastic, particularly in the short run; (3) demand increases slowly over time; and (4) supply increases over time, typically faster than demand. The result of these four elements is that agricultural prices fall over the long run; indeed, given the inelastic nature of demand, the shifts in supply need only be marginally greater than the shifts in supply in order to generate quite substantial drops in price. In the short run, prices can be quite volatile as transitory demand or supply shocks, in combination with inelastic supply and demand curves, cause significant changes in prices (Cochrane, Gardner).[1]

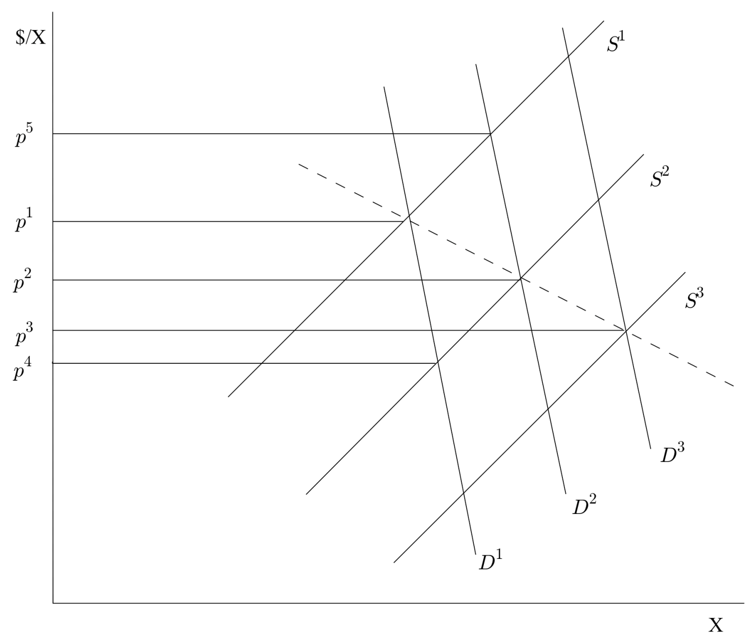


Figure 1: Agricultural Price Determination: The Basic Supply and Demand Model

Figure 1 illustrates the basic model. As population and income increase over time, agricultural product demand shifts out from D^1 to D^2 to D^3. In the absence of supply shifts, these demand

[1] As Gardner points out (p. 64), the basic supply-demand framework outlined above is a partial equilibrium model. While a full modeling of agricultural price determination requires a general equilibrium analysis, the basic argument remains the same when such a framework is adopted.

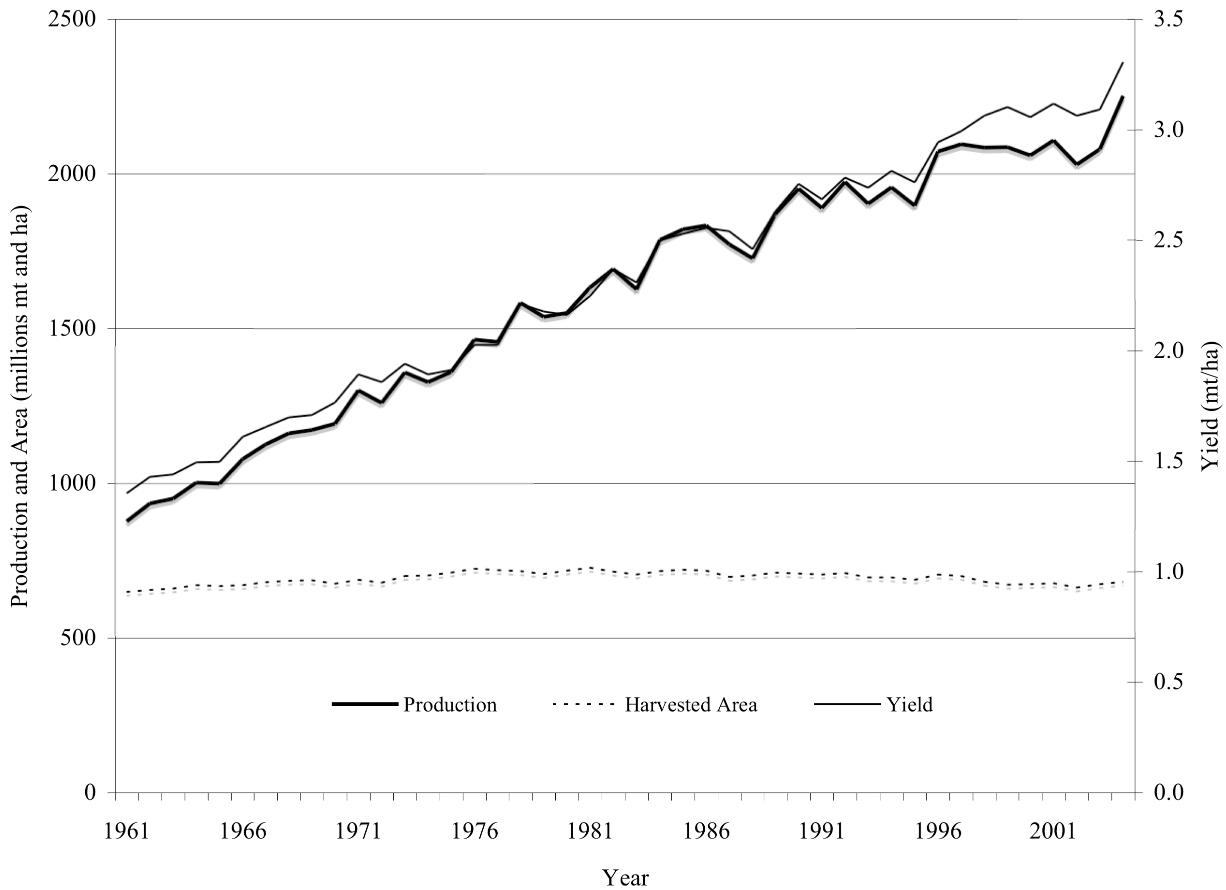
shifts would lead to substantial price increases – e.g., price would rise from p^1 to p^5 with a shift in demand from D^1 to D^2). Supply, however, also shifts out over time – e.g., from S^1 to S^2 to S^3 – because of increases in productivity and acreage. A shift in supply without a corresponding shift in demand can cause significant price variability. For example, price can be expected to fall from p^1 to p^4 when supply shifts from S^1 to S^2 without any shift in demand – this scenario captures the case where an excellent harvest in a particular year results in a substantial price decline. Over the long run, agricultural prices decline since the shifts in supply are generally larger than the shifts in demand. The dashed line shows the decline in price that occurs over the long run.

The dynamics of this long-term price decline have been further developed by Cochrane in his agricultural treadmill model. The basis of Cochrane's model is the observation that it is farmers who adopt agricultural technology, and understanding the incentives for them to do so is critical to understanding what happens to supply over time. Cochrane describes two factors that are work. The first is that farmers always have an incentive to adopt technologies that lower their costs or increase their yields, since doing so will raise their individual returns (for any farmer, the price of the product is taken as given; hence any reduction in costs raises returns). However, while the adoption of new technology by a single farmer has no effect on output, and hence price, this is not true when many farmers are considered. As discussed above, the adoption of a new technology by a substantial number of farmers will result in a shift outward of the supply curve, which in turn leads to a fall in price.

The second factor at work is that farmers are differentiated in their willingness and ability to adopt new technology. As has been widely discussed in the adoption and diffusion literature (see Rogers for an overview of this literature), people typically do not adopt a new technology at the same time. Adoption begins with the innovators and the early adopters; if the technology is successful it is then adopted by the majority of individuals, although some – the late adopters – may be very slow to adopt (if they in fact ever do). The implication of different adoption rates is that the innovators and early adopters may be able to lower their costs by more than the resulting price drop. By the time that the majority of farmers have adopted the technology, however, the resulting price decline has offset most of the reduction in cost. Thus, these farmers see fewer benefits from the adoption of the technology than do the innovators and early adopters. However, while the benefits are smaller, the incentive to adopt nevertheless remains, since to not do so would leave a farmer with higher costs and a lower price, and hence reduced returns. The late adopters of the technology are typically forced to leave agriculture, since they cannot survive economically when faced with high costs/low yields and a low price.

Over time, the impact of the two factors described above is a continual shift outward of the supply curve over time as farmers attempt to lower costs and increase returns; this outward shift of the supply curve results in a reduced price, which in turn provides a continued incentive for farmers to adopt new technology. Cochrane likens the outcome to a treadmill – farmers have to keep adopting new technology and lowering their costs just to remain in business. Although Cochrane developed his model to describe the situation facing farmers in the U.S., his model does have application to the competitive position of different regions, as well as to farmers within these regions. This application will be explored in section 4.

As will be seen in the next section, the historical evidence on agricultural prices is very much in agreement with the predictions of the basic model presented above. The assumptions of this model are also roughly in line with what is observed in agriculture. Demand for agricultural products at the farm level has been found to be inelastic, while the supply of agricultural products is inelastic, particularly in the short run (see Gardner for details). While the demand for food does increase over time with increases in population and income, the low income elasticity for agricultural products means the outward demand shift slows as incomes grow; this slowing is further strengthened because higher incomes also tend to result in slower rates of population growth. On the supply side, outward shifts of the supply curve have occurred because of increases in productivity and by increases in acreage planted.



Source: FAO 2004a

Figure 2: World Production, Harvested Acreage and Yield of Cereals, 1961-2004

As an example, Figure 2 shows the increase in the production of cereals that has occurred since 1961 as a result of shifts in supply (similar data on other crops are presented in the next section). Historically, these supply shifts have been substantial, with the result that world agricultural prices for most commodities have fallen over the last 80-100 years.[2] The next section of the paper examines in more detail the historical pattern of agricultural prices.

[2]Declining agricultural prices, however, do not necessarily mean low farm incomes. To understand why farm incomes may be low requires an analysis of farm factor markets, and in particular the market for farm labour (Gardner).

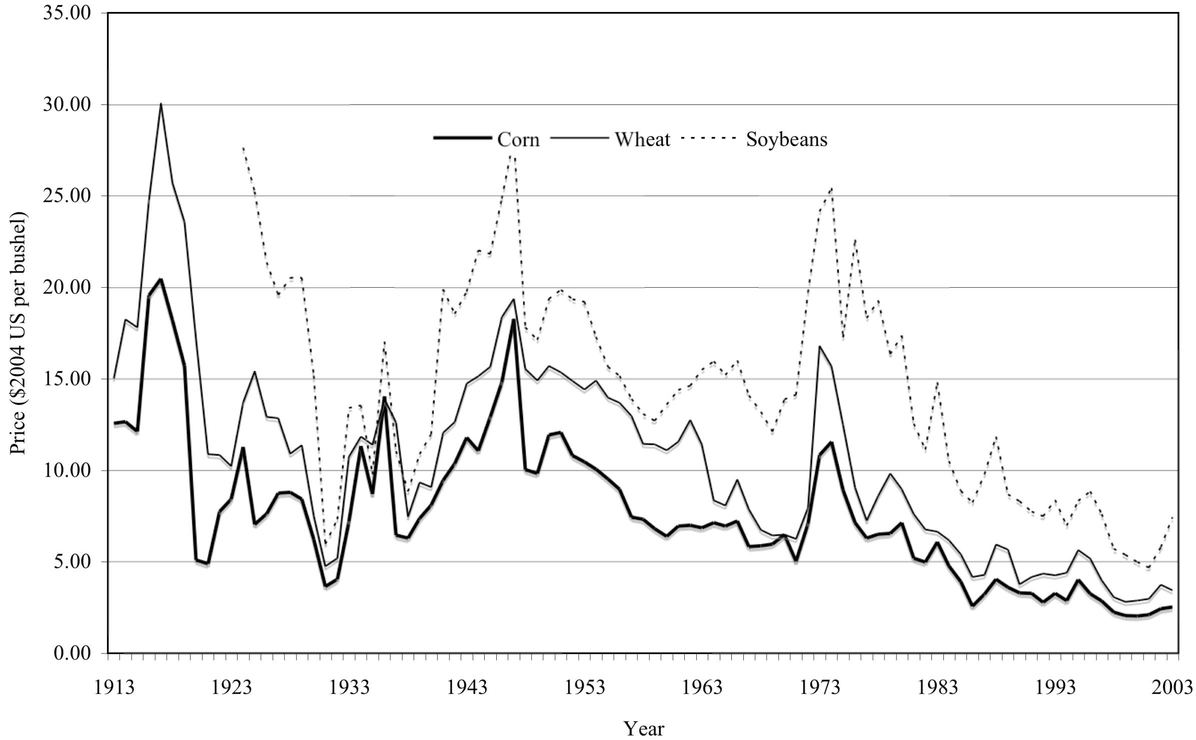
3 Agricultural Prices: The Empirical Evidence

3.1 Historical Prices

Over the last 100 years, agricultural prices – particularly those of crops – have fallen when measured in real terms (i.e., when the impact of inflation has been removed). Figure 3 shows the prices (in $2004) received by U.S. farmers for wheat, corn and soybeans since 1913 (from 1924 onward in the case of soybeans). While there has been much variation in the prices from year to year, the overall trend in these prices has been clearly downward. Since 1913, real corn prices have fallen on average 1.79 percent per year, while wheat and soybean prices have fallen on average 1.64 percent per year and 1.66 percent per year, respectively. This downward trend has not been uniform. Prices were high during the First World War; the price decline that occurred after the war continued through the 1930s. Prices then rose during the Second World War, only to once again fall over the 1950s and 1960s. Prices rose again in the early 1970s with the jump in oil prices and the Russian grain deal. Since then prices have largely been in decline; in recent years prices have been at levels equal to or less than those in the 1930s.

Figure 4 shows the real prices of selected agricultural products from 1961 to 2002 on world markets. With the exception of dairy, horticultural crops and meat, world prices of agricultural commodities have trended downward over the last 40 years. All the commodities whose prices declined experienced a sharp increase in prices during the early 1970s. It is noteworthy that only crops, aside from horticulture, have experienced a long-term price decline (although evidence will be presented later that livestock prices in the U.S. have trended downward).

As was outlined in the previous section, the long-term fall in price has been the result of supply increasing faster than demand. Demand for farm level production is directly linked to two key variables – population and income. While increases in population result in a direct increase in the demand for agricultural production (i.e., a shift out of the demand curve), the impact of changes

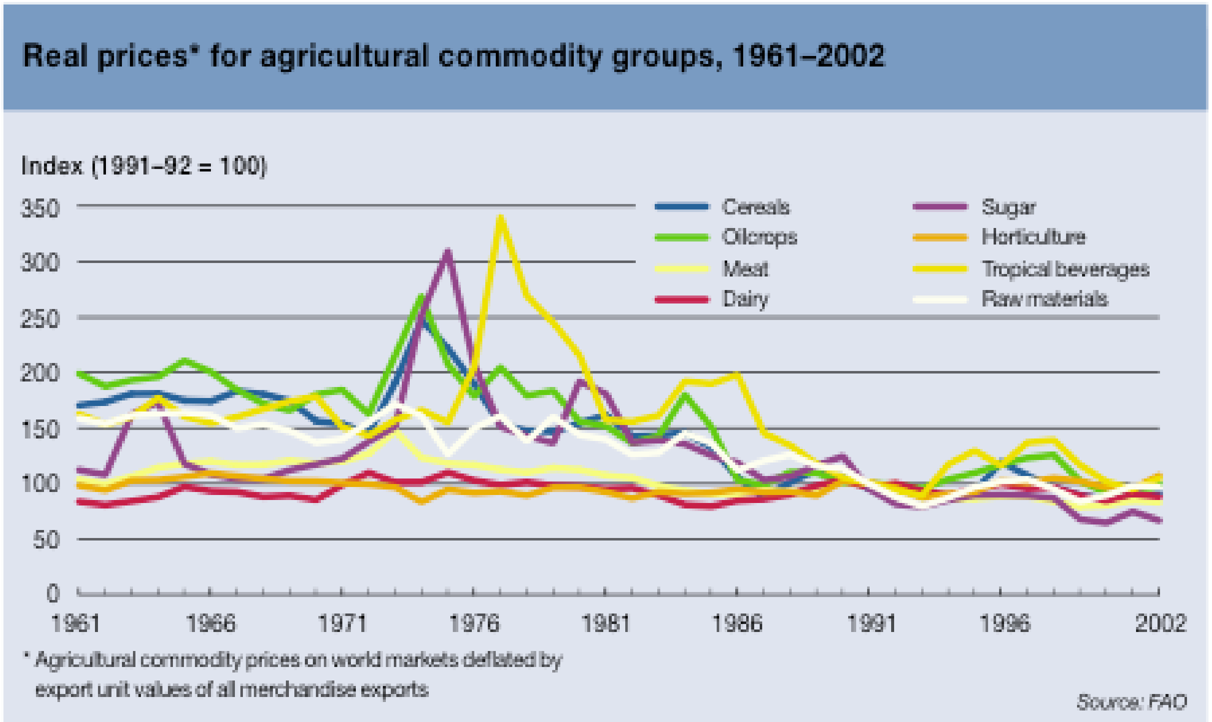


Source: USDA

Figure 3: US Real Prices ($2004) for Wheat, Corn and Soybeans, 1913-2004

in income is more complex. When income levels are low, an increase in income leads to a greater demand for food that can meet basic caloric needs (e.g., cereals and root crops). Even under these conditions, however, not all the income increase will be used for additional food consumption – some of the income increase will be used for other needs such as shelter (i.e., food demand is said to have an income elasticity of less than one).

As income grows, people begin to demand higher quality cereal crops, fruits and vegetables, and meat. This impact of income growth could be one factor explaining why world prices of dairy, meat and horticultural crops have not fallen over time (see Figure 4). As income grows further, the demand shifts to products that require less preparation and to food consumed away from home (e.g., in restaurants). At this stage, the demand for farm level products actually changes very little with a change in income. Overall, while increases in income will shift out the demand curve for agricultural production, this shift grows smaller as income levels rise. Rising incomes also tend to



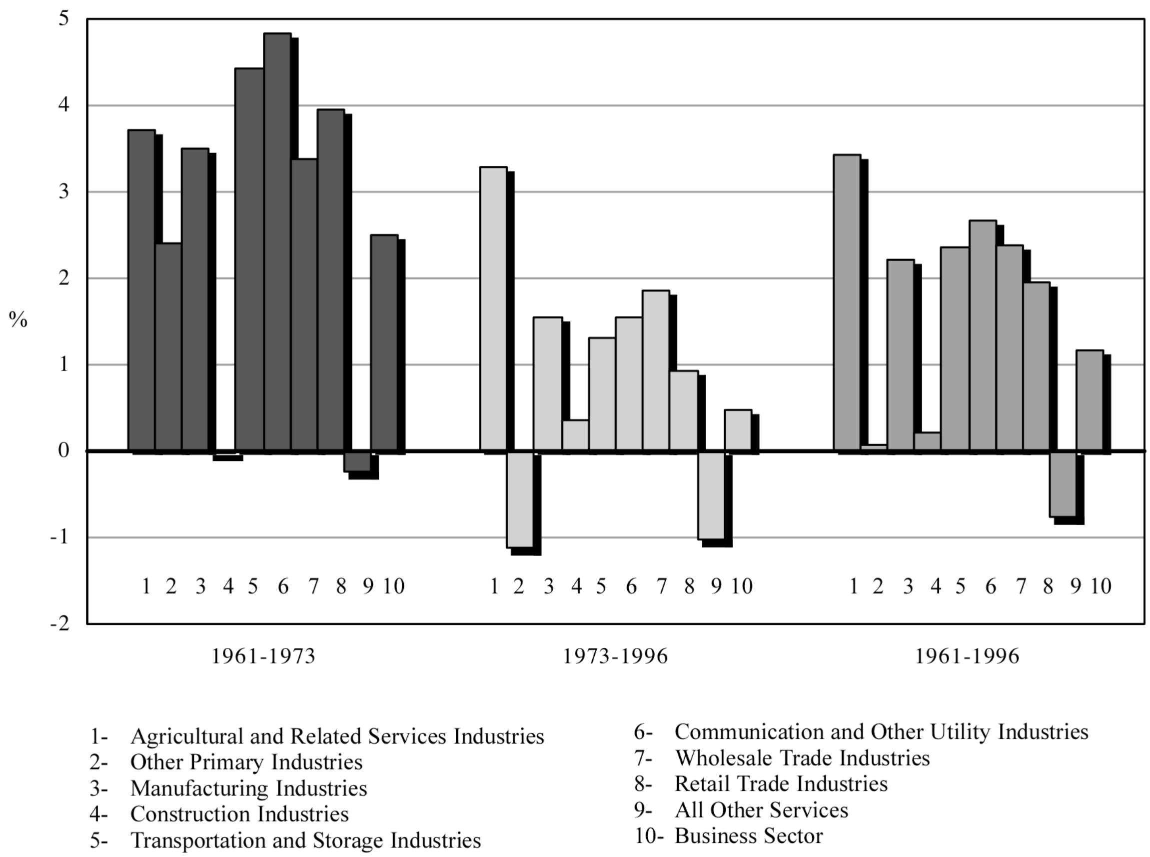
Source: FAO 2004b. p. 11.

Figure 4: World Real Prices (1991-92 Index = 100) for Agricultural Commodities, 1961-2002

slow population growth in low income countries, which further slows the increase in the demand for agricultural products.

On the supply side, the supply curve of agricultural products has shifted out due to two primary factors. One source has been an increase in agricultural acreage. While acreage increases were an important source of supply increases prior to the 1950s, since then they have become less important as will be discussed below.

The second and more important source is an increase in productivity. For instance, over the period 1961-1996, agriculture had the fastest rate of productivity growth of any sector in the Canadian economy. Baldwin, et al. estimate that labour productivity grew at 4.5 percent annually, while multifactor productivity grew at an annual rate of almost 3.5 percent (see Figure 5 for a comparison of multifactor productivity growth in agriculture and other sectors of the Canadian economy).



Source: Baldwin, et al., p. 19

Figure 5: Canadian Multifactor Productivity by Industry Group, Annual Growth Rates, selected periods

Agriculture contributed 13.0 percent of the aggregate productivity growth in Canada over this period, even though the sector made up only 4.0 percent of value-added activity in the economy.

As well, productivity growth in Canadian primary agriculture has been greater than that in the U.S. over the 1960s and 1970s. Capalbo and Denny estimate that over the period 1962-78, labour productivity in Canada grew at an annual rate of 5.54 percent (compared with the U.S. rate of 4.87 percent), while total factor productivity grew at 2.37 percent (compared with 1.41 percent in the U.S.).[3] The U.S., it should be noted, has had greater productivity growth than countries in western Europe (Ball, et al.).

[3]The greater growth in total factor productivity in Canada was the result of greater output growth and lower input growth compared to the U.S. Total input use in Canada increased by only 0.01 percent over the 1962-78 period, while total inputs increased by 0.31 percent in the U.S. Total output in Canada rose 2.37 percent, while total output in the U.S. rose 1.72 percent (Capalbo and Denny).

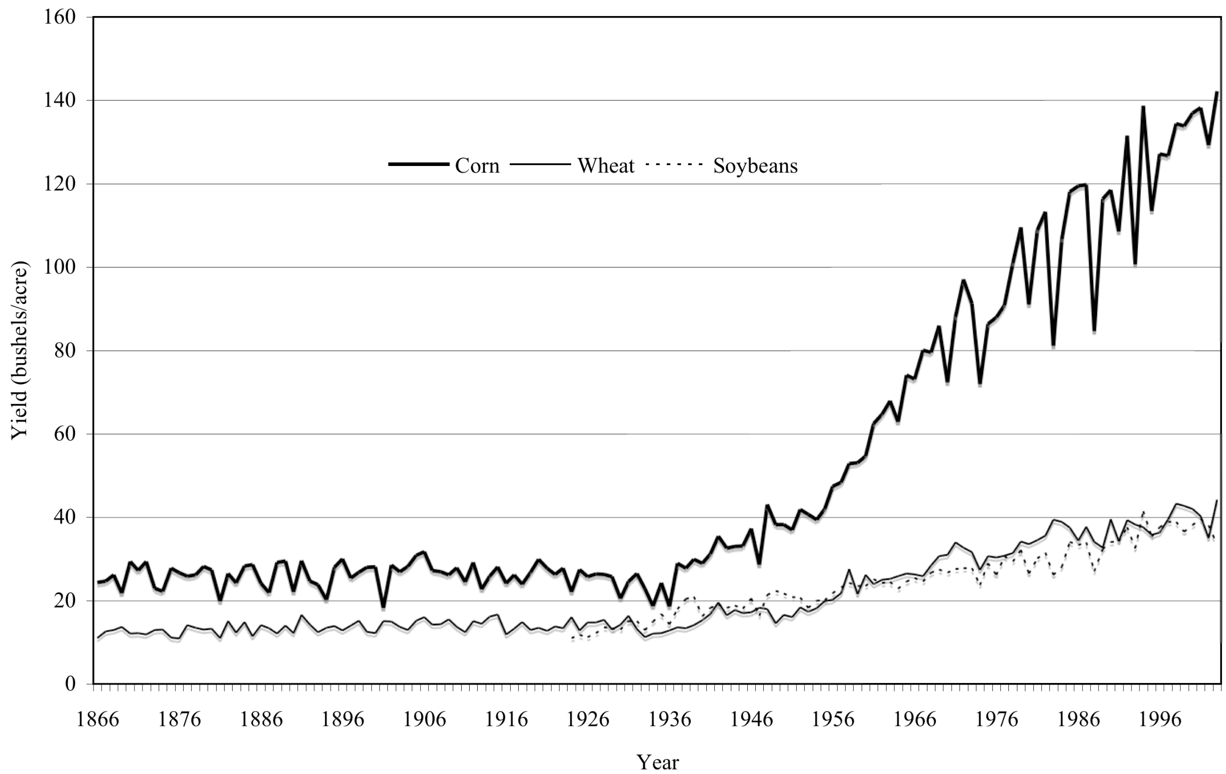
Productivity increases in agriculture have come from two related sources. One source has been the general tendency to reduce labour in agriculture and to substitute it with machinery and other inputs such as fertilizer and chemicals (Gardner). This input substitution has generally resulted in a lowering of the costs associated with production. The second source of productivity increase has been an increase in yields as the result of the development of new varieties; these new varieties typically required significant inputs of fertilizer and chemicals to realize their yield potential, thus providing a key linkage between these two sources of productivity growth.

The source of these productivity increases has been investments in research, development, and extension work by public and private organizations. Beginning with the work of T.W. Schultz and Zvi Griliches in the 1950s, the return to investment in agricultural research has generally been found to be high – typically above that of investment elsewhere in the economy (see Alston, Norton and Pardey, and Gardner, for a review of this literature).

Figure 6 shows the yields of corn, wheat and soybeans in the U.S. from 1866 (from 1924 in the case of soybeans) until the present. Yields were relatively flat until the latter half of the 1930s when they began to increase for all three crops. Although yields have continued to increase on average, there is some evidence that the rate of growth is slowing over time.

Table 1 shows the average annual growth rate of corn, wheat, and soybeans in the U.S. for selected periods. For both corn and wheat, yield growth was largest from the 1940s through to the 1960s. The growth in yield during this period is consistent with the introduction of hybridization in corn, and the move to varieties of corn and wheat that responded well to fertilizer and more intensive management. Both corn and soybeans also had relatively high growth rates in the 1980s. Growth rates over the last 15 years have been relatively low for corn and soybeans (although wheat yields during this period have shown substantial growth). Evidence of a similar slow down in growth at the world level will be presented in the next section.

The changes outlined above have been occurring around the world. Figure 2 shows aggregate world



Source: USDA

Figure 6: US Yields for Wheat, Corn and Soybeans, 1866-2004

production and harvested acreage of cereals from 1961-2004; the figure also shows the average yield over the same period. Cereal production has increased by nearly 250 percent over the period. This increase is due almost entirely to a rise in yields, since harvested acreage has remained flat. As Figures 7 and 8 illustrate, the same story holds for pulse crops and for roots and tubers. Although there has been a small increase in harvested area since the late 1970s, most of the increase in production that has occurred has been due to higher yields.

A different picture exists for oil crops. As Figure 9 shows, both harvested acreage and yield have gone up during the period 1961-2004, with the result that total production has increased by nearly 500 percent. The situation with vegetables and melons is similar, with both yield and harvested acreage increasing – the result has been a roughly 400 percent increase in production (see Figure 10).

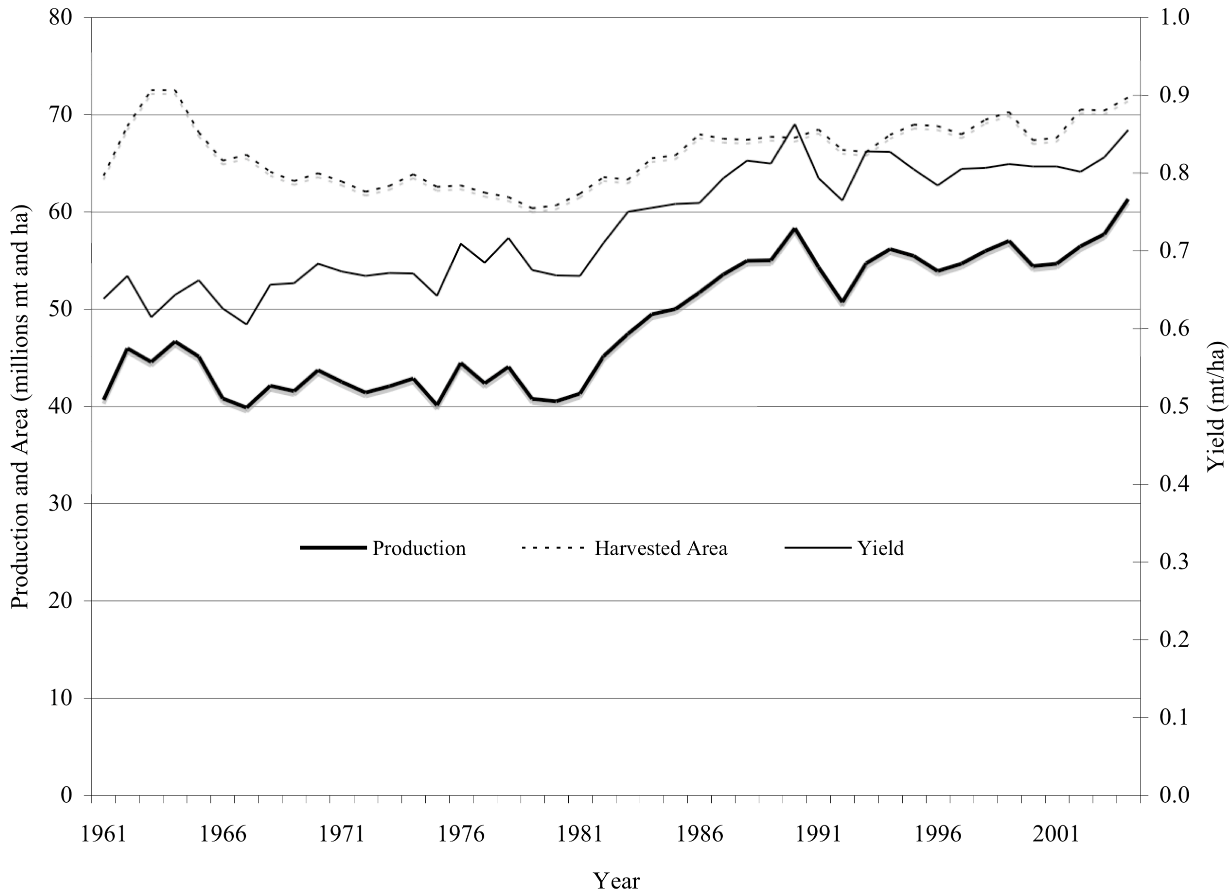
Table 1: Average Annual Yield Growth Rates for U.S. Corn, Wheat, and Soybeans, selected periods

Period	Crop		
	Corn	Wheat	Soybeans
1866-76	0.94	-0.09	–
1877-86	-1.02	2.57	–
1887-96	2.19	-0.97	–
1897-06	0.55	2.23	–
1907-16	-2.74	-2.96	–
1917-26	0.64	2.11	–
1927-36	-3.23	-1.38	2.44
1937-46	6.93	2.95	3.60
1947-56	2.42	1.61	0.61
1957-66	4.33	2.64	1.53
1967-76	1.86	1.42	0.27
1977-86	3.05	1.27	2.44
1987-96	0.62	0.54	1.21
1997-03	1.60	2.81	-1.69

Source: USDA

The price pattern for livestock products in the U.S. appears to follow that described above for crops. Figure 11 shows the real price of cattle, hogs and broilers in the U.S. over the 1950-2004 period. Generally prices have trended downward, with the possible exception of broiler prices during the 1990s. This different price pattern for broilers could be a result of the different industrial structure of this sector – i.e., the dominance of this industry by a small number of integrators may enable supply to be controlled so that price is maintained. As well, because of the high degree of vertical integration in the broiler industry, the reported prices have to be viewed with some skepticism (for instance, there is no spot market for broilers in the U.S.).

As with crops, part of the reason for this price decline is an increase in productivity. USDA figures, for instance, indicate the average number of pigs in a litter rose from 8.10 in 1993 to 8.94 in 2004 (USDA). This price pattern, however, is not uniformly found around the world. For instance, as Figure 4 shows, meat prices at the world level are been relatively flat since the early 1960s. As Tweeten (1998) points out, livestock offers more limited opportunities for expanded productivity than do crops, which could be one of the reasons for this discrepancy between the U.S. and world experience. The different price patterns could also be a result of the much smaller potential for the



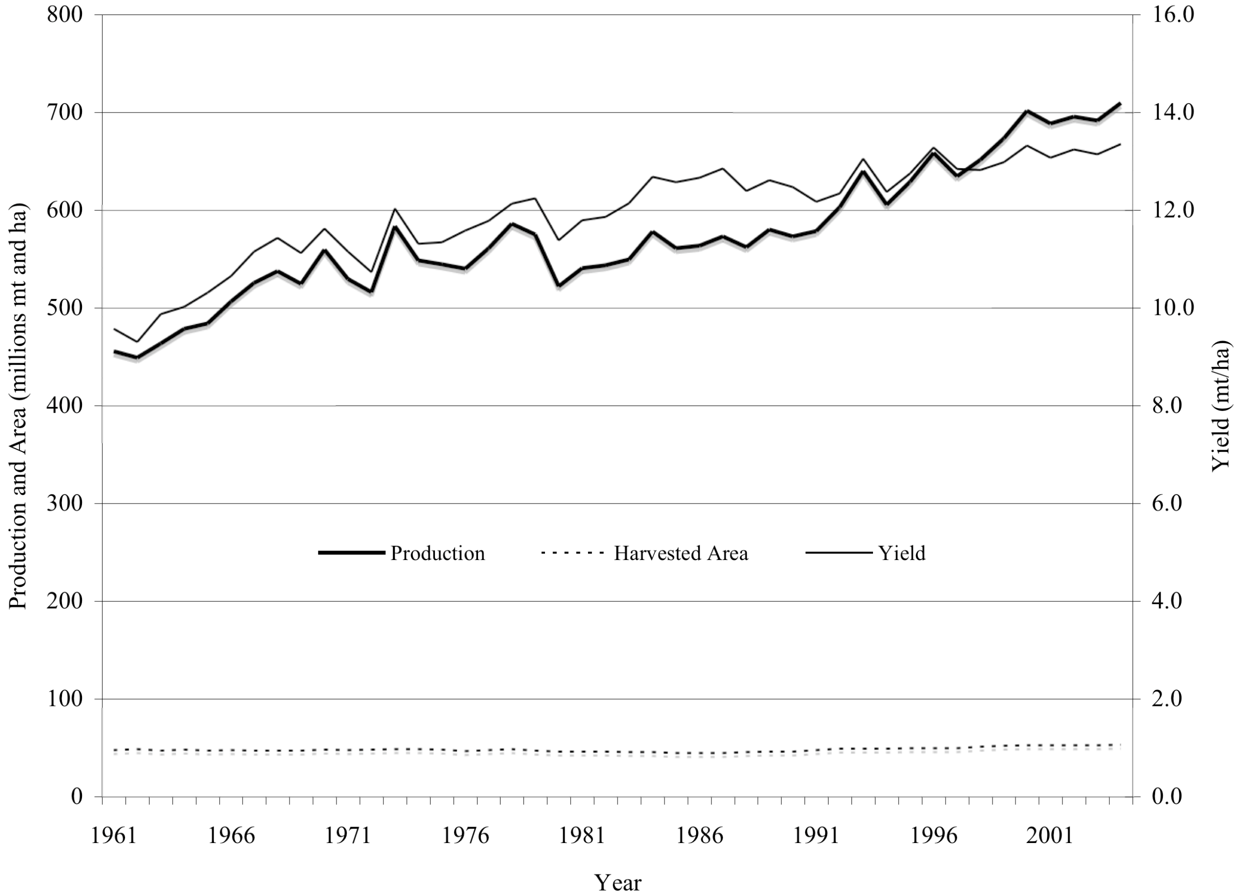
Source: FAO 2004a

Figure 7: World Production, Harvested Acreage and Yield of Pulse Crops, 1961-2004

growth of meat demand in the U.S. (the consumer shift to meat in response to higher incomes has already occurred in the U.S. while it is still occurring in much of the rest of the world).

3.2 Future Price Expectations

As has been discussed, the historical pattern of falling prices is the result of supply increasing more quickly than demand. The future pattern of prices will depend on this same supply and demand dynamic. However, both supply and demand are difficult to forecast into the future. As Tweeten (1998) documents, numerous examples – including some within the last 40 years – exist of analysts



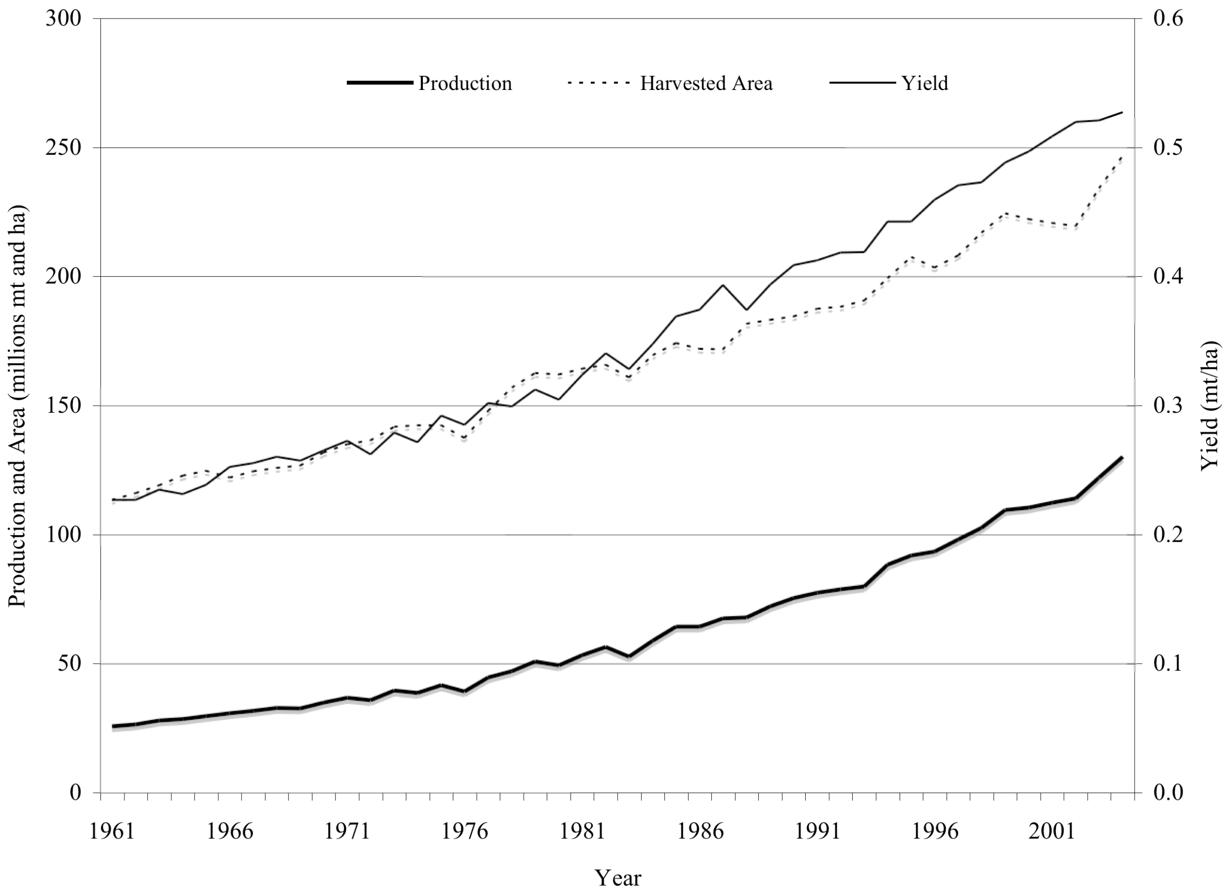
Source: FAO 2004a

Figure 8: World Production, Harvested Acreage and Yield of Root and Tuber Crops, 1961-2004

and observers predicting substantial increases in price, increases which never materialized.[4]

With this background in mind, it is interesting to examine what is happening to supply and demand currently and what might be expected in the future. There is some evidence that yield increases are slowing for some agricultural products. Table 2 shows that the growth in yield appears to be falling over time for cereals, vegetables and melons, and roots and tubers. In contrast, the yield growth of pulses appears to be remaining fairly constant, while the growth rate in the yield of oil crops appears to be increasing (see Tweeten (1998) for similar results). If this slowing of yield growth is a

[4]The best known example of a failed price prediction is likely Malthus' *Essay on the Principle of Population*. Other examples include Erlich's *The Population Bomb* and Meadows' *The Limits to Growth*. See Tweeten (1998) for details.

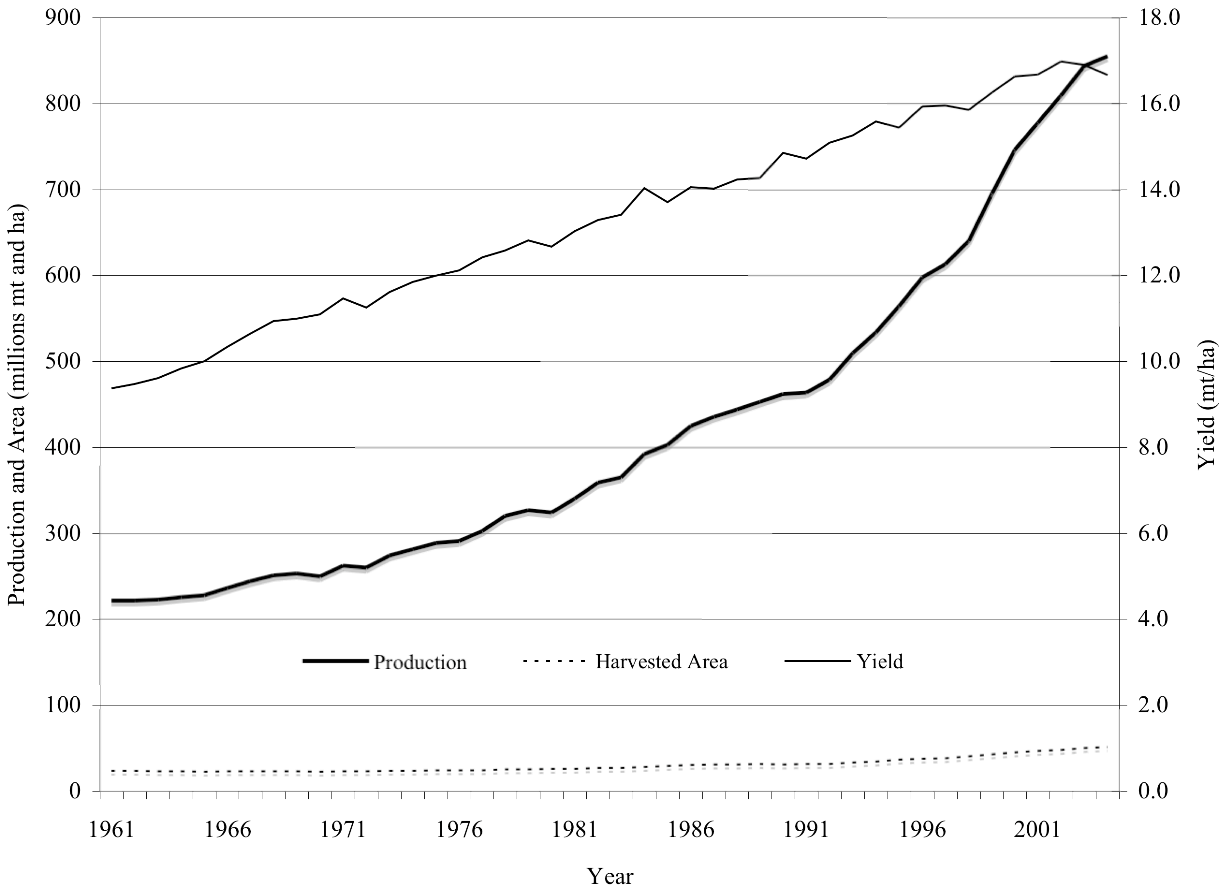


Source: FAO 2004a

Figure 9: World Production, Harvested Acreage and Yield of Oil Crops, 1961-2004

result of the increased difficulty in developing new varieties that yield better than existing varieties, then this slowing of growth may be expected to continue.

As was pointed out above, yield increases are only part of the reason for a shift outward of the supply curve. Increases in acreage can also increase supply. As Figures 2–10 indicate, acreage increases only appear to be significant in the case of oil crops and vegetables and melons. There is some evidence that acreage increases are still possible in Brazil, for instance. However, the degree to which production will be able to expand in that country depends on a host of factors, including disease problems, soil erodibility, transportation infrastructure, and R and D expenditures (Matthey, Fabiosa, and Fuller).



Source: FAO 2004a

Figure 10: World Production, Harvested Acreage and Yield of Vegetable and Melons, 1961-2004

On the demand side, there is even more uncertainty. Population and income forecasts differ substantially (Tweeten (1998) reports estimates of the number of years to zero population growth that range between 35 years and 133 years), which in turn dramatically affects the estimates of food demand. While Tweeten suggests that demand growth is likely to put some upward pressure on prices over the next 50 years, he is also careful to note that the price rises are unlikely to be major. However, large population growth combined with reduced agricultural production capacity (perhaps because of environmental problems) could lead to a situation where prices move sharply upward.

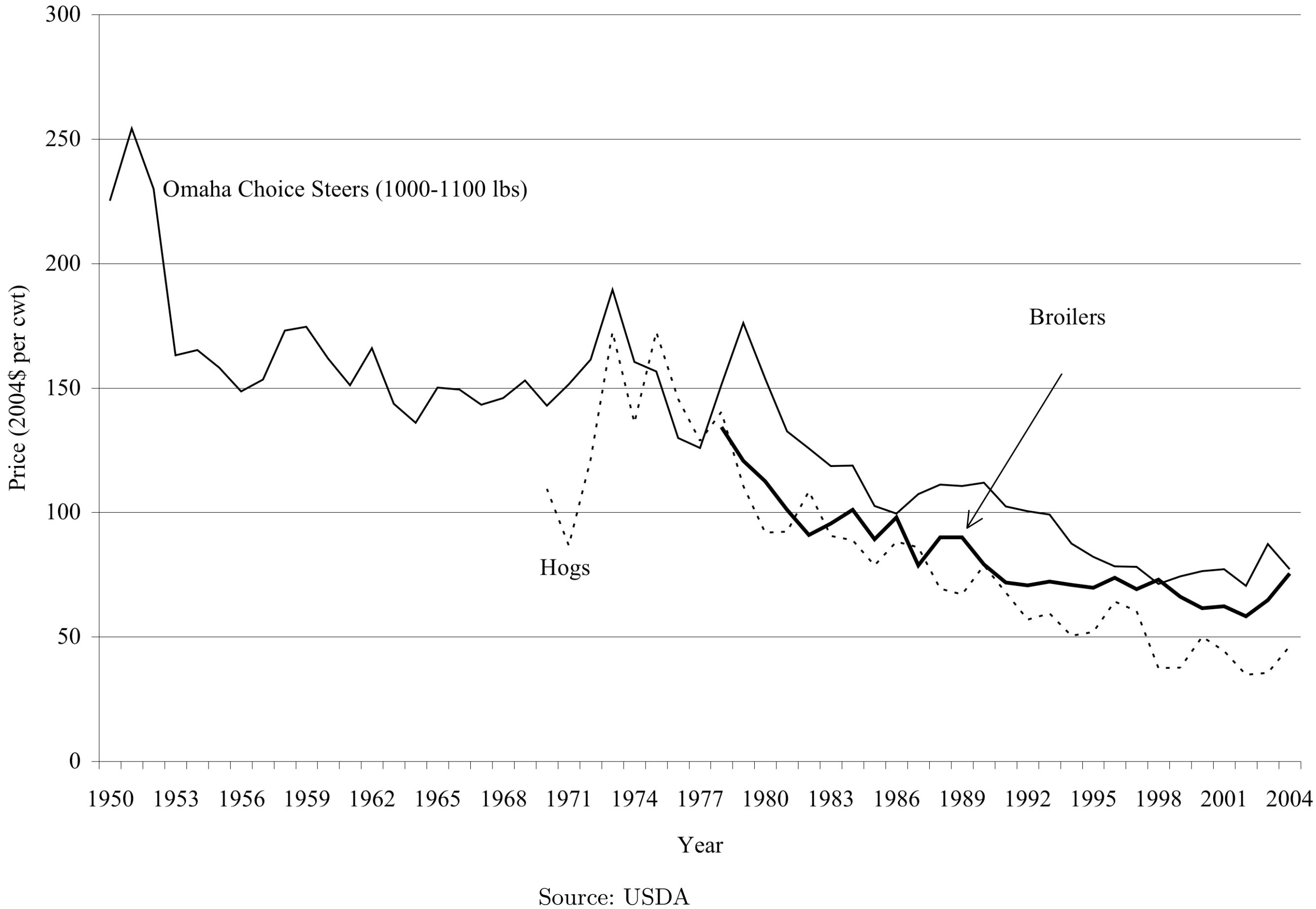


Figure 11: US Real Prices ($2004) for Beef, Hogs and Broilers, 1950-2004

4 A Reformulation of the Basic Model

The basic supply and demand model presented above takes as an underlying assumption the notion of a representative consumer and a representative producer. Thus, for instance, on the supply side, agricultural output is expected to rise as price rises because producers – each of whom is more or less the same – in a region and around the world intensify their use of inputs in response to the increase in the output price. While this representative agent model provides some key insights into the basic underlying economics of farm price determination, the assumption of relatively homogeneous agents does not capture an important feature of agriculture, namely that both producers and consumers differ in some very important ways.

Table 2: Yield World Growth Rates for Selected Agricultural Commodities, selected periods

Crop	Period			
	1961-71	1971-81	1981-91	1991-2004
Pulses	0.54	-0.09	1.73	0.57
Cereals	3.35	1.72	1.78	1.60
Vegetables and Melons	2.02	1.28	1.22	0.96
Roots and Tubers	1.53	0.55	0.32	0.71
Oil Crops	1.84	1.72	2.43	1.89

Source: FAO 2004a

Within a country or region, farmers differ in in such things as education, management skills, and the technology that they have adopted, and hence in their costs (or equivalently in their efficiency) of production. Cost also differ among countries because of different agronomic and climatic factors, different expenditures on research and development, different levels of education, and different levels of infrastructure. Consumers also differ, whether it be in their demand for certain types of food products (e.g., genetically modified food) or in their willingness to pay for food health and safety. As Fulton and Giannakas show, incorporating these differences into a model of the agricultural and food sector generates new insights into the distribution of the benefits and costs of changes to the agricultural system.

The purpose of this section is to develop a supply model that incorporates cost differences among farmers, both in a region and among regions. In this reformulation, an upward sloping curve is the result of a differential cost structure; as prices rise, farmers that previously found it too expensive to produce a particular product now find it profitable to do so, and the supply of the product subsequently increases.

The model – which is fully developed in the Appendix – considers m regions, each of which can potentially grow the product X; within each region, producers are differentiated according to a characteristic x_i, where i denotes the region in which the producers are located. Producers with higher values of x_i have higher costs; all 'producers', however, produce the same yield y_i. The differential cost of production can be due to differences in the productivity of land owned by farmers, differences in managerial ability, and/or differences in technology that the farmers have adopted.

Differences also exist among the m regions that can potentially grow product X. Different regions may have different yields (represented by y_i), different transportation costs to world markets (represented by t_i), different farm input costs (represented by w_i), as well as a different pattern of productivity differences among farmers due to differences in education or the technology that they have adopted (represented by the parameter μ_i).

Producers in region i can either produce product X or they can undertake an alternative activity. The model shows that producers with a differentiating characteristic less that x_i^* will produce product X, where x_i^* is the characteristic of the producer for whom the world price p_w just equals total cost $c_i + \mu_i x_i$ – i.e., x_i^* solves $p_w = c_i + \mu_i x_i^*$. The parameter c_i equals $t_i + w_i + r_i$ – i.e., $c_i = t_i + w_i + r_i$, where r_i is the opportunity cost of undertaking the alternative activity – and $\mu_i x_i$ is the additional cost over and above c_i that is incurred by a producer with characteristic x_i. The term $\mu_i x_i$ means that producers with different values of the characteristic variable x_i have different costs. Since the opportunity cost r_i is determined in part by the yield of product X relative to that of the alternative activity, increases in y_i have the effect of reducing r_i (see Appendix for details).

Figure 12 shows the determination of x_i^* in three different regions. Consider the case where the world price is p_w. In region 1, x_1^* is determined by the intersection of p_w and $c_1 + \mu_1 x_1$ (see the left hand side panel), while in region 2, x_2^* is determined by the intersection of p_w and $c_2 + \mu_2 x_2$ (see the middle panel). Region 3, however, has no producers producing X, since $p_w \leqslant c_3$ (see the right hand side panel).

A rise in the world price to p_w' leads to an increase in the characteristic of the marginal producer in region 1 from x_1^* to $x_1^{*'}$; in region 2, the characteristic of the marginal producer rises from x_2^* to $x_2^{*'}$. In region 3, some of the producers are now producing the product; the marginal producer has a characteristic $x_3^{*'}$.

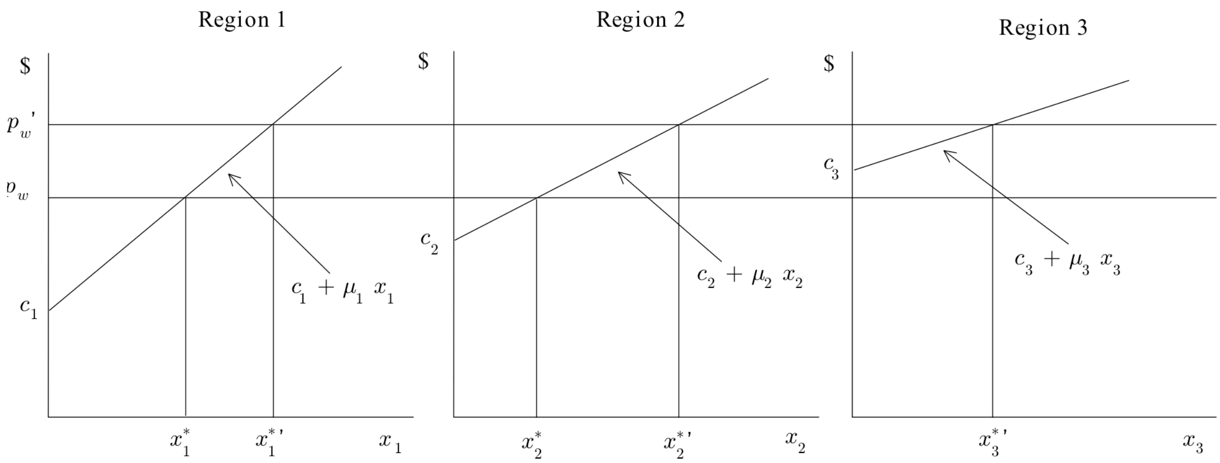


Figure 12: Determination of the Marginal Producer

Total output in each region is determined by taking the number of 'producers' in a region producing product X (which is assumed to be directly linked to the magnitude of x_i^*) and multiplying this by the common yield of the region (and each producer). Aggregating the production produced at each value of the world price over all the producing regions gives the aggregate world supply curve.

As Figure 13 indicates, an increase in the world price leads to greater output – i.e., the aggregate supply curve S is upward sloping. Two forces are at work to create this increase. The first is that as illustrated in Figure 12, an increase in the world price increases output in all producing regions, thus increasing output at the aggregate level. The second force at work is that as the world price rises, regions that were previously not producing the product may now find it profitable to do so (recall from Figure 12 how region 3 began production when the world price rose to p_w'). Thus, an increase in the world price can also affect the number of regions over which output is being summed.

If a region is large enough, changes in the underlying costs c_i or yield y_i of the region can result in a pivoting of the aggregate supply curve at the price point (and the corresponding output point) where this country enters production. The same outcome occurs if a number of regions all reduce their costs or increase their yields.

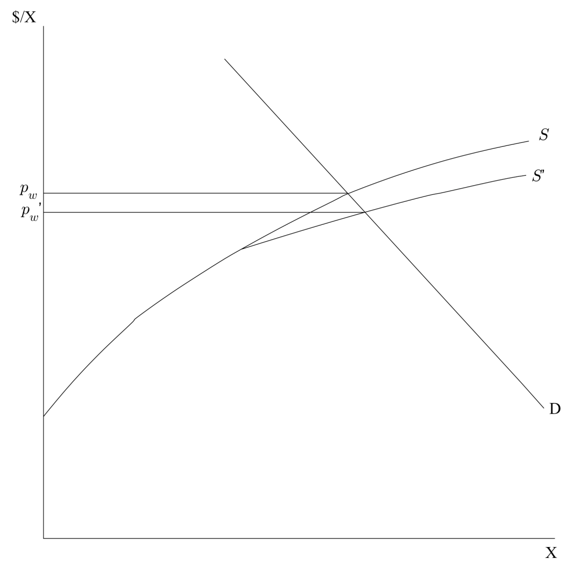


Figure 13: Shifting of the Aggregate Supply Curve

Taken in conjunction with the world demand curve, the downward pivot of the supply curve leads to a lower world price. Figure 13 illustrates how the downward pivot of the aggregate supply curve from S to S' results in a price drop from p_w to p'_w.

As discussed in earlier sections, the aggregate supply curve for field crops has been shifting outward over time. This outward shift of supply differentially affects producers within a region, as well as differentially affecting the different regions. The remainder of this section will examine these differential outcomes in more detail.

To provide some context to the analysis, soybeans will be used as an example. As shown in Figure 9, world production of oil crops has moved sharply up over the last 40 years. This increase has been in part due to increased yields and in part due to increased acreage. In recent years, much of this increased acreage has been in Argentina and Brazil, with Brazilian production more than doubling and Argentine production nearly tripling between 1991 and 2001. Brazil and Argentine have also increased their yield to the point where they are now roughly comparable to that of the U.S.

Both Brazil and Argentina have the potential to increase production significantly, since both have vast amounts of land that could be converted to soybean production. However, storage and transportation infrastructure in the two countries is much less developed than that in the U.S., the other major soybean producer; while this infrastructure is being improved, very large investments are still required to realize the full production potential of these two countries. The result of this poorer infrastructure is higher transportation and storage costs in Brazil and Argentina. Despite similar yields, variable costs of production are lower in the U.S. – in part due to better access to inputs such as fertilizers and chemicals. Land prices, in contrast, are much lower in Argentina and Brazil (Schnepf, Dohlman, and Bolling).

With this background, the remainder of the section will examine the impact of shifts in the aggregate supply curve on producers within a region and on producers in different regions.

4.1 Impact on Producers Within A Region

To begin the analysis, consider the impact of a region such as Brazil making an investment that lowers its transportation costs or increases yield. Suppose, for the moment, that only Brazil makes this investment. Since Brazil is a major player in the soybean market, this investment will likely have an impact on the world price. Specifically, as outlined in Figure 13, world price can be expected to fall.

Since other regions in the world have not changed their costs or yields, they will find that their price–cost margin has been lowered. The lowering of the price–cost margin has two major impacts on producers within a region. The first is that output falls somewhat as some farmers (i.e., the so-called marginal producers) shift from producing product X to producing the alternative crop. The second is that the returns (or rents) earned by farmers falls.

Figure 14 illustrates these two impacts. Consider first the impact on output. Suppose the world price is p_w. As Figure 14 indicates, the characteristic of the marginal producer is x_i^*; x_i^* also shows the total output produced in region i. With a fall in the world price to p'_w, the characteristic of the

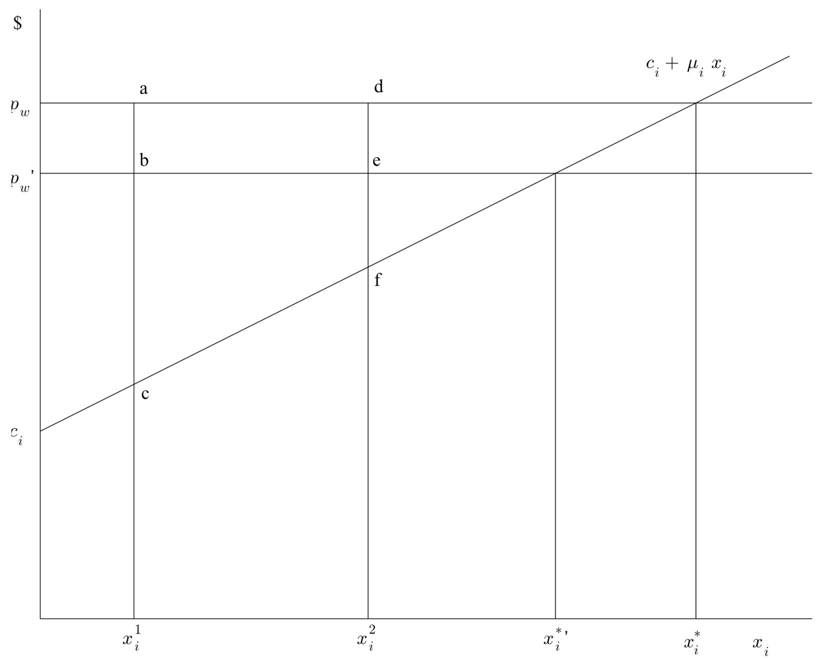


Figure 14: Price–Cost Margin and Economic Rent

marginal producer falls to $x_i^{*\prime}$ – the result is a fall in the total output produced in the region.

Now consider the impact of the price decline on the returns or rent earned by farmers in region i. Recall from above that farmers with characteristic $x_i \leqslant x_i^*$ earn a positive return from producing X, since for these farmers the world price is greater than their cost $c_i + \mu_i$ of producing the product. This return is referred to as economic rent. Since the producers in region i differ in their costs of producing X, the rents earned by the producers also differs. For instance, the rents earned by the producer with characteristic x_i^1 are equal to the distance ac, while the rents earned by the producer located at x_i^2 are equal to the distance df. Thus, as expected, the producers with the lower costs earn higher rents.[5]

This rent falls as the world price p_w falls. With a fall in price to p'_w, the rent earned by the producer located at x_i^1 falls from ac to bc. Similarly, the rent earned by the producer located at x_i^2 falls from

[5]Strictly speaking, the rent earned by a producer with characteristic x_i is equal to $(p_w - c_i - \mu_i x_i)y_i$. If yield y_i is assumed to roughly equal one, then the analysis in the text provides a rough approximation of the rent that is earned.

df to ef. Thus, as will be further discussed below, cost savings or yield increases in one country – recall that these changes were the cause of the price decline – lead directly to a loss of economic rents in the other countries.

In economic terms, the rents earned by producers are said to represent the residual returns to the fixed factors of production. The fixed factors of production are the inputs that the producer has to finance regardless of whether the product is produced or not. Thus, the fixed factors include inputs such as land, technology (which is embodied in machinery and equipment), and labour/management (which embodies education and training). Since the rents earned by producers represent what is available – after all other expenses have been met – to cover the fixed factors, rents are said to represent the residual returns to the fixed factors.

Since rents differ among producers, producers differ in their ability to purchase the fixed factors. Thus, producers that have lower costs (i.e., farmers with lower values of the characteristic x_i) will have a greater ability to pay the cost associated with the fixed factors. This differential ability to pay has a number of implications. For instance, given the price of land, producers with lower costs will be able to pay more for new technology than will producers with higher costs. In the context of a technology diffusion model (see the discussion in section 2), for instance, producers with lower costs of production may be in better position to adopt a new technology than farmers with higher costs. Since the adoption of new technology is often a way of lowering operating costs or increasing yields, financially successful farmers are often more likely to remain successful, while those that are not successful may find themselves unable to continue in operation.

Another important implication of differential costs among producers shows up in the land market. For field crops, farmers must have land to produce the crop and thus have access to the rents. As a consequence, the price of land is determined, in part, by the magnitude of the residual returns that are generated – i.e., the greater are the rents that can be generated, the more farmers will be willing to pay for land. Note that since the rents differ depending on the region (and the underlying cost differences among the regions), the price paid for land will be different in different regions. Under this interpretation, the lower land price in Brazil and Argentina is a reflection of the lower rents that can be generated in these two regions.

If all farmers were identical, then all would earn the same residual returns and everyone in a particular region would be willing to pay the same price for land. However, since it is explicitly assumed that farmers are differentiated, they will differ in the price that they are willing to pay for land. In particular, those farmers with relatively lower costs will have a higher willingness to pay for land. The consequence of this is that farmers with relatively high costs, if they want to purchase land, will often have to end up overpaying for land (this overpayment is relative to what they can afford to pay). Alternatively, these farmers may decide to forego the purchase of land, and with it the resulting gains in economies of scale that often accompany such a purchase. As long as agricultural prices remain high, these farmers can often continue to operate without too much financial difficulty. One way that they are able to do so is to effectively earn a lower return on labour. Indeed, many farmers appear willing to earn a lower return on labour in exchange for having ownership of the land, and hence the ability to obtain capital gains on this land when it is sold.

If agricultural prices fall, however, farmers with relatively higher costs are faced with a financial problem. Because farmers have different cost structures, the impact of the loss of economic rent is not uniformly distributed across farmers. Consider, for example, farmers that have relatively low production costs (i.e., a farmer like the one located at x_i^1 in Figure 14). While a fall in the world price will reduce their rents, they likely have some margin remaining that can be used to cover their fixed costs (e.g., land and/or labour costs). However, for farmers with higher costs, the drop in world price can reduce their margin to such a degree that fixed costs cannot be covered. The returns that their farming operations are able to generate are no longer able to cover the cost of land, technology and even a small return to labour – the result is that the farmer is no longer generating sufficient income to be able to continue operations.

In summary, a lowering of the price–cost margin has differential impacts across farmers in a region. In particular, the higher cost farmers often find it difficult to finance investments in new technology or in land, both of which represent ways of lowering costs. The consequence is that cost differences among farmers are likely to result in differences among the farmers in their ability to respond to lower prices, which in turn affects their cost differences.

4.2 Impact on Producers In Different Regions

The lowering of the price–cost margin also differentially affects regions. Suppose as outlined above that a region such as Brazil is able to lower its costs of production. If this region is large enough and the cost reduction is great enough, the world price can be affected.

Figure 15 illustrates the impact of this reduction of the world price on the region that initiated the cost saving, as well as on a region that did not introduce a cost saving. Suppose that before this cost reduction occurs, the world price is p_w. With the world price at p_w, output in region 1 and region 2 is given by x_1^* and x_2^*, respectively; aggregate rent in the two regions equal $p_w\, a\, c_1$ and $p_w\, d\, c_2$, respectively.

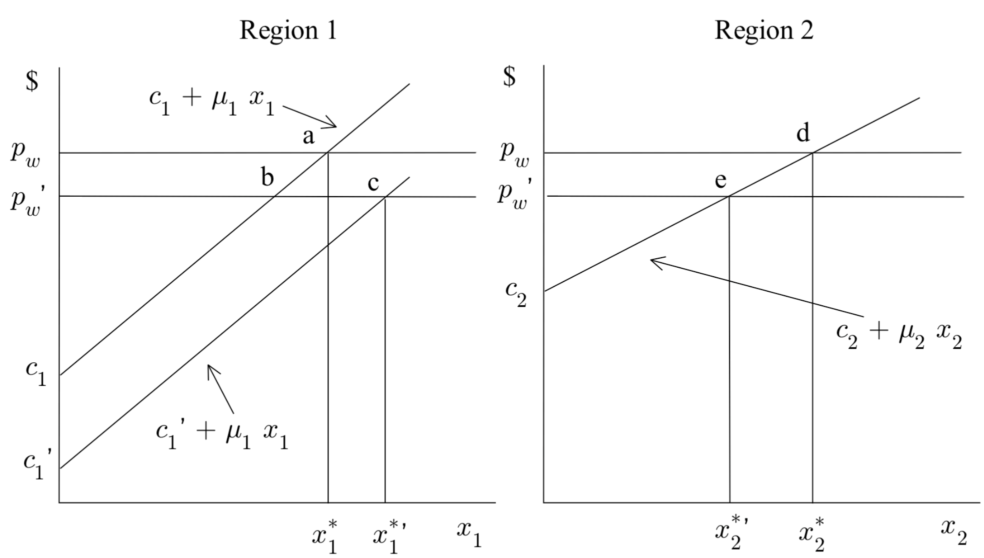


Figure 15: Regional Impacts of Cost Savings

Suppose now that region 1 is able to lower its costs of production – e.g., by lowering transportation costs t_1 or by increasing yields y_1 – and that region 1 is sufficiently large that this reduction in cost leads to a rotation downward of the aggregate supply curve (see Figure 13). This new world price is given by p'_w in Figure 15. Note that since region 1 makes up only a portion of world supply and the world demand curve is not perfectly inelastic, the reduction in the world price will be less than the reduction in costs.

The impact of the reduction in costs by region 1 and the subsequent fall in the world price can be traced through using Figure 15. Since the costs in region 1 have fallen by more than the fall in the world price (costs in region 1 are now given by c'_1), output in region 1 increases from x_1^* to $x_1^{*'}$. Output in region 2, however, falls from x_2^* to $x_2^{*'}$. Aggregate rent in region 1 increases from $p_w\,a\,c_1$ to $p'_w\,c\,c'_1$, while aggregate rent in region 2 falls from $p_w\,d\,c_2$ to $p'_w\,e\,c_2$. Thus, producers in region 1 are better off as a result of the cost reductions that were introduced in that region, while the producers in region 2 are worse off.

These same dynamics are, of course, at work if region 2 was the region lowering its costs; in this case region 2 would benefit from the lower costs, while region 1 would lose. Thus, both regions find it desirable to lower their costs and/or increase their yields. This conclusion holds regardless of whether the other region has been able to lower its costs or not. For instance, if, in the example in Figure 15, region 2 was able to lower its costs, it would be able to benefit from this drop in costs. Thus, regardless of what the other region does, regions always find it desirable to lower their costs and/or increase their yields.

Table 3 illustrates this situation in the context of a game between two regions. Each region has two strategies that they can employ: (1) make an investment that lowers costs; or (2) not make the investment and have costs remain the same. If neither region makes the investment, both regions earn rents equal to 10 (the absolute magnitude of the rents is not important; what is important is their relative size). Note that the first term in the bracket refers to the rents of region 1, while the second term refers to the rents of region 2. If region 1 makes the investment, while region 2 does not, then region 1's rents rise to 15, while those of region 2 fall to 7. Conversely, if region 2 makes the investment, while region 1 does not, then region 2's rents rise to 15, while those of region 1 fall to 7. If both regions make the investment, their respective rents equal 12. The equilibrium solution to this game is that both regions will invest and lower their costs. As discussed earlier in the report, one of the implications of the two regions choosing these strategies is that the world price of the product being produced will fall.

Table 3: Two Region Investment Game

		Region 1	
		Don't Invest	Invest
Region 2	Don't Invest	(10,10)	(15,7)
	Invest	(7,15)	(12,12)

In the game illustrated in Table 3, the equilibrium outcome gives rise to greater rents for both regions. This outcome is not the only one that is possible. Table 4 illustrates a situation where both regions lose if they undertake the investment strategy (the payoff (9,9) is worse than the payoff (10,10)). However, despite the fact that both regions are worse off by investing, the equilibrium strategy is for both regions to invest. This conclusion emerges from the observation that region 1 always benefits from investing, regardless of what region 2 does. Similarly, region 2 always benefits from investing, regardless of what region 1 does. Thus, in equilibrium, both regions will invest.

The situation illustrated in Table 4 is an example of the well-known Prisoners' Dilemma. Although Cochrane did not frame his treadmill model in game theory terms, the situation that he describes has strong similarities to the Prisoners' Dilemma.

Table 4: Two Region Investment Game: The Prisoners' Dilemma Case

		Region 1	
		Don't Invest	Invest
Region 2	Don't Invest	(10,10)	(13,6)
	Invest	(6,13)	(9,9)

The question of whether the conditions in world commodity markets are best captured by the game presented in Table 3 or the game presented in Table 4 remains an open one. It is known, for instance, that if the investment decisions lead to a parallel shift outward of the aggregate supply curve (see Alston, Norton and Pardey), then the game in Table 3 applies – i.e., investment by all regions leads to increased benefits for all regions (of course, each region would prefer that the other regions did not invest, but given that they do, each region still benefits). However, if the shift out of the aggregate supply curve is not parallel, then it is possible that the situation illustrated in Table 4 is relevant. As was shown in the first part of this section, explicitly considering the diversity among regions gives rise to an aggregate supply curve that does not shift out in a parallel fashion, thus giving rise to the possibility that regions may face a Prisoners' Dilemma situation.

Regardless of which game structure applies, however, the overall conclusion is clear. Each region (and each producer in a region) has an incentive to make investments that reduce its costs and increase its yields. Over the last century, this incentive has resulted in tremendous productivity gains in primary agriculture and a shift outward of the aggregate supply curve. For many commodities, this increase in supply was greater than the increase in demand coming from increased population and higher incomes. As a result, prices of primary agricultural products have tended to fall over time, with this price pattern more likely to occur in field crops.

5 Discussion and Implications

Agricultural prices are determined in a world market by the forces of supply and demand. Historically, the price of agricultural products has tended to decline as supply increases, linked primarily to research and development, have outstripped demand increases. The conceptual model developed in Section 4 shows that aggregate world supply is determined by a host of factors, including the cost of production and yield levels in various regions around the world. As a consequence, changes in these factors will have an influence on aggregate supply and hence on world prices.

Given this context, a region can remain competitive only if it is able to reduce its costs and increase its yields at the same time that other regions are doing likewise. As discussed in the paper, failure to do so will result in lower output and, perhaps more importantly, a loss of rent. The loss of rent from the inability to remain competitive has differential impacts on producers. While all producers suffer a loss, those with higher costs may be particularly hard hit.

The mechanisms available to a region to maintain its competitiveness are well known and involve actions and activities by producers, governments and private business. Farmers can contribute towards remaining competitive by ensuring they are using the best varieties for their region and that they are effectively using chemicals and fertilizers. Education is critical (while the provision of education may be something that government helps provide, farmers must be aware of the benefits that it can provide), as is the adoption of appropriate technology.

Individual action by producers, while critical, is not sufficient to guarantee that a region can remain cost competitive. Also important are the actions by private business and government. Transportation and storage infrastructure, for instance, must be constantly enhanced. Inputs must be made more effective, and new varieties – be they in the public or private domain – must be developed. Since there appears to be some evidence that yield increases are being increasingly difficult to obtain, greater investment in research and development will be required just to keep yields constant; this, of course, is not enough since a region will likely require substantial yield increases to remain competitive with other regions.

The costs faced by producers are not just determined by the price of fertilizer or the rate charged by the elevator or railway. Also included in the costs are what can be called transaction costs – the costs of such things as making deals, fulfilling contracts and obligations, and monitoring performance. These costs cannot be lowered by technological innovations – rather, they must be addressed through organizational innovations – changes to the way that activities and business are organized and structured.

Attention must also be paid to the fact that producers are not homogeneous, and that they can often find themselves in a downward spiral in which higher costs restricts their ability to bid for land or purchase new technology, which in turn further reduces their cost competitiveness. More generally, it is critical to note that unless all farmers have access to resources that can be used to maintain and enhance their cost competitiveness, it is likely that they will eventually be pushed out of the industry. This conclusion is, of course, predicated on the belief that agricultural commodity prices will continue to decline over the long run. While this outcome is not a given, historical evidence along with best guesses of the future indicate that betting against this outcome would likely be foolhardy.

Given this background, the question must be asked whether existing policy measures are effective as they can be in ensuring on-going competitiveness for the Canadian agricultural sector. For instance, do the revenue/income stabilization programs that have been used in Canada over the last 20 years provide farmers with both the incentive and the ability to remain cost competitive? Do the existing policies provide sufficient incentive and opportunity for organizational innovation?

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A Appendix

Consider the producers in region i (there are m potential regions, with $i = 1, \dots, m$). Within this region, producers are differentiated according to a characteristic x_i, where x_i is assumed to take values between zero and one. Each "producer" in the region is assumed to have access to the land and inputs necessary to produce a yield y_i of product X. However, because of producer cost differences, the returns (or rents) earned from this output differ among producers. Specifically, the profits earned by farmer x_i in region i are given by $\pi_i = (p_w - t_i - w_i - \mu_i x_i) y_i$, where p_w is the world price for product X, t_i is the transportation costs of getting the product from region i to the world market, w_i is the cost of farm inputs, and $\mu_i x_i$ are additional costs unique to each producer. The parameter μ_i is a non-negative cost parameter; the interaction between this parameter and the producer characteristic x_i means that producers with higher values of x_i have higher costs of production. This differential cost of production can be due to differences in the productivity of land owned by farmers, differences in managerial ability, and/or differences in technology that the farmers have adopted.

Differences also exist among the m regions that can potentially grow product X. Different regions may have different yields, different transportation costs, different farm input costs, as well as a different pattern of productivity differences among farmers due to differences in education or the technology that they have adopted. Thus, the parameters t_i, w_i, y_i and μ_i can all differ among regions.

Producers in region i are assumed to have two options – they can either produce product X or they can produce an alternative product. The returns from the alternative product are assumed to be the same for all producers and to be equal to $\pi_i^a = r_i y_i$, where r_i is the yield-adjusted per unit return of the alternative product (the per unit return is adjusted so that the nominal yield of the alternative product equals that of product X – as a consequence, an increase in the yield of product X results in a fall in r_i).[6] Each producer is assumed to produce the product that provides the highest returns.

Specifically, producers with $x_i \leqslant x_i^*$ will produce product X, while those with $x_i > x_i^*$ will produce the alternative product, where x_i^* is the characteristic of the producer such that $\pi_i(x_i^*) = \pi_i^a(x_i^*)$. Thus, x_i^* identifies what can be defined as the marginal producer – the producer that is just indifferent between producing product X and the alternative product. The characteristic x_i^* can be determined by solving $(p_w - t_i - w_i - \mu_i x_i)y_i = r_i y_i$ for x_i. Thus,

$$x_i^* = \frac{(p_w - c_i)}{\mu_i} \tag{1}$$

where $c_i = t_i + w_i + r_i$. Note that since t_i, w_i, μ_i and y_i (and hence r_i) differ among regions, c_i also differs among regions.

Rearranging equation 1 shows that x_i^* is the characteristic of the producer for whom the world price p_w just equals total cost $c_i + \mu_i x_i$ – i.e., x_i^* solves $p_w = c_i + \mu_i x_i^*$. Figure 1 shows the determination of x_i^* in three different regions. Consider the case where the world price is p_w. In region 1, x_1^* is determined by the intersection of p_w and $c_1 + \mu_1 x_1$ (see the right hand side panel), while in region 2, x_2^* is determined by the intersection of p_w and $c_2 + \mu_2 x_2$ (see the middle panel). Region 3, however, has no producers producing X, since $p_w \leqslant c_3$.

A rise in the world price to p_w' leads to an increase in the characteristic of the marginal producer in region 1 from x_1^* to $x_1^{*'}$; in region 2, the characteristic of the marginal producer rises from x_2^* to $x_2^{*'}$. In region 3, some of the producers are now producing the product; the marginal producer has a characteristic $x_3^{*'}$.

To determine total output from each region, assume that x_i is uniformly distributed between zero and one. Thus, x_i^* gives the percentage of the producers in region i that produce product X. Since each "producer" produces a yield y_i and assuming that there are n_i producers in region i, total

[6] An example illustrates the formulation of r_i. Suppose y_i =1.0 mt/ha, while the price and yield of the alternative product are \$50/mt and 0.80 mt/ha, respectively. Thus, $r_i = \frac{50*0.80}{1.0}$ =\$40/mt. An increase in the yield of product X to y_i =1.25 mt/ha results in a fall in r_i – i.e., r_i falls to $\frac{50*0.80}{1.25}$ =\$32/mt.

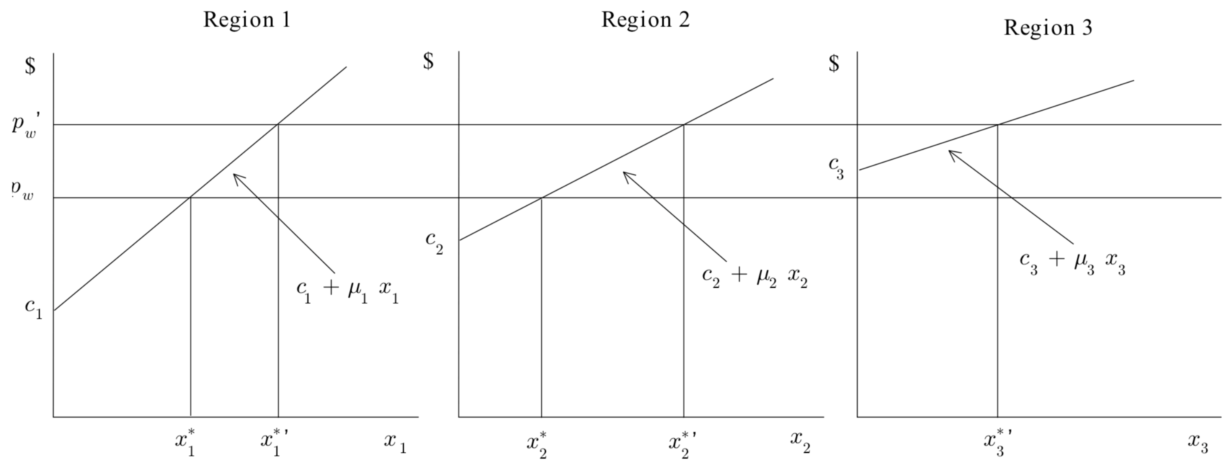

Figure 1: Determination of the Marginal Producer

output $X_i = x_i^* n_i y_i$ from region i is given by

$$X_i = (p_w - c_i)\lambda_i \tag{2}$$

where $\lambda_i = \frac{n_i}{\mu_i} y_i$.

Equation 2 indicates that regional output is proportional to the difference between the world price of the product and the cost c_i of producing this product, where the cost (c_i) contains the production and transportation costs $(t_i + w_i)$, as well as the opportunity cost (r_i) associated with the production of the alternative product. An increase in the world price of the product leads to an increase in production in region i as producers that were previously producing the alternative now shift production to what is now a more profitable product. Regional output is also proportional to the weighted regional yield $(\frac{n_i}{\mu_i} y_i)$, where the weight is number of producers n_i divided by the non-negative cost parameter μ_i. Thus, an increase in the regional yield – for instance, because of the development of new varieties – will lead to an increase in production. In addition, since r_i is a yield-adjusted per unit return, increases in y_i also reduce r_i, thus leading to a further increase in output.

Total world supply X for any given world price p_w is obtained by summing the output over all regions. Thus,

$$X = p_w \sum_{i=1}^{k} \lambda_i - \sum_{i=1}^{k} c_i \lambda_i \tag{3}$$

where k ($k \leqslant m$) is the number of regions in which the production of X occurs. In inverse form, the supply curve can be written as

$$p_w = \frac{\sum_{i=1}^{k} c_i \lambda_i}{\sum_{i=1}^{k} \lambda_i} + \frac{X}{\sum_{i=1}^{k} \lambda_i} \tag{4}$$

At the aggregate level, an increase in the world price leads to greater output – i.e., the aggregate supply curve is upward sloping. Two forces are at work to create this increase. The first is that, as outlined in equation 2 and illustrated in Figure 12, an increase in the world price increases output in all producing regions, thus increasing output at the aggregate level. The second force at work is that as the world price rises, regions that were previously not producing the product may now find it profitable to do so (recall from Figure 12 how region 3 began production when the world price rose to p'_w). Thus, an increase in the world price can also affect the number of regions over which output is being summed.

Routine calculations show that the intercept of the aggregate inverse supply curve in equation 4 will increase as a high cost region is added to the summation – i.e., the intercept increases if the costs c_i of the new region are greater than those of any of the existing regions. This condition, of course, holds when a new region enters production due to a rise in the world price – the reason this region had not previously produced is that its costs were higher than the world price (note from equation 1 that a region will not be producing if $p_w \leqslant c_i$) and hence higher than the costs of the regions that were producing (for the countries that are producing, $p_w \geqslant c_i$). It is also easily shown that the slope of the aggregate inverse supply curve becomes smaller with the addition of a new region (the term $\sum_{i=1}^{k} \lambda_i$ always increases when an additional λ is added). Thus, as the price rises, the output curve presented in equation 4 shifts upwards and rotates downwards. The lower envelope of the set of supply curves that is generated as price rises represents the aggregate supply curve for product X.

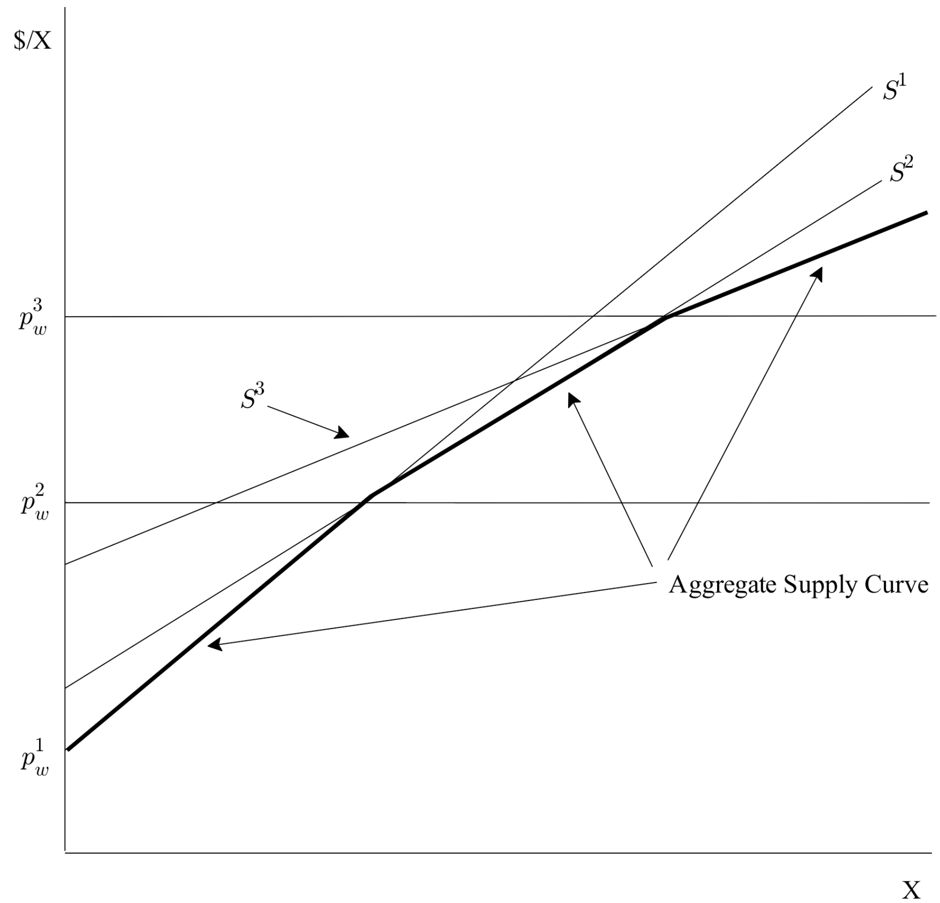

Figure 2: Determination of the Aggregate Supply Curve

Figure 2 shows the construction of the aggregate supply curve. Supply curve S^1 is the operable supply curve when the price is above price p_w^1 but below price p_w^2. When price moves above price p_w^2, a new region enters and the supply curve represented in equation 4 shifts up to S^2. However, only the portion of S^2 that lies below S^1 is relevant, since when price falls below price p_w^2 the supply curve price S^1 is once again the operable supply curve. When price moves above price p_w^3, another new region enters and the supply curve represented in equation 4 shifts up to S^3. However, as discussed above, only the portion of S^3 that lies below S^2 is relevant. Taken together, the aggregate supply curve is represented by the lower envelope or boundary of S^1, S^2, and S^3. This lower boundary (shown as the dark line in Figure 2) is the aggregate supply curve at the world level.