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AN ECONOMIC ANALYSIS OF THE IMPACT OF RISING REAL ENERGY PRICES ON INTERREGIONAL COMPETITION IN FRESH POTATO AND APPLE PRODUCTION AND DISTRIBUTION

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AN ECONOMIC ANALYSIS OF THE IMPACT OF RISING REAL ENERGY PRICES ON INTERREGIONAL COMPETITION IN FRESH POTATO AND APPLE PRODUCTION AND DISTRIBUTION

By

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ABSTRACT

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The objective of this thesis is to analyze the economic impact of rising real energy prices on the cost competitiveness of producing and marketing Michigan's fresh apples and potatoes, as compared with Washington's. Most literature on the topic suggests that energy input costs represent a small portion of the cost of production, and thus will not increase agricultural prices significantly as compared to other input costs such as land and labor. Rather than concentrating on energy as a percentage of costs alone, the emphasis here is on interregional competition. If interregional competition is altered due to energy input price increases, then it must be concluded that rising energy input prices do have a significant impact on agriculture. The conclusion reached is that it is in the increased cost of transportation, and not production costs, where total cost changes the competitive balance between the regions. This study concludes that the crucial factor in any regional change in competitive position due to energy input price

increases is related to the distance from the production site to the market.

Dedicated to

Margery L. Jordan

whose hard work and self-sacrifice
over the past five years has taught
me the meaning of responsibility

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While most leave to the end an acknowledgment of the author's spouse, I would like to begin with a word of thanks to Sherry A. Maddock. Rather than simply thanking her for support, more importantly, I would like to acknowledge both her emotional and intellectual force.

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My one regret is that my father is not here to share in this accomplishment.

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CHAPTER I

INTRODUCTION

The issue to be addressed is: "What increase in the price of fossil fuel inputs is required to affect the production flows in interregional competition?" The objective of this study is to analyze the economic impact of rising real "energy" prices on the cost competitiveness of Michigan's fresh apples and potatoes. The analysis will employ the following four steps; to:

1. construct comparative per unit cost of production and transportation budgets for Michigan and Washington in apples and potatoes;
2. construct comparative per unit energy budgets for the same states and commodities; the per unit dollar amount, and type, of energy will be measured, examining both direct and indirect energy requirements;
3. with the use of the above two budgets, the price of energy inputs will be increased to find the threshold price that changes the competitive balance between the two states and commodities; that is, can energy prices--both direct and indirect--affect the cost of production enough to shift the

costs in favor of the state that now produces and ships at greatest cost?

4. provide estimates of which market areas Michigan's commodities can be delivered to at lower cost; by varying the distance to market, the impact of rising energy prices on the viability of long-haul transportation can be tested. Concommitantly, the impact of transportation costs on interregional competition can also be examined.

As will be noted in the next chapter, many analysts have been concerned primarily with the amounts of energy used in the production process. However, from the view-point of the producer, the issue to address is in terms of dollars of output relative to dollars of input, rather than energy output relative to energy input. In a value-oriented society,[9] the producer makes decisions on the basis of the value society places on his/her products; the cost of energy being only one of the costs of production. Thus the emphasis is on the price of energy rather than simply the amount employed in the production and transportation stages.

Procedure

This is the first of a two-part study. The comparative statics approach employed here does not deal with the dynamics of the implied adjustment process. Part Two of the study will examine the adjustments and dynamics that will follow the conclusions here reached.

Washington has been chosen in part because their fresh apple and potato industries compete successfully with Michigan's, even over great distances. Furthermore, regional variations in the energy consumed in agricultural production appear related primarily to irrigation and chemical use. Due to the amount of irrigation necessary in the Northwest, that area is sensitive to increased energy prices, particularly when compared to the rain fed areas around the Great Lakes. Dvoskin and Heady conclude that a tripling of energy prices will result in declining farm income in three regions: the South Central, Southwest, and Northwest. The South Atlantic and the North Central regions, including Michigan, increase farm income by 27 percent and 14 percent, respectively.[16]

For the commodities chosen, Washington transports much of its fresh produce to the Midwest. Washington's fresh produce is in direct competition with the Michigan apple and potato industries in both the Midwest and elsewhere. Therefore, not only will irrigation costs increase due to energy price increases, but the cost of transportation will also be affected. On the other hand, the use of energy-intensive chemicals in Michigan produces a situation which may adversely affect Michigan farmers when the price of energy inputs rise. Thus, given the energy price effects on irrigation, chemical use and transportation, plus the fact that Washington and Michigan compete in many of the same markets, a comparison between these two states should give a clear example as to whether interregional competition will change due to price increases in energy inputs.

Three related reasons account for the choice of potatoes and apples as the selected commodities. First, these commodities represent sizable industries in both states. Second, Michigan and Washington compete in these commodities. Finally, both commodities require substantial fossil fuel inputs.

Organization of Thesis

The literature review of Chapter II will focus primarily on those sources, published since 1973, which deal generally with the "energy and agriculture" topic. While literature on the energy/agriculture topic has expanded rapidly over the past five years, the interest here is on a relatively few, basic resources from which most other materials appear to be derived.

Chapter III will examine the appropriate economic theory. The appropriate economic theory will be that which explains the substitution and output effects of a change in input price, and the changes in patterns of production and interregional competition. The assumptions underlying the analysis will also be introduced in Chapter III; assumptions modifying the economic theory and those relevant to energy use will be considered.

Chapter IV is a brief institutional description of both the fresh apple and potato industries and a description of each of the markets. Of interest will be the present regional supply distribution of Washington and Michigan products.

In Chapter V the comparative cost of production and transportation and energy budgets will be estimated. Of special concern will be the estimation of the cost related to the variable energy inputs, both direct and indirect energy requirements. The primary analytical section appears in Chapter VI, which will take place in three steps:

1. Examination of the budgets to analyze the proportion of total production costs accounted for by energy inputs, both with and without transportation costs.
2. Establishment of various "threshold" energy prices at which regional competition shifts in favor of the state that had previously produced and shipped at the highest cost.
3. The above will be repeated in each of the markets in which Michigan and Washington compete. Thus, not only will a set of threshold prices be established, but also the "threshold distance" will be found at which transportation costs cause a shift in the cost of supplying a market region.

Chapter VII will summarize the results, discuss the direction and strength of any changes, describe what rising energy prices will mean to Michigan producers, and suggest further points and issues to be taken up in subsequent studies.

CHAPTER II

REVIEW OF LITERATURE

Energy from fossil fuels is used in agriculture because it has been profitable to do so.[9] If this were not the case, United States agriculture would not have evolved into the most energy-intensive system of farming in the world.[40] There appears to be widespread agreement in the literature (for example, 9, 17, 25, 42) that despite the unquestioned importance of fossil fuels in the United States food system, they still contribute a relatively small share of total food cost.[42] While some studies[16,17,42] did attempt to empirically test this conclusion, most investigators appear to take it for granted that even a doubling or tripling of fossil fuel input prices will change production costs only about 2 to 8 percent. The conclusion is that fossil fuel prices do not have a significant impact on agricultural production, particularly relative to land as a residual claimant, and labor costs. On the other hand, some studies (notably, 9, 36, 40) suggest that such increases in fossil fuel input prices will have a measurable and important effect on food costs. In one (as noted in 36), Slesser examining the case for England, suggests that a quadrupling of real energy prices in the next 40 years would bring about a six-fold increase in food prices.

What must be noted when comparing these opposite conclusions is that the impact of rising fossil fuel prices differs among energy sources. The impact of natural gas or LP gas price increases are different than those of electricity.[8] Second, while fossil fuel costs do indeed constitute a small portion of the final costs of all food, more fossil fuels are used to produce and market some foods than others.[40] Furthermore, when examining the conclusion that the cost of production of food is only affected slightly by fossil fuel prices, one is confronted with two basic omissions. First, some studies, particularly Whittlesey and Lee[42], examine only the disembodied, or direct energy requirements in agriculture. Energy embodied in the manufacture and delivery of tractors, trucks, processing machinery, packaging materials, etc. was not measured or included. Recognizing this gap in data suggests that estimates of the significance of energy in agriculture remain tenuous. Here, an attempt will be made to include estimates of the indirect energy used in fertilizer and pesticides, as well as the embodied energy in truck transportation.

The use of energy also differs between regions due to fertilizer application, irrigation requirements, and transportation costs. While the price of energy may only increase costs 2 to 8 percent generally, the regional differences in irrigation as suggested by Dvoskin and Heady[16], and transportation costs, can in fact affect the competition between regions. Where two regions compete for the same market, an increase in the price of energy inputs can alter the existing competitive situations. As Carter and Youde point out[6]:

> The competitive position of a region or country in the production of a particular commodity may improve or deteriorate as a result of increased energy costs. Casavant and Whittlesey identify commodity and regional characteristics that determine the impact of higher energy-related transportation costs on interregional and international competition. Commodity factors include perishability, transportation mode adaptability, extent and location of processing, and elasticity of demand. Regional characteristics affecting competitive position include distance to (domestic or export) markets, available transport alternative, back haul possibilities, and seasonability of product movements. (p. 833)

While "literature reviews" are often a listing and critique of relevant bibliographical material, this chapter will instead establish some of the assumptions that will apply to the analysis, by way of the existing literature. The first assumption culled from the literature is related to why the concern is with changes in the price of fossil fuel inputs, rather than supply restrictions or interruptions. Adjustments facing agricultural producers are likely to be price-related rather than supply-related.[6,8,40] In developing the Mandatory Petroleum Allocation Program, the Federal Energy Administration (now Department of Energy) granted top priority to agricultural production. That is, 100 percent of current needs in agricultural production and processing of perishable products has been guaranteed.[40] In commenting on recent supply restrictions in California and throughout the country, both President Carter and then-Energy Secretary Schlesinger guaranteed agriculture would receive enough energy to meet current needs. While recent demands for increased amounts of diesel fuel by independent truckers forced President Carter to rescind this allocation temporarily, he reaffirmed the priority of the agricultural system in the July 15 "energy speech".

In addition, the literature suggests a concern with relatively large real price increases. While the exact level of price increases in the future is unpredictable, the model that will be developed will examine real energy price increases of up to 400 percent. If the current 15 percent per year real increase that existed between 1972 and 1976 (1976=100) continues, this assumption is not unrealistic, and the price in 1985 will be 300 percent higher than in 1975.[17] All of this of course is in addition to the recent price increases due to OPEC decisions which have raised imported crude oil almost 60 percent in six months, the crisis in Iran, and the new government's desire to sell their 3 to 6 million barrels a day production at a rate 30 percent higher than existing rates, and President Carter's "import quotas" set at 1977 levels. Each of these actions imply that the price of imported oil from the Mideast will continue to rise to unpredictable, and probably higher levels. Also, phased decontrol of domestic oil prices effective June 1, 1979 will have a significant, as yet undetermined, impact on energy prices, with or without a "windfall profits tax". Although this study will not be concerned with supply problems, it has been noted[8,9,17] that supply reductions may in fact occur in agriculture's use of natural gas and LP gas. About 70 percent of the LP gas is processed from natural gas, and agricultural production uses about 20 percent of the LP gas in the United States.[8] In fact, even diesel fuel seems to be in short supply in some parts of the country, delaying this year's planting. Yet, Carter and Youde have concluded that even if large energy price increases, relative to land and other inputs, did justify a "radical retooling" of the energy use in agriculture, a long lead time would be required.[6] Therefore, at least in the very short-run, there exist few substitutes for the energy inputs in agriculture.

It has also been observed that given the relatively small amount of energy use in the United States' food system (3 to 4 percent on farm) and the fact that capital equipment designed to operate on LP or natural gas is already in place, the potential for conserving large amounts of energy in agriculture will be limited and will be assumed impossible in the short-run.[6,8,16,17] More importantly, for the present analysis it will be assumed that the capital equipment has already been paid for. Furthermore, even if conservation were possible in the short-run, Dvoskin and Heady estimate that a 10 percent energy reduction would have a severe impact on food costs (up 55 percent) and would do almost nothing toward reducing United States energy consumption. The 10 percent reduction in energy use in agriculture would amount to only a 0.2 percent reduction in total United States energy consumption in 1972.[16]

With regard to sources of energy for agriculture, Connor[8] points out that agriculture is basically a solar energy processing machine and that solar energy has seldom been included in energy accounting analysis. However, from an economic viewpoint, the amount of solar energy stored in food commodities is of little concern because this energy is both free and has an unlimited supply.[17] The concern then is with fossil fuel energy and its numerous and quite different forms: natural gas, LP gas, electricity, etc. When solar energy is excluded, 99.89 percent of the energy inputs in rice production in the United States, for example, are from fossil fuel.[16]

Carter and Youde[6] contend that major long-term adjustment problems for agriculture will result from indirect effects such as the impact of energy prices on general price levels and economic growth rates. Although this may be true, this study will be concerned with the direct effects of increases in energy prices. That is, the effect of real energy price increases in electricity, fuel, fertilizer, transportation, irrigation, etc. This is done for two reasons; first, as Connor[8] notes, these indirect effects are difficult to assess since a general equilibrium model would be required (page 6). Second, it is believed that the indirect effects Carter and Youde discuss are far enough into the long-term that they will not affect the perception by farmers of a change in competitive advantage related to real energy input price increases.*

Most of the literature that examines the role of energy use in agriculture[16,17,25,26,27,30,31] concentrates primarily on production. Yet while 24 percent of the energy inputs in agriculture are used in the production stage, 39 percent of the energy used is during the processing of agriculture products.[36] Since such a large amount of the energy in agriculture is used during the processing stage, it is important that the impact of rising energy prices from the production stage through the processing stage be examined. Furthermore, the analysis must be taken to the point of delivery to wholesalers or regional distribution centers. A second study will be particularly concerned with the energy costs incurred in the processing of apples and potatoes. Here, the cost of transportation from the farm to regional distribution centers will be included.

Finally, it is necessary to discuss energy accounting analysis. Connor's study[8] is particularly useful in establishing several deficiencies and strengths of major works that have utilized an energy accounting approach. Connor identifies four problems with the kind of energy accounting

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*This discussion of the indirect effects of energy price increases on the general economy is not to be confused with the previously mentioned indirect energy inputs into the agricultural system, such as nitrogen fertilizer, etc.

exhibited in major studies including Pimental's[31] and Steinhart and Steinhart's[36].

1. The utility or human value derived from energy with respect to time, form and place is ignored. The calories of energy embodied in LP gas do not have the same value as calories of energy in labor.

2. The relationship between energy inputs in agricultural production receives only cursory attention. Energy embodied in agricultural inputs have complementary relationships for some production technology and substitute relationships for other types of technology.

3. Solar energy has seldom been included in such analysis, although agriculture is basically a solar energy processing machine.

4. Differences in the supply-demand situation for each energy category need to be recognized. The supply and demand situation for natural gas is quite different from that for electricity. Hence, the net energy or the output-input ratio is not as important in appraising the energy efficiency of an agricultural production system, as the amounts of specific types of energy inputs and the amounts and types of energy produced.

Of these four points, the concern with the complementary and substitutability of energy inputs will be discussed in Chapter III. The concern about the accounting for solar energy has already been discussed. It is because of the problems with energy accounting outlined in numbers one and four above that enable the conclusion that the role of energy use in agriculture may be better handled from an economic analysis approach.

CHAPTER III

ECONOMIC FRAMEWORK

Although only the static economics of changing the price of one variable input with all others held constant is being considered, it is recognized that the problem involves several analyses. Specifically, economic theory explains that over a period of time, factor substitution is possible, fixed assets become variable, restrictions in supply may occur, markets change, and demand for final products should also be considered. However, if the increase in energy input prices does not change the competitive balance between regions in the restrictive case of static economics, then it will probably not change when firms can employ dynamic adjustments. Thus, knowledge of the relationship between energy price increases and changes in comparative static advantage is needed.

The following assumptions help to create a static situation and clarify those areas that will not be covered until the dynamic analysis. While recognizing that some of these assumptions do not reflect conditions under which decision-making will occur, at least in the long-run, it is believed that they are sufficiently accurate in the short-run to allow for consistent analysis. Most of these assumptions will be relaxed in the second study.

Assumptions of Static Economics*

The specification of the fixed variables and the elimination of random variables are the first steps in constructing a static theory of economics. The term static economic theory has a variety of meanings. Hence, when one tries to outline the assumptions underlying static economics, a rather specific definition is required. The theory usually considered when the word static is used is a theory of a given number of exact relationships among the same given number of economic variables. In a theory of exact static relationships, the magnitudes of certain variables can and are permitted to change as the theory is used to explain changes which occur when the value of one or of a set of variables is changed. Thus, the price of the energy variables will be permitted to change.

The assumptions which secure static equilibrium theory in its usual form fall into three categories: 1) those which make the system static with respect to (a) production functions, (b) consumption functions, and (c) institutions; 2) those which eliminate random variables; and 3) those concerning motivations. As these are considered, more concern will be with the first of the categories than the others.

In formulating the problem, the most important static assumption is that which fixes the production function, the

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*The following discussion on the assumptions of static economics is taken from Course Notes, Agricultural Economics 805, Production Economics, Glenn L. Johnson, Michigan State University, 1978.

state of the art is assumed constant. That is, the total production of any given set of production factors remains fixed. What is of interest here is not differences in production functions, but the impact of real energy price increases given the fixed production functions of the two regions. All other assumptions of static economics remain. However, assumptions that eliminate random elements, i.e., perfect knowledge and perfect foresight, are rather limiting when discussing decisions facing a farmer. Although these assumptions are necessary to make the system static, they will not be strictly enforced here. Whether the farmers in Michigan and Washington have perfect knowledge and foresight will not change the problem under consideration.

Shift in Factor Price

When questions are asked about the effect of a change in the price of energy on agriculture, it is the basic economic theory of changes in factor price that is applicable. Referring to Figure 1.1, the firm faces a set of budget constraints KL, K'L', K"L", which are tangent to isoquants I, II, III. The expansion path OG represents the line of least cost combination, or points where the firm will produce A, B, C. When the input price of one factor increases, in this case real energy inputs, the budget lines shift as represented by the dashed lines in Figure 1.1. The new expansion path OH illustrates the effect of an increase in

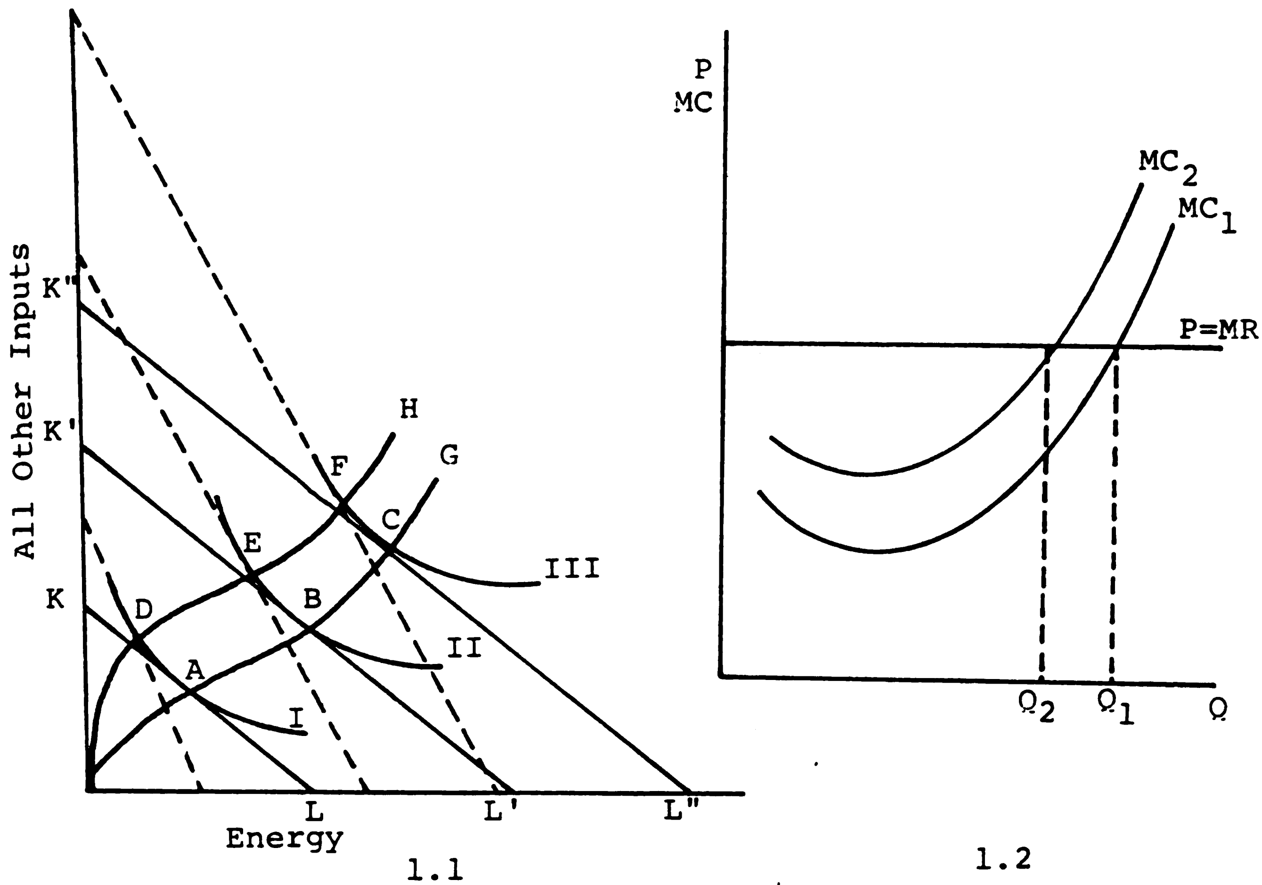

Figure 1.--Changing Expansion Path, Marginal Cost and Output with an Increase in Energy Input Prices.

energy input prices. When the price of a factor of production changes, this change will also affect the marginal cost of output and therefore the rate of output that the firm will choose to maximize profits. If the price of a factor increases, marginal cost will increase and output will be reduced, as shown in Figure 1.2. Thus, any change in the budget constraint that results from a change in factor prices implies that a change in the rate of output will occur. Depending on the demand for the product and the production function, the firm will produce at some level below

Q_1, the exact level depending on the rise in marginal cost that occurs as the price of energy inputs increases.

As applied to the specific interest in the competitive position of apples and potatoes between Michigan and Washington, what this study will want to know is not the change in energy usage, but whether or not the change in input prices will cause output in either state or either commodity to fall drastically. This can be illustrated if apples shipped to the Midwest from Washington and Michigan are considered as two different products. The question in general then becomes: Will the shift in factor prices (energy) be greater or lesser in either state because of irrigation, chemical use, and transportation requirements, causing output to fall, changing the competitive situation?

To further understand this process, the demand for factors of production will be put in mathematical terms, employing the notation given by R. G. D. Allen.[1]

If a good X, produced under constant returns to scale, is sold in a competitive market at price p equal to the constant average cost, then $p_a/f_a = p_b/f_b = \pi/x = p$. So $p_a = pf_a$ and $p_b = pf_b$. This is the law of "marginal productivity"; the price of a factor equals the marginal product of the factor valued at the selling price of the product.

If the demand for X is $x = \phi\ (p)$ with elasticity $\eta = -p/x\ dx/dp$, the amounts (a and b) of the factors and selling price (p) in terms of given factor prices (p_a and p_b) is determined by three conditions:

1. $f(a,b) = \phi\ (p)$

2. $p_a = pf_a$

3. $p_b = pf_b$

The output $x = f(a,b) = \phi\ (p)$ and total cost $\pi = px = ap_a + bp_b$ are also determined. Full competitive equilibrium, with constant returns to scale, is thus determined.

When one of the factor prices (p_a) changes while the other (p_b) remains constant, new demands can be determined for each of the factors of production. For the linear homogeneous function $x = f(a,b)$, we have

$$f_{aa} = -b/a\ f_{ab} \quad \text{and} \quad f_{bb} = -a/b\ f_{ab}$$

The elasticity of substitution between the factors is $\sigma = f_a f_b / x f_{ab}$. Therefore:

4. $f_{aa} = -b/a\ f_a f_b / x\sigma$

$f_{bb} = -a/b\ f_a f_b / x\sigma$

$f_{ab} = f_a f_b / x\sigma$

The equations (1), (2) and (3) hold for any values of p_a and p_b and can be differentiated partially with respect to p_a:

$$f_a\ \partial a/\partial p_a + f_b\ \partial b/\partial p_a = \phi'(p)\ \partial p/\partial p_a = -\eta\ x/p\ \partial p/\partial p_a,$$

$$1 = f_a\ \partial p/\partial p_a + p(f_{aa}\ \partial a/\partial p_a + f_{ab}\ \partial b/\partial p_a),$$

$$0 = f_b\ \partial p/\partial p_a + p(f_{ab}\ \partial a/\partial p_a + f_{bb}\ \partial b/\partial p_a).$$

Making use of (2), (3) and (4), we have:

$$x\eta\ \partial p/\partial p_a + p_a\ \partial a/\partial p_a + p_b\ \partial b/\partial p_a = 0,$$

$$x\sigma\ \partial p/\partial p_a - b/a\ p_b\ \partial a/\partial p_a + p_b\ \partial b/\partial p_a = xp/p_a\sigma,$$

$$x\sigma\ \partial p/\partial p_b + p_a\ \partial a/\partial p_a - a/b\ p_a\ \partial b/\partial p_a = 0.$$

This produces three linear equations in three unknowns, $\partial p/\partial p_a$, $\partial a/\partial p_a$ and $\partial b/\partial p_a$. The values of these partial derivatives can be found and written:

$$\partial a/\partial p_a = -a/p_a\ (ap_a/xp\ \eta + bp_a/xp\ \sigma) \text{ and}$$

$$\partial b/\partial p_a = -ab/xp\ (\eta-\sigma).$$

Write $Ea/Ep_a = p_a/a\ \ \partial a/\partial p_a$ and $Eb/Ep_a = p_a/b\ \partial b/\partial p_a$ for the elasticities of demand for the factors with respect to p_a and $k_a = ap_a/xp$ and $k_b = bp_b/xp\ (k_a + k_b = 1)$ for the proportions of total receipt going to the factors. Then

$$Ea/Ep = -(k_b\sigma + k_a\eta) \text{ and}$$

$$Eb/Ep_a = k_a\ (\sigma-\eta).$$

The interpretation of these results given by Allen is:

> If the price of the factor A rises, the demands for <u>both</u> factors are affected, and in two ways. In the <u>first</u> place, the cost of production is increased, the product is dearer and (for a decreasing demand law with η positive) less of the product is bought. There is then a proportional decrease in the demand for both factors. This is shown by the negative term $(-k_a\eta)$ in the expression for both elasticities of demand. Secondly, the factor B is now cheaper <u>relatively</u> to the factor A and it pays to substitute B for A in production as far as possible. The demand for B thus increases at the expense of A, as is shown by the positive term $(k_a\sigma)$ in the expression for one elasticity and the negative term $(-k_b\sigma)$ in the other. The total effect on demand is found by addition. The demand for A falls in any case, but that for B may rise or fall according as the substitution effect is stronger or weaker than the effect through the demand for the product.[1]

Let it be clear, however, that in this study, what the above economic theory explains will not be strictly followed.

That is, in the very short-run (one season), it will be assumed that the same quantities and configurations of fuels will be used for production at each input price level. Although it is recognized, as Connor points out, that the energy used in agriculture has complementary relationships for some production technology (i.e., diesel fuel and tractors) and substitution relationships for others (i.e., nitrogen fertilizers and organic fertilizer) in this static analysis, it will be assumed that the farmers will first be faced with the price increases and will not adjust immediately.

A further word is necessary to explain the assumption that farmers cannot adjust immediately to energy price increases and why they are confronted with higher costs and not substitution possibilities. Substitutes do exist for some energy inputs, as Connor suggests, therefore when prices change only slightly relative to each other, it pays to adjust production plans quickly so as to utilize the cheaper of the two. As a corollary, it pays to keep a business so organized that it is easy to shift between the use of good substitutes when small changes occur in their relative prices. Yet, agriculture in the United States has become so energy dependent that farms are not organized to quickly shift from energy inputs to something else, or even between inputs. These adjustments may be made in the long-run, but a quick adjustment is assumed unlikely.

Furthermore, Connor also suggests that economic analysis of energy use in agriculture does not account for complements in production. In fact, the existence of nearly perfect complements also helps explain why farmers will not be able to react quickly to energy price increases. As capital has been substituted for labor in U.S. agriculture, much of that capital requires direct, not to mention indirect, energy resources. Until other forms of engines are produced, tractors need a certain amount of diesel fuel to move. That is, when a production process utilizes two nearly perfect complements, it is unnecessary to keep the production process flexible with respect to the proportions of X_1 and X_2 which can be handled, as changes in relative prices will not have large effects on the most profitable proportion in which such inputs should be combined.*

Methodology

In order to analyze the impact of a change in the price of energy inputs, the price will be increased, holding the prices of other factors of production constant. In order to later change the variable costs of production, variable costs will be divided into three categories:

1. variable costs of production with no fossil fuel component;

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*The discussion on substitutes and complements is drawn from Bradford, L. A. and G. L. Johnson, Farm Management Analysis (New York: John Wiley & Sons, Inc., 1953).

2. variable costs of production with a direct fossil fuel component, i.e., fuel for tractors, gasoline for trucks, etc.; and

3. variable costs with indirect fossil fuel components, i.e., fertilizer and pesticides.

The cost formulas will be as follows:

$$\sum_{i=1}^{m} (P_i X_i) = \sum_{i=1}^{m} C_i \qquad i=1\cdots m, \text{ all variable inputs with no energy components} \qquad (1)$$

where: X_i = quantity of variable inputs with no energy component

P_i = price per unit of all variable inputs with no energy component

C_i = cost of all variable inputs with no energy component

$$\sum_{j=1}^{k} (X_j P_j) = \sum_{j=1}^{k} C_j \qquad j=1\cdots k, \text{ all variable inputs with direct energy components} \qquad (2)$$

where: X_j = amount of energy used with variable inputs requiring direct energy components, i.e., electricity used to run irrigation pumps, fuel for tractors, etc.

P_j = price per unit of energy used with variable inputs requiring a direct energy component. Since X_j will be some form of energy input, each P_j will be the per gallon, per KWH, or per MCF price, depending on the type of energy used.

C_j = cost of all direct energy inputs, used in those variable inputs with direct energy components

$$\sum_{d=1}^{t} (X_d P_d) = \sum_{d=1}^{t} C_d \qquad d=1\cdots t, \text{ all variable inputs with indirect energy components} \qquad (3)$$

where: X_d = quantity of variable inputs with indirect energy components, i.e., fertilizer and pesticides

P_d = price per unit of variable inputs with indirect energy components. Part of P_d will reflect the cost of the indirect energy component.

C_d = cost of variable inputs with indirect energy components.

Therefore, the total cost formula will be

$$\sum_{i=1}^{m} C_i + \sum_{j=1}^{k} C_j + \sum_{d=1}^{t} C_d + FC = TC \qquad (4)$$

and the per unit cost of output will be:

$$1/N \sum_{i=1}^{m} C_i + 1/N \sum_{j=1}^{k} C_j + 1/N \sum_{d=1}^{t} C_d + 1/N\ FC = 1/N\ TC \qquad (5)$$

where: N = total output per state, per commodity.

In order to analyze the impact of rising real energy prices, the following computation will be employed. Since $\sum_{i=1}^{m} C_i$, the variable costs with no energy component, and fixed costs do not have an energy component that will change (since the indirect energy input to fixed costs has already been included before the price increase), they will remain constant. Since $\sum_{j=1}^{k} C_j$ represents those variables with direct energy components, i.e., LP gas, natural gas, electricity, diesel fuel, it will be necessary to multiply each X_j by a new price, P_jV_j where V_j in this analysis will represent the percentage increase in the price of various energy sources. Therefore, equation (2) will be adjusted to read:

$$\sum_{j=1}^{k} \{X_j(P_jV_j)\} = \sum_{j=1}^{k} C_j^* \qquad V_j = \frac{\%}{100} \text{ increase in energy cost} \qquad (2)'$$

To account for increases in the indirect energy component, a different measure is required, since the indirect energy cost in fertilizer for example, is merely a portion of the total cost of the input. Therefore the ratio P/BTU will be used in order to increase the price of the input by that proportion which is affected by rising energy prices. Here, the X_d in equation (3) is composed of (r) amount of BTU's. If for example, the BTU's in the input are all of the same energy source, P/BTU will be the ratio of the price of the energy source by the amount of BTU in that energy source. If the input is made up of different types of energy sources, the BTU shown in the ratio will be the average of each energy source. Since each input has (r) amount of BTU's in it, then P/BTU · r = S, where S = the indirect energy cost. To derive the proportion of indirect energy cost to the price of the input, we have (S/P_d). To change the indirect energy price by a percentage increase then:

$$(S \cdot V_d) + (P_d \cdot U_d) = C_d^*$$

where: S, V_d and P_d are as before. U_d = the quantity of variable input. Therefore equation (3) will be adjusted to read:

$$\sum_{d=1}^{t} \{(S \cdot V_d + P_d)U_d\} = C_d^* \qquad (3)'$$

The new total cost formulas, incorporating the changes in energy price inputs will be:

$$\sum_{i=1}^{m} C_i + \sum_{j=1}^{k} C_j^* + \sum_{d=1}^{t} C_d^* + FC = TC^* \qquad (6)$$

and the per unit cost of output will be:

$$1/N \sum_{i=1}^{m} C_i + 1/N \sum_{j=1}^{k} C_j^* + 1/N \sum_{d=1}^{t} C_d^* + 1/N\ FC = 1/N\ TC^* \qquad (7)$$

By way of example, the method used to calculate indirect energy costs will be clarified. Referring to Chapter V for the precise figures, the total cost of fertilizer in Michigan apple production is $37.08 per acre. The energy embodied in fertilizer, nitrogen and potash, is 6685 BTU per acre (1000). The price of energy per acre in Michigan is $59.95 and the total BTU's per acre used in apple production is 31,922 (1000). To get the P/BTU ratio then, the two figures are divided: 59.94/31922000 = .0000018. To get the indirect energy cost in fertilizer, the above is multiplied by the BTU's per acre of fertilizer: .0000018 · 6685000 = $12.03. Subtracting these totals (S) from the total fertilizer costs (P), gives the non-energy costs: $37.08 - $12.03 = $25.05.

Indirect Energy Costs in Machinery

While this study includes only the indirect energy in fertilizers and pesticides, work has been done on the indirect energy costs of producing farm machinery. While only a few such studies exist, Garnett Bradford, Vernon Eidman and Harold Jensen, University of Minnesota, have analyzed and modified these reports in a staff paper, "A Systems Model of the Indirect Energy Expended in Farm

Machinery Production and Use" (1978). In their report, Bradford et al. calculated the indirect energy requirements in terms of kilocalories of energy expended. As an example of their work, the following table represents modified estimates of the energy required to produce selected 1974 farm machinery, as modified from studies by Doering et al.[10], Beny and Fels[3] and Bullard et al.[5].

Table 1.--Indirect Energy in Farm Machinery.

Machine Specification[a]	Input-Output Energy in Intensity Method (kcal x 10^6)	Modified Doering Results	Beny-Fels plus Doering Results
Tractor, John Deere 4420 diesel, 2-wheel drive; 9926 lbs; $11,490	142.74	93.96	101.64
Combine, New Holland 13 ft 1400 self-propelled; 13367 lbs; $17,438	216.63	102.91	127.40
Forage Harvester, Allis-Chalmers model 782, PTO; Base Unit, 3390 lbs; $2,913	35.66	22.14	26.77
Corn Planter, 400 cycle 1H, 6-row narrow with strip tillers and dry fertilizer applicators; 3521 lbs; $4,328	53.76	43.92	29.72
Disc Harrow, 18 ft tandem, 3800 lbs; $3,264	40.55	31.71	30.99

[a]Prices shown are for Spring 1974.[4]

In the long-run dynamic adjustment process, the farmer will find it necessary to account for the rise in indirect energy input prices into farm machinery. In this short-run analysis, the rise in energy input prices, both direct and indirect, will only affect the producers as they purchase those variable inputs such as fertilizer that must be acquired each season. Simply, the producer already has what farm equipment is necessary and the rise in the indirect energy input costs of farm machinery will not be of immediate concern.

Factors of Distance

An additional issue should be discussed here due to its relevance to the analysis: The effect of distance from the market on both costs and prices, i.e., transportation costs, and the impact of these transportation costs and distance on the economic return to land, that is, land rent.

A situation where two products (Washington commodities and Michigan commodities) compete in the same markets, at different distances from that market site, produces issues surrounding transportation costs. The price received for a commodity at any particular point tends to vary directly with distance from the central market or consuming center.[21] Under competitive conditions, the price to the producer would be the central market price less the cost of transportation services. Drawing from Heady's discussion[21], in the absence of variations in costs of transportation services between the production and consuming points, Figure 2 illustrates the geographic pattern of prices. The upper portion of Figure 2 assumes that (a) each producer has equal access to the consuming site, and (b) transportation modes are not more favorably situated for one producer than for another. Therefore, an "iso-price" boundary (circles P_1... P_6) exist for each point equally distant from the market. The price is the same for all producers on a given price line and is equal to the central market price less the cost of transportation. On boundary line P_1, the producer price of $1.80 is the central market price of $2.00 less $.20 for transportation costs. The lower portion of the figure illustrates the nature of the decline in producer price as the point of production becomes more distant from the market.

The location of production is also an important land-rent determinant.* Essentially, when crops produced for a central market are grown on lands of like fertility, the lands located nearest the market will enjoy a rent advantage over those located at greater distance. Here, land-rent is defined as the economic return that accrues, or should accrue, to land for its use in production. This economic rent is the surplus of income above the minimum supply price it takes to bring a factor into production. For example, if a commodity is worth $15.00 a ton delivered

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*This discussion is from Barlowe[2].

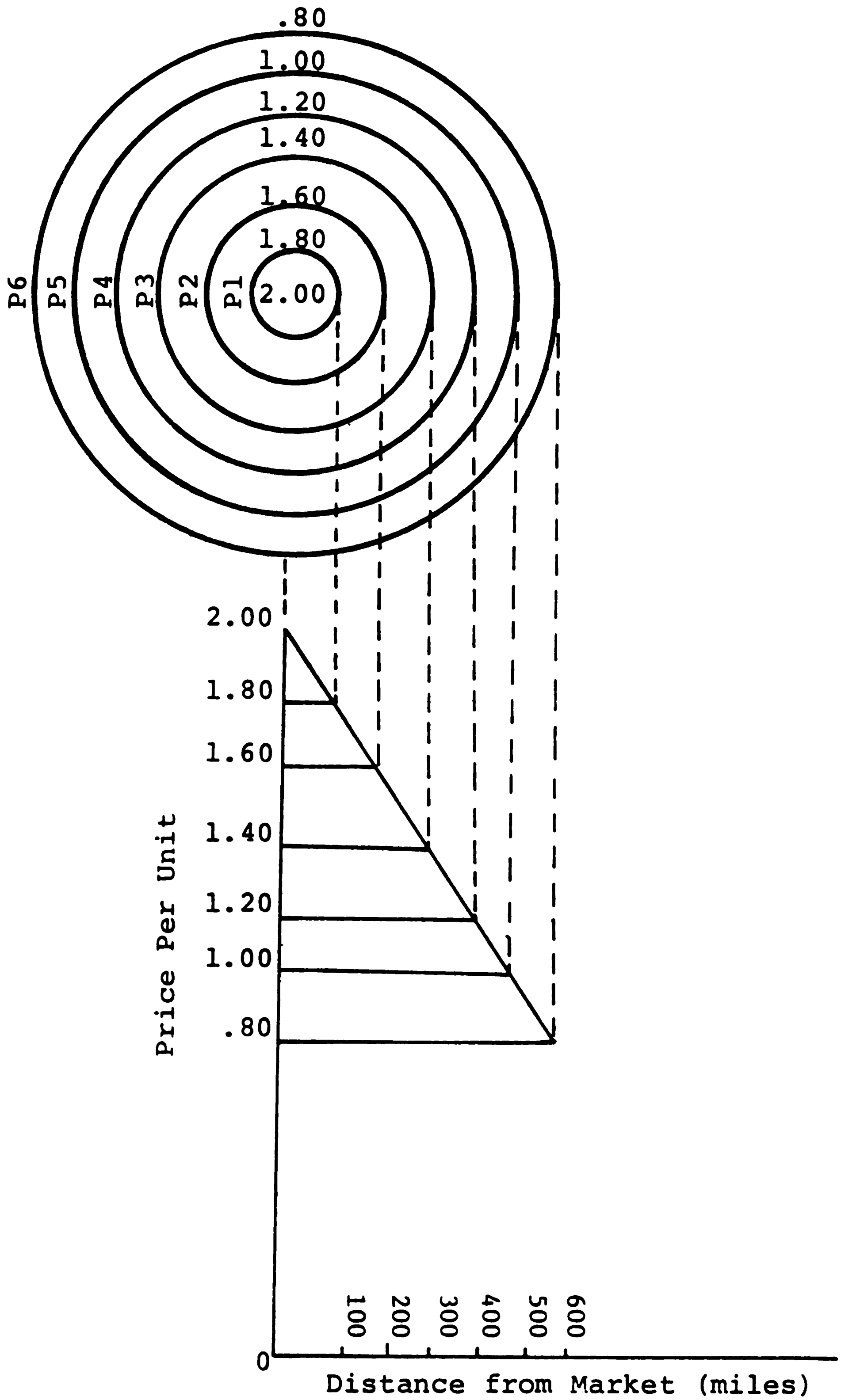

Figure 2.--Distance and Product Price.

at a factory and can be produced at an average cost of $13.80 a ton (including loading costs and a fair return on the operator's capital, labor and management), a surplus of $1.20 a ton will be available as land rent on those lands located at the market. With an average yield of ten tons per acre, this would result in a land rent of $12.00 per acre at this location.

When the commodity is produced at a greater distance from the market, there exists a higher transportation cost and thus less rent is produced. With an average transportation cost of three cents per ton-mile (once the commodity is loaded in trucks), the amount of land rent drops three cents a ton, or $.30 an acre for every additional mile between the producing and consuming points; this is illustrated with the use of land-rent triangles below. What this implies is that there can be only $6.00 in land rent per acre at locations 20 miles from the consuming point and the rent drops to the zero or no-rent point 40 miles from the market. Some production may take place beyond the no-rent point, but only with a reduction in payments that normally would go to labor. At points A and B below, the no-rent margin, rent stops and production costs exceed total market value at all points beyond this no-rent margin (Fig. 3).

Examining this with the use of cost curves, it can be seen that the further a tract of land used to produce a commodity is from the market, the more it costs to get

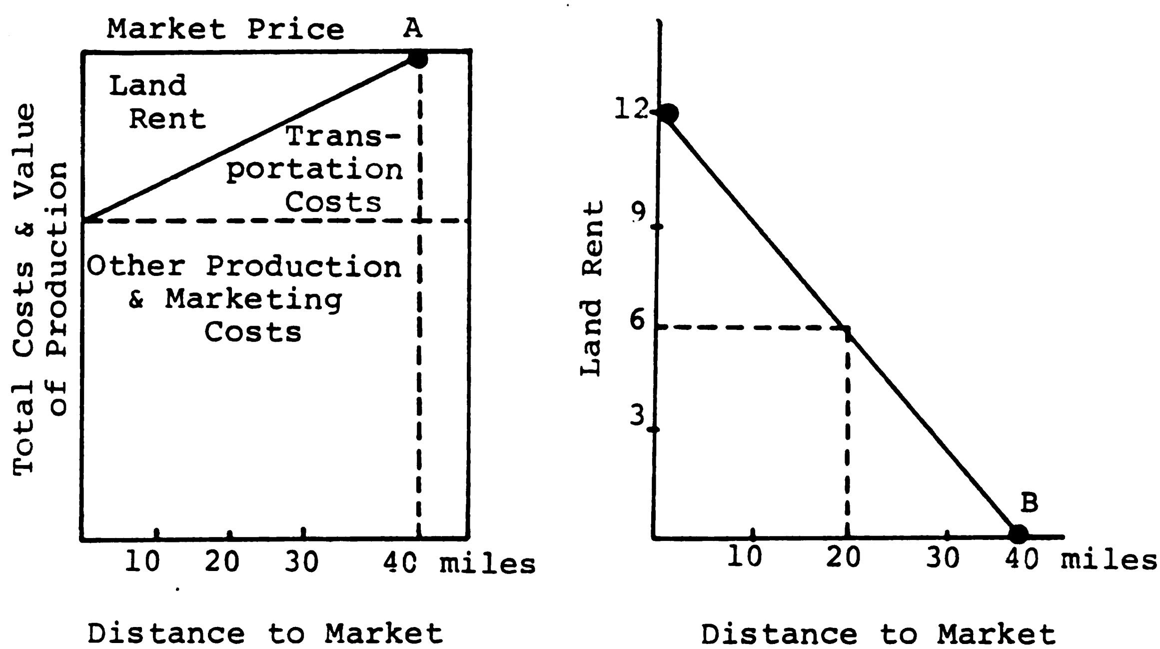

Figure 3.--Effects of Transportation Costs Upon Land Rent.

products there, land rent is affected even on land of comparable productive quality. The first diagram below (Fig. 4A) represents the land rent received by land at the site of the market; no transportation costs exist. As production is carried on further from the market site, shipping costs occur. Since shipping costs vary with output sold, higher shipping costs exist to transport 100 units as opposed to 10, it may be treated as a price-depressing factor, which lowers the actual prices received by producers at greater distances. As net price is lowered, the amount of land rent received also decreases, as shown in the shaded areas below. Thus, while the site 500 miles from the market is just as productive as that land at the market,

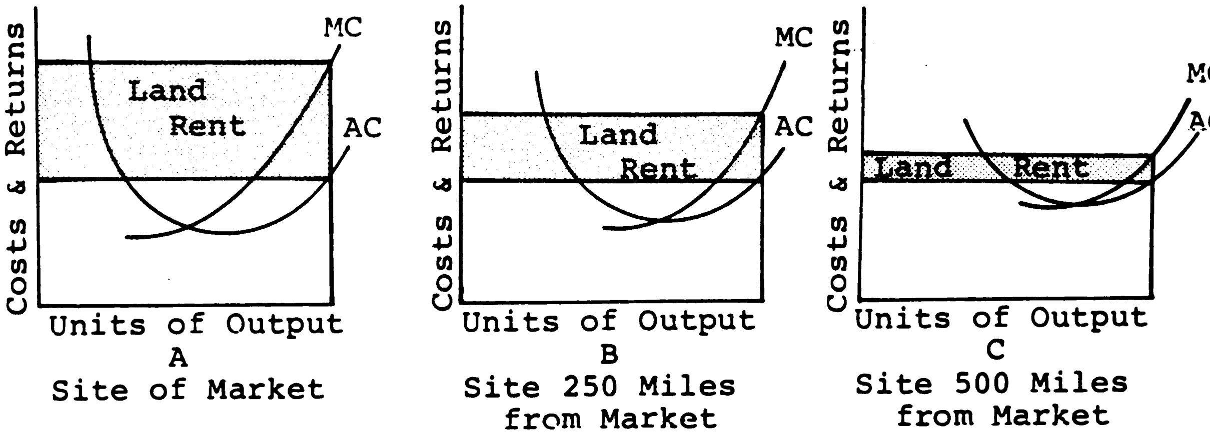

Figure 4.--Cost Curves and Transportation Costs.

operators encounter a transportation cost that forces them to gear their production to a lower net price level, possibly affecting the variable inputs that can be employed.

CHAPTER IV

INDUSTRY AND MARKET DESCRIPTIONS

The purpose of this chapter is to establish an institutional description of both the fresh apple and potato industries, and a description of their various markets. The emphasis will be on presenting the regional distribution patterns of Washington and Michigan products.

Apple Industry in Michigan and Washington: Interregional Competition

While Washington is a nationwide supplier of fresh apples, Michigan sells predominately to markets in the Midwest: Washington supplies 35 percent of the nation's fresh apples; Michigan averages seven percent of the U.S. market.[32] Both the Michigan and Washington apple industries have some notable competitive advantages and disadvantages. As Ricks illustrates, those advantages in Michigan that relate to the fresh apple industry include:

1. Lower transportation costs to eastern and midwestern U.S. population centers.
2. Relatively less supply fluctuations such as Washington has with periodic severe winter freezes which can kill many apple orchards.
3. Lower costs for land in Michigan.

4. Little or no cost for irrigation in Michigan.
5. More dependable water supplies in a year like 1977, at least compared to Washington's (1977) unusually bad situation.
6. Little or no costs for orchard heating.
7. A diversity of varieties of apples in Michigan.

Some of the advantages which Washington has over Michigan in the fresh apple industry include:

1. Favorable climatic conditions for growing apples. This results in: a) higher average yields per acre; b) high quality fruit for fresh market with regard to desirable color, finish and shaped Red and Golden Delicious; and c) lower spray costs.
2. Higher average price per packed box of fresh apples due to the conditions listed above.
3. Ample amounts of irrigation water under normal conditions.
4. A high percentage of orchards on size-controlled rootstocks in high density plantings.
5. Lower transportation costs to substantial and rapidly growing markets in California and southwestern U.S.
6. Large volumes of fresh market Red and Golden Delicious which are continuously available to the buying trade throughout a year's apple marketing season.

7. Large and apparently quite effective advertising and promotional program.[32]

If these 14 items are examined, it can be seen that 11 of them deal with either quality/promotional aspects, or those related to energy use. The quality/promotional items may account for the popularity of Washington apples. On the other hand, the six items that relate to energy, mostly irrigation and transportation, may account for future competitive changes between Michigan and Washington apples. In fact, Ricks reports that Michigan's most important competitive advantage is the substantially lower transportation costs to eastern U.S. population centers.[32] Furthermore, most Michigan apple growers have little or no cost for irrigation.

Yet, before real energy prices are increased, the fact remains that Washington's fresh apples successfully compete with Michigan fresh apples. Although Washington apples must be transported long distances, Washington's product still accounts for a large share of the eastern market. Of 18 U.S. cities* which are major demand points for fresh apples, Washington and Michigan compete in 10. The cities where the products compete are: Chicago, Detroit, St. Louis, Cleveland, Houston, Minneapolis, Cincinnati, Buffalo, Dallas, and

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*These are: New York, Los Angeles, Chicago, Philadelphia, Detroit, Boston, San Francisco, Washington, D.C., Pittsburg, St. Louis, Cleveland, Baltimore, Houston, Minneapolis, Cincinnati, Buffalo, Dallas, Milwaukee.

Milwaukee. Of the other eight cities, Washington supplies fresh apples, while Michigan does not. If only those cities where Michigan's and Washington's fresh apples compete are analyzed, the dark lines in Figure 5 indicate more apples on a percentage basis flow to every city from the Yakima Valley in Washington, except for Detroit. This is further indicated in Table 2. Other than the fact that Detroit is the only city where Michigan supplies more fresh apples than Washington, eight of the ten cities are essentially in the Midwest. Therefore, Michigan growers supply fewer apples to seven of eight midwestern cities than does Washington.

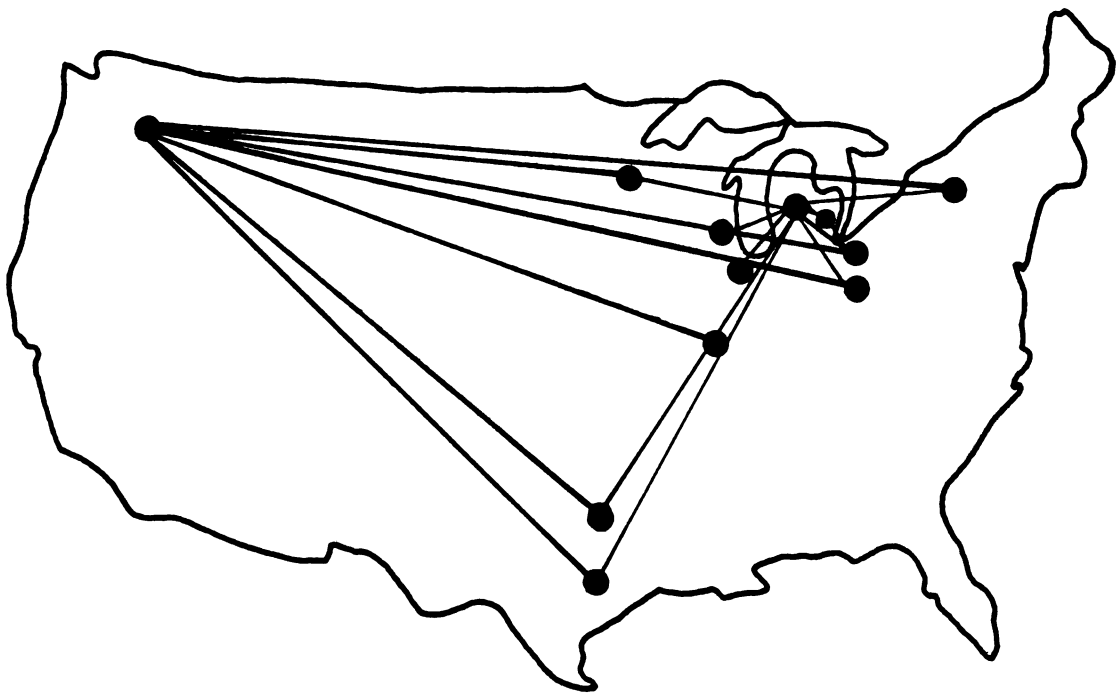

Figure 5.--Interregional Competition in Ten Major Demand Points: Apples.

Table 2.--Percentage of Market Accounted for by Washington and Michigan Apples in Ten Cities.*

City Where Washington and Michigan Compete	Washington's % of Market	Michigan's % of Market
Chicago	48	28
Detroit	30	49
St. Louis	49	19
Cleveland	34	16
Houston	54	9
Minneapolis	69	5
Cincinnati	30	21
Buffalo	9	3
Dallas	56	6
Milwaukee	45	25

*Since the above 1969 figures were taken from a bar graph, the percentages are approximate. Of the other eight cities, Michigan does not ship fresh apples. Of the above ten, the percentages do not add to 100 percent because each city has other suppliers, i.e., New York, Virginia, West Virginia, North Carolina, Maine, etc. all supply apples to the eastern market.

Source: 29.

Due to this situation, one is led to assume that Washington apples compete successfully with Michigan and in fact must either cost less to produce and ship or have much more marketable quality, or both.

Potato Industry in Michigan and Washington: Interregional Competition

Although this study is interested in the fresh potato market, the last 20 years has witnessed a hastened decline in per capita consumption of fresh potatoes corresponding to an increase in per capita consumption of processed potato products.[35] At the same time, potatoes themselves have shifted from a secondary crop to a highly specialized, primary crop requiring large-scale production techniques.[35]

Sparks attributes 94.1 percent of total U.S. potato production (1970) to 19 states. Within these 19 states, Washington potato production ranked third, contributing 10.3 percent of total U.S. supplies. Michigan ranks eleventh nationally, producing 3.2 percent of U.S. supply. While Michigan production accounted for only 3.2 percent in 1970 and 2.9 percent in 1977, the potato industry in Michigan has averaged $45.5 million in value of production in 1975-1977*; in both states, the potatoe industry is significant.

In order to analyze the flow of potatoes in the U.S., Sparks identified four major consumption regions: the Eastern region, the Southern region, and Midwestern region, and the Western region.** Forty-one cities were identified as regional demand points: nine cities in the Eastern region; 12 in the Southern region; 10 in the Midwest; and six in the West. Of these four regions, Washington and Michigan now compete in three, excluding the Western region.

Figure 6 as suggested by Sparks[35] divides the country into four demand regions. While Sparks lists a number of cities in each region, a representative city was chosen for

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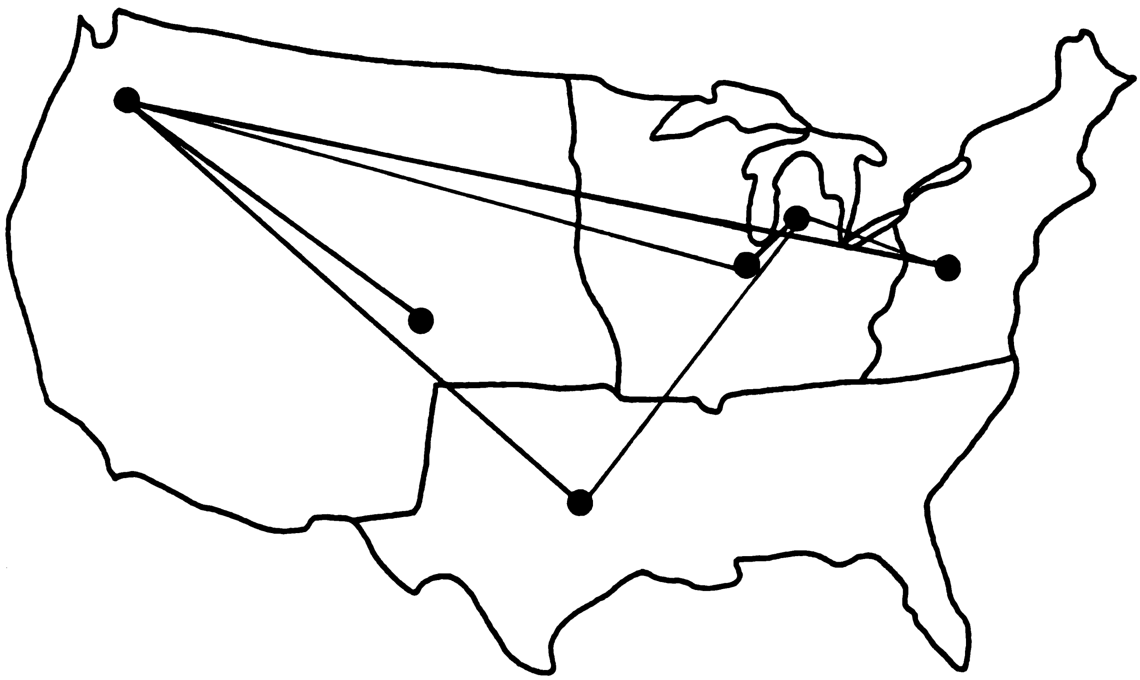
*28, page 21.

**See Sparks[35], for further information on data compilation and limitations.



Region I: Eastern Region--Representative City: Philadelphia
Region II: Southern Region--Representative City: Dallas
Region III: Midwest Region--Representative City: Chicago
Region IV: Western Region--Representative City: Denver

Figure 6.--Interregional Competition in Four Major Demand Regions: Potatoes.

each region in order to calculate transportation distances. As with apples, the dark lines in Figure 6 indicate which state ships more potatoes to the regions in which they compete. Washington supplies 950 carlots of raw potatoes to the Eastern region (1971), while 668 carlots are shipped from Michigan. The 668 carlots, however, is an aggregate figure including unloads from Michigan, Oregon, North Dakota, Minnesota, Texas and Alabama. Thus, Washington supplies the Eastern region with far more raw potatoes than does Michigan. Similarly, Washington supplies more raw potatoes to the

Southern region. From Washington, 864 carlots were transported to the South in 1971, while 871 came from a number of states including Michigan (Oregon, New Jersey, Michigan, Virginia, Pennsylvania, North Carolina). It is only in shipments to the Midwest region that Michigan supplies more fresh potatoes than Washington. Michigan unloaded 4774 carlots of raw potatoes in the Midwest in 1971, compared to 858 from Washington. Finally, Michigan and Washington do not now compete in the Western region. In fact, the Western region is unique in that all major suppliers of raw potatoes are located within the region.[35]

As with apples, Washington's products compete successfully with Michigan potatoes, even in markets near Michigan. Although Washington must transport its potatoes greater distances to the Midwest and East, they supply more in the East and a significant amount to the Midwest, as compared to Michigan. It therefore appears possible that when energy prices increase, particularly in diesel fuel for transportation, Michigan may find its competitive position improved. That Washington is able to transport significant amounts of their commodities to directly compete with Michigan products indicates that farmers in Michigan should be interested in the effects of changing real energy input prices.

CHAPTER V

1976 COSTS OF PRODUCING APPLES AND POTATOES IN MICHIGAN AND WASHINGTON INCLUDING ENERGY COSTS

Potato Budgets

Construction of both potato and apple budgets will follow the methodology outlined in Chapter III. The variable costs of production are divided into three categories: 1) variable costs of production with no fossil fuel energy component; 2) variable costs with a direct fossil fuel component; and 3) variable costs with indirect fossil fuel components. The fixed costs and those variable costs such as labor that do not have a fossil fuel component, will be considered the factors of production to be held constant.

All of the budgets used in this analysis will take the form of Table 3 which is a partial budget including only those costs that will not be changed when energy prices are increased (which explains the blank spaces). In order to construct the entire budget, the cost of fossil fuel inputs for a base year of 1976 will be added to Table 3, and the costs of these inputs will be increased until reaching a threshold price which shifts the competitive cost structure between regions. The question will be: How high do energy prices have to increase before this shift occurs?

Table 3.--Partial Estimated Cost of Production, $/acre: Potatoes. Including Only Costs to be Held Constant. Base Year, 1976.

ESTIMATED COSTS	WASH.	MICH.
Variable Cost		
1. Without Energy Component		
Seed	$117.04	$112.50
Equipment Repairs	37.65	31.24
Labor	40.13	32.26
Irrigation Repairs	6.60	6.60
Irrigation Labor	6.40	6.40
	$207.82	$189.00
2. With Direct Energy (including irrigation)		
Gasoline		
Diesel		
Electricity		
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost		
Non-Energy Cost	$ 96.70	$ 85.11
Total Cost		
Pesticide		
Indirect Energy Cost		
Non-Energy Cost	$152.78	$104.51
Total Cost		
Total Variable Cost, per acre		
Total Variable Cost, per ton (excluding transportation)		
Fixed Cost		
Equipment Costs		
Depreciation	$ 48.07	$ 48.07
Interest	45.18	45.18
Sprinkler Irrigation		
Depreciation	27.98	27.98
Interest	34.03	34.03
Operating Capital	16.35	23.86
Land Costs	86.07	56.63
Total Fixed Cost, per acre	$257.68	$235.75
TOTAL COST, per acre		
TOTAL COST, per ton (excluding transportation)		
TRANSPORTATION COST (by truck)		
TOTAL COST PER TON TO CHICAGO		

With regard to potatoes, the data has largely been adopted and indexed to a base year of 1976 from Greig.[19] Greig estimated the cost of production of potatoes for eight regions, covering the major Fall crop-producing areas, including the Columbia Basin of Washington and Oregon, and Michigan. Cost estimates were established using published data from each of the areas and calculated under a standard formula.

1. Variable Costs with No Fossil Fuel Component.

Seed: Seed potato prices were obtained by Greig from USDA price reports, by state. In Washington 19 cwt of seed was applied per acre at a cost of $6.16 per cwt. For Michigan, 17 cwt was used at $6.60 per cwt.

Equipment Repairs: In Greig's study, this category also included equipment operations, and thus included the cost of gasoline and diesel fuel used to operate the farm equipment. Since the interest here is only in those costs of production with no fossil fuel input, the cost of gasoline and diesel fuel has been subtracted. Equipment costs were standardized because operations are essentially the same in all areas, and reliable data was not available regionally. Therefore, the equipment costs for Michigan and Washington were listed as $53.24 per acre. In order to count only equipment repair costs, the cost of gasoline and diesel fuel in Washington ($15.59) and

Michigan ($22.00) has been subtracted, resulting in equipment repair costs of $37.65 per acre in Washington and $31.24 in Michigan.*

Labor: The quantity of labor used per acre was standardized at 12.7 hours and the price of farm labor was obtained from USDA data under the heading "all hired farm workers", at 1976 wages. In Washington, 12.7 hours of labor per acre was used at a price of $3.16 per hour; in Michigan the wage rate was $2.54.

Irrigation Repairs and Labor: As with equipment costs, only irrigation repairs and labor are included here; when variable costs with a direct energy component are examined, the water and fossil fuel costs of irrigation will be included. The irrigation costs used by Greig assumed that surface water was supplied to the farm by an irrigation district and that circle or center pivot systems were used. The cost of irrigation labor and repairs has been standardized here because Greig's data includes only the Washington figures. Although Greig assumes Michigan farmers do not irrigate, irrigation does take place, albeit at a much lower level than is necessary in Washington.

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*The figures for gasoline and diesel fuel prices and amounts used will be introduced below, when variable costs of production with direct fossil fuel energy inputs are considered.

2. Fixed Costs.

Equipment Costs: As was the case with equipment repairs, the depreciation and interest costs on equipment have been standardized due to unreliable regional data and the similarity of operations. Depreciation was calculated at $480.07 per acre, capital cost depreciated at ten percent per year, yielding the $48.07 figure for both states. Interest on equipment was calculated at $480.74 per acre at a 1976 interest rate of 10.64 percent, yielding $45.18 fixed cost in interest per acre.

Sprinkler Irrigation: Due to the fact that Greig assumes no Michigan irrigation, capital costs for sprinkler irrigation have been standardized so as to include this category in the cost of production budget. Data shows that of the 41,184 acres of potatoes harvested in Michigan in 1974 (data from 1974 Census of Agriculture, Vol. 1, Part 22), 16,227 were irrigated--40 percent. What is more important however, as indicated in Table 5, is the difference irrigation makes on yields. The figures used for Michigan potato yields are not statewide averages because irrigated land produces higher yields. For example, in Montcalm County where 90 percent of the potato crop is irrigated, yields are 13.5 tons per acre. In Monroe County where 88 percent of the potato crop is not irrigated, the yields are 8-9 tons per acre. Depreciation on sprinkler irrigation is estimated to be $319.80 per acre, minus $40 per acre salvage value, depreciated at ten percent a year, resulting in a depreciation cost of $27.98 per acre. At the $319.80 capital cost, interest was calculated at the 1976 rate of 10.64 percent, producing an interest cost of $34.03 per acre.

Operating Capital: This was taken at ten percent for six months at 1976 rates for both Michigan and Washington.

Land Costs: Land costs were estimated by multiplying the value of land per acre by a 1976 land interest rate of 9.06 percent. For Washington then, land costs are estimated at $950 at 9.06 percent, to be $86.07 per acre. In Michigan the estimated value per acre is $625 at 9.06 percent for a $56.63 land costs. In agriculture, the calculation for value of land per acre is generally in terms of the next best alternative use of that land.

As indicated by Table 3, the variable costs of production with no energy component have been estimated to be $207.82 per acre in Washington and $189 in Michigan. The fixed costs for potato production are estimated to be $257.68 per acre in Washington and $235.75 in Michigan. Although costs with no energy components are indeed variable costs (such as repairs), both those and fixed costs will not change when energy input prices are increased.

3. Variable Costs of Production with Direct Energy Component.

Table 4 shows the entire 1976 base year potato budget. For purposes of distance figures, Washington's potatoes are transported from the Columbia River Basin, and Michigan's from the southwestern area of the state.

In order to derive the cost figures for potato production, it is necessary to first start with the amount of energy used on the farm, Table 5. The data from USDA research[39] includes all energy directly used on the farm for crop production purposes: field operations, irrigation, crop drying, mechanized feeding, space heating, farm business auto use, etc. To find the cost figures of Table 4 the total amount of energy used will be multiplied by a set of 1976 price parameters and divided by acres (Table 6). When the amounts of energy used are multiplied by the appropriate per unit price, the cost of energy figures in Table 7 are derived. Finally, when each category in Table 7 is divided by the acres harvested as shown in Table 5, the result is the variable cost of production with direct energy. Note that because the use of fuel oil, LP gas, natural gas, and coal are at such low levels (less than 500 gallons/one-half million cu. ft.) per year, the cost figures were not calculated. Due to the amount of electricity used to irrigate in the Columbia Basin, Washington's direct energy costs are $73.17 per acre, Michigan's are $38.35.

Table 4.--Estimated Cost of Production, $/acre: Potatoes. Including Energy Costs. Base Year, 1976.

ESTIMATED COSTS	WASH.	MICH.
Variable Cost		
1. Without Energy Component		
Seed	$117.04	$112.50
Equipment Repairs	37.65	31.24
Labor	40.13	32.26
Irrigation Repairs	6.60	6.60
Irrigation Labor	6.40	6.40
	$207.82	$189.00
2. With Direct Energy (including irrigation)		
Gasoline	$ 9.92	$ 12.93
Diesel	5.67	9.07
Electricity	57.58	16.35
	$ 73.17	$ 38.35
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$ 33.39	$ 25.35
Non-Energy Cost	96.70	85.11
Total Cost	$130.09	$110.46
Pesticide		
Indirect Energy Cost	$ 3.00	$ 1.22
Non-Energy Cost	152.78	104.51
Total Cost	$155.78	$105.73
Total Variable Cost, per acre	$566.86	$443.54
Total Variable Cost, per ton (excluding transportation)	$ 25.19	$ 38.40
Fixed Cost		
Equipment Costs		
Depreciation	$ 48.07	$ 48.07
Interest	45.18	45.18
Sprinkler Irrigation		
Depreciation	27.98	27.98
Interest	34.03	34.03
Operating Capital	16.35	23.86
Land Costs	86.07	56.63
Total Fixed Cost, per acre	$257.68	$235.75
TOTAL COST, per acre	$824.54	$679.29
TOTAL COST, per ton (excluding transportation)	36.65	58.81
TRANSPORTATION COST (by truck)	14.52	1.51
TOTAL COST PER TON TO CHICAGO	$ 51.17	$ 60.32

Table 5.--Energy Use in Potato Production: USDA 1974 Data Base.

	Acres Harvested (1000)	Yield per acre	Gal. of Gas (1000)	Gal. of Diesel (1000)	Gal. of Fuel Oil (1000)	Gal. of LP Gas (1000)	Cu. Ft. of Nat. Gas (mill)	Tons of Coal	KWH of Elec. (mill)	Total BTU's (bill)	BTU's per acre (1000)
Mich. Potatoes	41.6	11.5 tons[a]	1281	1001	--	--	--	--	17	1207	29,014
Wash. Potatoes	124.0	22.5 tons[b]	2901	1842	--	--	--	--	255	2995	24,153

[a]A further explanation of potato yields in Michigan is found in the text.

[b]Acres harvested and yield per acre data from Washington Agricultural Statistics, 1976.
The numbers may not add up exactly due to rounding.
Dashes indicate less than one-half unit.

Table 6.--1976 Energy Parameter Values.

Item	Michigan $	Washington $
Gasoline (gallons)*	0.420	0.424
LP Gas (gallons)	0.350	0.380
Diesel (gallons)*	0.377	0.382
Electricity (KWH)	0.040	0.028
Fuel Oil (gallons)	0.469	0.464

*Refundable State and Federal full taxes have been subtracted.

Table 7.--1976 Cost of Energy Use in Potato Production.

	Gasoline ($1000)	Diesel ($1000)	Fuel Oil ($1000)	LP Gas ($1000)	Elec-tricity ($1000)	Total Energy Cost ($1000)
Mich. Potatoes	538.020	377.377	---	---	680	1595.397
Wash. Potatoes	1230.024	703.644	---	---	4080	6013.668

4. Variable Costs of Production with Indirect Energy Component.

In order to account for increases in the indirect energy component, a different measure is required, since the indirect energy cost in fertilizer and pesticides is merely a portion of the total cost of the input. To derive the breakdown in fertilizer and pesticide costs the P/BTU·r = S formula will be used: where P = the price of energy per acre, r = BTU's per acre of fertilizer and pesticide used, and S = the indirect energy cost. To get the constant non-energy cost, (S) is subtracted from the total cost which is shown in Table 4.

The energy input in fertilizer as shown in Table 8 is derived from Table 4. The price of energy per acre

Table 8.--Energy Use in Potato Production: Fertilizer.[a]

	Nitrogen lbs. (1000)	Phosphate (P_2O_5) lbs. (1000)	Potash (K_2O) (1000)	BTU per acre (1000)
Mich. Potatoes	26076	---	---	19500
Wash. Potatoes	34300	33684	29513	11129

[a]Source: 39.

Dash = less than one-half unit.

has already been established at $73.17 for Washington and $38.35 for Michigan. From Table 5 the total BTU's per acre used in potato production is 29,014,000 in Michigan and 24,153,000 BTU's per acre in Washington. The P/BTU ratio for each state is: Washington = $73.17/24153000 = $.0000030; Michigan = $38.35/29014000 = $.0000013. Finally, to arrive at the indirect energy cost in fertilizer from Table 8: Michigan = $.0000013·19500000 = $25.35, and Washington = $.0000030·11129000 = $33.39. Subtracting these totals (S) from the total cost (P) gives the non-energy costs: Washington = $130.09 - $33.39 = $96.70, and Michigan = $110.46 - $25.35 = $85.11.

The whole procedure is repeated for pesticide costs, as shown in Table 4 and Table 9. The price of energy

Table 9.--Energy Use in Potato Production: Pesticide.[a]

	Herbicide lbs. (1000)	Insecticide lbs. (1000)	Fungicide lbs. (1000)	Other lbs. (1000)	BTU per acre (1000)
Mich. Potatoes	248	126.9	103.2	---	938
Wash. Potatoes	1029	349.1	15.7	---	999.2

[a]Source: 39.

Dash = less than one-half unit.

is from Table 4 and divided again by the total BTU's per acre from Table 5. The indirect energy cost in pesticide for Michigan = $\$.0000013 \cdot 938000 = \$1.22$; Washington = $\$.000003 \cdot 999200 = \$3.00$. Subtracting this from the total cost leaves the constant non-energy costs of $152.78 for Washington and Michigan's cost of $104.51.

5. Total Costs and Transportation Rates.

Total variable cost per acre is the summation of the variable costs in Table 4, since these figures were already in per acre terms. Referring to Table 5, it is found that the yield per acre is 11.5 tons in Michigan and 22.5 tons in Washington; dividing these figures into the total variable cost per acre gives the total variable cost per ton, excluding transportation of $25.19 in Washington and $38.40 in Michigan. While Michigan has a lower total variable cost figure on a per acre basis, the total variable cost per ton is actually lower in Washington when the nearly doubled yields are taken into account.

Total cost per acre is the summation of total fixed and variable costs. This total cost per acre is divided by the yield per acre in tons to derive cost per ton, excluding transportation. Washington at $36.65 has a lower total cost than does Michigan at $58.81: Washington can produce a ton of potatoes at about 62 percent of the cost for Michigan.

The following transportation model it is recognized, is a rather simple model. Yet, since the interest is in the changes in transportation rates due to real fuel price increases, it is felt that the following model is both consistent and useful for the purpose at hand. First, only the cost of the fuel used in transportation rates has been calculated to the Midwest, specifically to Chicago, which is approximately 1900 miles from the Columbia Basin and 200 miles from Michigan's producing region (in Chapter VI other market destinations will be introduced). What is calculated is the cost, per ton mile, of transportation as manifested in the cost and gallons of diesel fuel used. At the 1976 parameter value of diesel fuel used

Table 10.--Cost of Transportation Model.[a]

	Tons	Miles	Ton Miles	Ton Miles per Gallon	Gallons of Diesel fuel
Washington	1	1900	1900	50	38
Michigan	1	200	200	50	4

[a]Source: 40.

in Table 6, the cost of transportation is shown here in Table 11.

Table 11.--1976 Transportation Rates by Truck to Chicago.

	Gallons of Diesel Fuel	Price of Diesel Fuel per gallon	Transportation Cost per ton
Washington	38	.382	$ 14.52
Michigan	4	.377	1.51

When transportation costs are added to the total cost of production, Washington can still produce and ship potatoes to the Midwest at a lower cost, but is now 85 percent of the cost of Michigan's production. Thus, relative to Michigan's cost, transportation costs increased Washington's production and shipping more than 20 percent.

Apple Budgets

The data for these budgets are primarily from two sources: for Washington, Doran, Tukey and Hunter[15]; and for Michigan, Kelsey and VanDerbeck[24].

As Greig indicated with regard to potatoes, comparable, consistent data for apple production costs is not easily obtainable. In this case, the data used is for semi-dwarf trees in western Michigan and the Columbia Basin. The most important immediate difference in the two sets of data is that, as indicated in Table 12, the planting in Washington is 217 trees per acre, while in Michigan it is 108 trees.

Table 12.--Partial Estimated Cost of Production, $/acre: Apples. Including Only Costs to be Held Constant. Base Year, 1976.

ESTIMATED COSTS	WASH. 217 trees/acre	MICH. 108 trees/acre
Variable Cost		
1. Without Energy Component		
Labor	$576.22	$304.38
Equipment Repairs	23.72	28.79
Materials	48.40	37.79
Irrigation Labor	32.50	
	$680.84	$370.96
2. With Direct Energy		
Gasoline		
Diesel		
Fuel Oil		
LP Gas		
Electricity		
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost		
Non-Energy Cost	$ 7.98	$ 25.05
Total Cost		
Pesticide		
Indirect Energy Cost		
Non-Energy Cost	$131.77	$ 88.88
Total Cost		
Total Variable Cost, per acre		
Total Variable Cost, per ton (excluding transportation)		
Fixed Cost		
Equipment Costs		
Depreciation	$ 76.71	$ 89.68
Interest	81.17	
Irrigation	14.00	
Land Costs	110.40	80.00
Taxes	20.00	10.00
Orchard Management	56.60	40.66
Total Fixed Cost, per acre	$358.88	$214.68
TOTAL COST, per acre		
TOTAL COST, per ton (ex. trans.)		
TRANSPORTATION COST		
TOTAL COST PER TON TO CHICAGO		

Information in the Columbia Basin study[15] was obtained from a committee of apple producers in the northern area through group discussions and individual interviews. The data on their 1976 costs for hired labor, machinery ownership and use, supplies, taxes, insurance, interest and the like were reviewed by the committee and other local industry people along with those concerned with apple production. Due to the procedure used and the variable orchard situation in the study, the data do not reflect "average" production costs. The Michigan data was similarly gathered. The cost data for Michigan[24] is an update of costs developed in small group discussions with apple growers in prior years. As with Washington, the data do not reflect the "average" production costs but do give an indication of what it costs to produce apples in western Michigan.

Referring to Table 12, the breakdown of the costs are as follows:

1. Variable Costs with No Fossil Fuel Component.

   Labor: Includes the labor during pruning, brush disposal, spraying, gopher control, mowing, fertilizing, application repairs, picking, and bin distribution. Figures do not include labor insurance or labor for hand thinning, office work or tree repair. The large difference in labor costs represents the fact that much of the labor is hired at a per tree rate; since Washington has more than double the trees per acre, labor costs are naturally higher.

Equipment Repairs: Figures for equipment operating costs included the fuel used to run the machines. Therefore, the cost of the fuel will be subtracted from Doran's and Kelsey's figures. In considering equipment operating costs, Kelsey and Vanderbech considered initial cost, salvage value, years of life, annual usage, repair costs, insurance, interest and operating expenses. On a per acre basis, the cost of operating the growing machinery was given as $37.75. However, to make this consistent with cost data from Washington, $2.25 is subtracted from this to account for the fact that Washington has no custom airplane cost, as listed by Kelsey. Thus, total operating cost in growing is $35.50. Added to this is the cost in harvesting of $30.08 which brings total machinery operating cost to $65.58. The cost of gasoline, diesel, LP gas and electricity comes to $36.79 per acre, which leaves $28.79 for equipment repair costs in Michigan. For Washington, Doran shows machinery fuel and repairs to be $73.55 per acre. From this $6.50 is subtracted which consisted of utilities, office, travel, etc. which was not in the Michigan data, as well as $9.75 for irrigation since this is later represented in electricity costs, leaving $57.30. The cost of fuel (excluding electricity), $33.58, is subtracted, leaving equipment repair cost of $23.72 per acre.

Materials: The figures listed as materials[24] in Michigan are those used in weed control, bee rental, mouse baiting and airplane use. In Washington[15], the materials included are bee rental, gopher control, and mouse control.

Irrigation Labor: Although Michigan growers do some irrigation, the amount done is very small as compared to Washington. While well and pump operation is listed[24], no cost of labor is included. In Washington the frequency of surface irrigation depends on factors such as soil and topography, water-holding capacity of the soil, water applied each irrigation, climatic conditions, the rootzone of the trees, and the number of corrugations during the season. Doran shows ten irrigations per season, costing $32.50 in hired labor.

2. Fixed Costs.

Equipment Costs: In Washington, an annual interest rate of nine percent was charged on the investment in the equipment, buildings and vehicles at $81.17 per year. This amount does not include such annual costs as taxes and insurance which are included elsewhere. A straight line method of depreciation was used to determine depreciation on equipment and buildings. The $76.71 figure was calculated by subtracting the depreciation on trees from the total since trees will be included later. The Michigan data gives only one figure for both depreciation and interest of $89.68.

This fixed cost includes, however, depreciation, interest on investment, insurance and housing costs (interest, insurance, and housing equal 9.7 percent of average value).[24]

Irrigation: This charge, applying only to Washington, includes irrigation and weed district charges. This is a fixed cost that is separate from the cost of irrigation both in fuel and equipment use. The $14.00 represents an average charge to Washington growers.

Land Costs: In both Michigan and Washington, land costs include both the interest on the land itself and on the orchard. In Michigan, Kelsey identifies the value of land to be $450 and average orchard value of $550. At eight percent interest rates, the fixed cost of land in Michigan is $80.00 per acre per year. In Washington, land value is identified at $1500 which includes eight percent of the land devoted to roads, irrigation systems and buildings. Since this calculation was not explicitly included in the Michigan budget, it will be subtracted here to insure consistent data. Thus, the land value in Washington is estimated to be $1380, which at the eight percent interest rate means a fixed cost of $110.40 per acre per year.

Taxes: Since it is impossible to disaggregate these, the $20 in Washington includes the property taxes (real estate and personal property) as well as vehicle licenses. In Michigan, Kelsey simply identifies the $10 as property taxes.

Orchard Management: Rather than basing orchard management on some percentage of operating or land cost such as is often done, here the estimate of orchard management will be some hourly wage per hours of management per acre. In Michigan, Kelsey estimates management and labor supervision to be ten hours per acre at a wage of $3.50 per hour. In Washington on the other hand, management labor[14] is valued at $3.25 for about 17.5 hours per acre.

As shown in Table 12, the variable costs of production with no energy component have been estimated to be $680.84 per acre in Washington and $370.96 in Michigan. The fixed costs of production are estimated to total $358.88 in Washington and $214.68 in Michigan.

3. Variable Costs of Production with Direct Energy Components.

Table 13 shows the entire apple budget when those costs involving fossil fuel energy are added. The USDA figures used[39] include all energy directly used on the farm for crop production. The direct energy cost data of Table 13 represents the total amount of energy used (Table 14), multiplied by the 1976 price parameters (Table 6), and divided by acres; the cost of energy figures that result are shown in Table 15. Dividing each category in Table 15 by the acres harvested (Table 14), the result is the variable cost of production with direct energy. Once again the amount

Table 13.--Estimated Cost of Production, $/acre: Apples. Including Energy Costs. Base Year, 1976.

ESTIMATED COSTS	WASH. 217 trees/acre	MICH. 108 trees/acre
Variable Cost		
1. Without Energy Component		
Labor	$576.22	$304.38
Equipment Repairs	23.72	28.79
Materials	48.40	37.79
Irrigation Labor	32.50	
	$680.84	$370.96
2. With Direct Energy		
Gasoline	$ 10.64	$ 13.27
Diesel	22.94	21.52
Fuel Oil	21.52	23.15
LP Gas	.53	1.31
Electricity	77.78	.69
	$133.41	$ 59.94
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$ 8.27	$ 12.03
Non-Energy Cost	7.98	25.05
Total Cost	$ 16.25	$ 37.08
Pesticide		
Indirect Energy Cost	$ 17.42	$ 10.77
Non-Energy Cost	131.77	88.88
Total Cost	$149.19	$ 99.65
Total Variable Cost, per acre	$979.69	$567.63
Total Variable Cost, per ton (excluding transportation)	$ 47.24	$ 67.58
Fixed Cost		
Equipment Costs		
Depreciation	$ 76.71	$ 89.68
Interest	81.17	
Irrigation	14.00	
Land Costs	110.40	80.00
Taxes	20.00	10.00
Orchard Management	56.60	40.66
Total Fixed Cost, per acre	$358.88	$214.68
TOTAL COST, per acre	$1338.57	$782.31
TOTAL COST, per ton (ex. trans.)	64.54	93.13
TRANSPORTATION COST	14.52	1.51
TOTAL COST PER TON TO CHICAGO	$ 79.06	$ 94.64

Table 14.--Energy Use in Apple Production: USDA 1974 Data Base.

	Acres Harvested (1000)	Yield per acre tons[a]	Gal. of Gas (1000)	Gal. of Diesel (1000)	Gal. of Fuel Oil (1000)	Gal. of LP Gas (1000)	Cu. Ft. of Nat. Gas (mill)	Tons of Coal	KWH of Elec. (mill)	Total BTU's (bill)	BTU's per acre (1000)
Mich. Apples	58	8.40	1833	3311	2863	217	---	---	1	1852	31922
Wash. Apples	108	20.74	2711	6485	5010	151	---	---	300	3717	34422

[a]Calculation of yields per acre will be explained below. Numbers may not add up exactly due to rounding. Dashes indicate less than one-half unit.

Table 15.--1976 Cost of Energy Use in Apple Production.

	Gasoline ($1000)	Diesel ($1000)	Fuel Oil ($1000)	LP Gas ($1000)	Electricity ($1000)	Total Energy Cost ($1000)
Mich. Apples	769.860	1248.247	1342.747	75.95	40	3,476.804
Wash. Apples	1149.464	2477.270	2324.640	57.38	8400	14,408.754

and cost of electricity used to irrigate in Washington is much higher than in Michigan: $77.78 as compared to $0.69.

4. Variable Costs of Production with Indirect Energy Components.

Recalling the derivation of the costs employed the formula $P/BTU \cdot r = S$, where P = the cost of the energy per acre, r=BTU's per acre of fertilizer and pesticide used, and S = the indirect energy cost, the constant non-energy cost is derived by subtracting (S) from the total cost given by Kelsey and Doran. The total cost of fertilizer and pesticide use is given in Table 13: $16.25 and $37.08 for fertilizer in Washington and Michigan respectively; and $149.19 and $99.65 for pesticide. Table 16 shows the amount of energy used in fertilizer production.

Table 16.--Energy Use in Apple Production: Fertilizer.

	Nitrogen lbs. (1000)	Phosphate (P_2O_5) lbs. (1000)	Potash (K_2O) (1000)	BTU per acre (1000)
Mich. Apples	12064	---	2934	6685
Wash. Apples	7560	---	---	2177

Source: 39.

Dashes = less than one-half unit.

From Table 13, the price of energy per acre is given at \$133.41 for Washington and \$59.94 for Michigan. From Table 14, the total BTU's per acre used in apple production as listed is 31,922,000 in Michigan and 34,422,000 BTU's per acre in Washington. The P/BTU ratio for each state is: Washington = \$133.41/34422000 = \$.0000038, and Michigan = \$59.94/31922000 = \$.0000018. The indirect energy cost in fertilizer is multiplied by the BTU's per acre of fertilizer from Table 16: Michigan = \$.0000018·6685000 = \$12.03, and Washington = \$.0000038·2177000 = \$8.27. Subtracting the total (S) from the total fertilizer cost (P), gives the non-energy costs: Washington = \$16.25 - \$8.27 = \$7.98, and Michigan = \$37.08 - \$12.03 = \$25.05.

The procedure is repeated for pesticide costs, beginning with the total costs of Table 13 and the amounts of pesticides used in Table 17. From Table 13, the price of energy is divided by the total BTU's per acre from Table 14. The indirect energy cost in pesticide is: Michigan = \$.0000018·5986000 = \$10.77, and Washington = \$.0000038·4584000 = \$17.42. Subtracting this from the total costs leaves constant non-energy costs of \$131.77 for Washington and \$88.88 for Michigan.

5. Total Costs and Transportation Rates.

Referring to Table 14, the apple yield per acre in Michigan is 8.4, and 20.74 tons in Washington. Dividing these figures into the total variable cost per acre

Table 17.--Energy Use in Apple Production: Pesticide.

	Herbicide lbs. (1000)	Insecticide lbs. (1000)	Fungicide lbs. (1000)	Other lbs. (1000)	BTU per acre (1000)
Mich. Apples	80.4	2957.6	1417.7	---	5986
Wash. Apples	438.5	2874.5	---	467.7	4584

Source: 39.

Dashes = less than one-half unit.

gives the total variable cost per ton, excluding transportation, of $47.24 in Washington and $67.58 in Michigan. When total fixed costs per acre are divided by yields, Washington's growers face fixed costs of $64.54 per ton while Michigan's growers face a per ton fixed cost of $93.13. Washington can produce a ton of fresh apples at about 69 percent of the cost in Michigan.

Using the same transportation model as was employed in the potato budgets (Tables 10 and 11), Table 13 shows that Washington can still produce and ship to the Midwest at a lower cost, but at 84 percent of the cost of Michigan production. Similarly, before transportation, Washington produced potatoes at 62 percent of Michigan's cost and 85 percent after adding transportation. Thus, relative to Michigan's cost, transportation raised Washington's apple costs 15 percent.

In both cases, production and transportation costs calculated are for fresh apples and potatoes only, no storage or other packing and handling charges have been included. It is as if the produce was harvested on the farm directly to trucks that transported the goods to the market distribution center in the Midwest. The reason for excluding packing, handling and storage charges are twofold. First, what data does exist indicates that these costs do not vary greatly between regions. Second, useful comparative cost data between the two regions in this area does not exist. While a standard transportation model was adequate, no such method exists to estimate packing, handling and storage costs. Finally, it must be remembered that the cost data employed here are estimates and do not necessarily represent averages or exact costs that various farmers in either region may face.

CHAPTER VI

THE IMPACT OF RISING ENERGY PRICES ON INTERREGIONAL COMPETITION

The analysis of the impact of rising energy prices on interregional competition will take place in three steps:

1. An examination of the apple and potato enterprise budgets of Chapter V to analyze the proportion of total production costs accounted for by energy inputs, both with and without transportation costs. What is to be determined is whether Michigan or Washington, in either or both commodities, is relatively more energy intensive as a proportion of total costs. Does the proportion of energy costs change greatly when transportation costs are added and does this affect interregional competition? If so, although irrigation, chemical use and farm machinery account for much of the energy cost in agricultural production, it is fundamentally the cost and distance of transportation, and its dependence on diesel fuel, that accounts for regional variations in the impact of rising energy prices.

2. To establish various threshold energy prices where the cost differential shifts in favor of the previously disadvantaged state. That is, how high must the input price of energy go before the competitive situation is altered? Real energy prices will be increased, holding all other input

prices constant, until a point is reached at which the cost of differentials disappear. The margin at which this occurs is also the point at which the farmer would probably shift into the "next best" production possibility.

3. The above will be repeated in each of the markets in which Michigan and Washington compete in each commodity. Thus, not only will a set of threshold prices be established, but the "threshold distance" will also be found at which transportation costs cause a shift in the cost of supplying a market region. While the threshold prices and distances will be expressed in terms of specific values, they represent only estimates of the strength of change in energy input prices needed to shift cost differentials.

1976 Energy Cost-Total Cost Ratios

Referring to Tables 4 and 13, total cost of the production of apples in Michigan, excluding transportation, was $782.31 per acre, in 1976 prices. Washington's total cost per acre in apple production has been estimated at $1338.57.

When total and variable costs are taken on a per ton basis, Washington's total cost per ton is 69.3 percent of Michigan's. That Washington can produce a ton of apples at a much lower cost due to higher yields, accounts for the fact that Washington is able to ship its fresh apples to Chicago, over 1900 miles, and compete with Michigan apples, shipped only about 200 miles. When transportation costs are added to Table 13, apples from Washington remain less costly to deliver to Chicago per ton ($79.06 and $94.64 for Washington and Michigan respectively). Although transportation cost from Washington (to Chicago) is more than 960 percent above Michigan's, Washington still produces and ships apples at 83.54 percent of Michigan's cost.

The total cost of potato production, excluding transportation, was $824.54 per acre and $679.29 per acre in Washington and Michigan respectively, in 1976 prices (Table 4). As a proportion of total costs, the variable cost structure for potatoes is different than for apples. While each state exhibits approximately the same variable cost/ total cost ratio in apples, the potato production budget shows Michigan's variable costs to be approximately 65.3 percent of total cost, while the ratio goes to 68.8 percent in Washington. This 3.5 percent difference will mean that when real energy prices are changed, the difference in total cost in the base budget will close more rapidly in potatoes than in apples. Thus, it will take a smaller rise in real energy prices to reach a threshold in potato production costs, compared with apples.

While Washington's potato costs are 121.38 percent of Michigan's, per acre, the difference in yields per acre between Washington and Michigan once again make it less costly to produce potatoes in Washington. Potato yields in Washington of 22.5 tons per acre are nearly double the 11.5 ton yields in Michigan. When total costs are taken on a per ton basis, Washington can produce potatoes at a lower cost than

Michigan ($36.65 versus $59.07). Recalling that on a per acre basis, Washington's costs are 121.38 percent of Michigan's, the figure is now reversed, making Washington's cost only 62.05 percent of Michigan's. Even adding the cost per ton of transportation, Washington's costs remain less than Michigan's, at 84.47 percent. The above information is summarized in Table 18.

Table 18.--1976 Total Cost-Variable Cost-Relative Cost and Yield Comparisons With and Without Transportation Costs to Chicago.

Cost Category	Apples Mich.	Apples Wash.	Potatoes Mich.	Potatoes Wash.
Total Cost per acre --no transportation	$ 782.31	1338.57	679.29	824.54
Variable Cost	$ 567.63	979.69	443.54	566.86
Variable Cost/Total Cost · %	72.56	73.19	65.29	68.75
Relative Total Cost per acre · %	58.44	171.10	82.38	121.38
Yield per ton	8.40	20.74	11.50	22.50
Relative Yield · %	40.50	246.90	51.10	195.65
Total Cost per ton	$ 93.13	64.54	59.07	36.65
Relative Total Cost per ton · %	144.30	69.30	161.17	62.05
Transportation Cost per ton to Chicago	$ 1.51	14.52	1.51	14.52
Total Cost per ton--with transportation	$ 94.64	79.06	60.58	51.17
Relative Total Cost per ton · % Delivered Product	119.70	83.54	118.39	84.47

Examining further the proportion of total production costs attributed to energy inputs (Tables 4 and 13) will illustrate the intensity with which Michigan and Washington producers employ fossil fuel energy inputs. Separating the costs with and without transportation charges, the information on the proportion of energy costs to variable and total costs is summarized in Table 19. Two points can be made from Table 19. First, as a percentage of both variable and total costs, Michigan is relatively less energy intensive in both apple and potato production. As a proportion of variable costs, energy costs are 14.58 percent of apple costs and 14.64 percent of potato costs. On the other hand, 16.24 percent of apple costs and 19.33 percent of potato costs in Washington are accounted for by energy inputs. Similarly, the proportion of energy costs to total cost, undelivered, is 10.58 percent in Michigan apple production and 9.56 percent in potatoes. In Washington the figures are 11.88 percent and 13.29 percent respectively. Thus, in both cases, as real energy prices rise, with all other costs constant, production costs to Washington producers will go up faster than to Michigan.

Recalling that while Washington can produce and ship both apples and potatoes at a cost less than Michigan, the relative cost of producing apples, as compared to Michigan is higher than in producing potatoes. Without transportation costs, Washington produces potatoes at a variable cost 65.3 percent that of Michigan, while this goes to 68.8

Table 19.--1976 Energy Cost/Total Cost Comparisons With and Without Transportation Costs to Chicago.

Cost Category	Apples Mich.	Apples Wash.	Potatoes Mich.	Potatoes Wash.
1. No Transportation				
VC/acre	$ 567.63	979.69	443.54	566.86
VC/ton	$ 67.58	47.24	38.57	25.19
Var. E./acre[a]	$ 82.74	159.10	64.92	109.56
Var. E./ton[b]	$ 9.85	7.67	5.65	4.87
Var. E./VC[c] · %	14.58	16.24	14.64	19.33
TC/acre	$ 782.31	1338.57	679.29	824.54
TC/ton	$ 93.13	64.54	59.07	36.65
Var. E./TC[d] · %	10.58	11.88	9.56	13.29
2. With Transportation to Chicago				
TC/ton	$ 94.64	79.06	60.58	51.17
Var. E. + Trans. Energy[e]	$ 11.36	22.19	7.16	19.39
Relative Energy Cost, per ton·%	12.00	28.07	11.82	37.89

[a]Variable Energy Cost/acre = VC with direct energy + indirect energy in fertilizer + indirect energy in pesticide. For example: Var. energy cost in MI apples = $59.94 + $12.03 + $10.77 = $82.74 (figures from Table 13).

[b]Same method as above, except figure divided by yield per acre. For example, for MI apples: Var. energy cost per acre/ton yield = $82.74/8.4 = $9.85.

[c]Variable energy cost/variable cost is for both ton and acre since they come to the same percentage. That is, MI apples per acre = $82.74/567.63 = 14.58%, and MI apples per ton = $9.85/67.58 = 14.58%.

[d]Here still using the variable energy cost figures because we have yet to add energy cost of transportation. Therefore, since no energy cost exists as fixed costs, we still use variable energy cost, figured as in ff c. Again, the same percentages exist on a per ton or per acre basis, as explained above.

[e]To account for all energy used, including transportation, add variable energy cost above and transportation cost from Tables 4 and 13, since these transportation costs reflect just diesel fuel costs.

percent in apples. When looking at total costs, Washington produces potatoes at 62.05 percent of Michigan's cost while this goes up to 69.30 percent in apples. Thus, while Washington has an absolute cost advantage in both commodities, it costs relatively more to produce apples. Only after adding transportation cost does this change. When the energy cost/total cost ratio is examined prior to adding transportation costs, the difference between commodity ratios indicates that Michigan potato growers spend less on energy relative to Washington potato growers than do their apple-producing counterparts. Thus, as real energy prices increase, while Michigan potato farmers produce at a more costly rate, the cost differential will close faster in potato farming than for those producing apples. Energy price increases will affect the competition in potato production between the two regions faster than in apple production.

The second thing to note in Table 19 is that while the percentages of energy cost to total cost before transportation charges are relatively similar in Michigan and Washington, these ratios change slightly in Michigan, but more so in Washington, when transportation costs are added. In fact, in Washington potato production, the amount of total costs accounted for by energy price rises to 37.89 percent and 28.07 percent in Washington apples, compared to 11.82 percent and 12.00 percent for Michigan potatoes and apples. This of course indicates that when transportation costs are considered, the impact of rising real energy prices will affect Washington to a much greater degree than it will Michigan. What this indicates is that while Heady and Dvoskin's model predicts that the energy use in agricultural production, particularly in Washington's irrigation use, will adversely affect costs, it is not in production, but in transportation rate increases that real energy price increases close cost differentials. Distance to market will determine regional competition and not the production function difference between firms in different regions.

Energy Cost-Total Cost Ratio with Increased Real Energy Input Prices

Tables 20 and 21 represent the estimated costs of production of apples and potatoes when real energy prices are all tripled, holding all other costs constant. While a tripling appears to be arbitrary at the moment, the rationale for this will be discussed when threshold prices are introduced. The purpose at this time is to simply explore the cost relationships established in the preceeding section when real energy input prices are increased substantially.

Referring to Table 20, the total farm cost of production of apples in Michigan is $947.79 per acre. Washington's total cost per acre in apple production has been estimated at $1656.77, in 1976 prices. Thus, with a tripling of real energy input prices, the cost of production in Michigan has increased 21.15 percent ($947.79 and $782.31) while the cost of production in Washington has increased 23.77 percent.

Table 20.--Real Energy Input Prices: Tripled. Estimated Cost of Production, $/acre: Apples. Base Year, 1976.

ESTIMATED COSTS	WASH. 217 trees/acre	MICH. 108 trees/acre
Variable Cost		
1. Without Energy Component		
Labor	$576.22	$304.38
Equipment Repairs	23.72	28.79
Materials	48.40	37.79
Irrigation Labor	32.50	
	$680.84	$370.96
2. With Direct Energy		
Gasoline	$ 31.92	$ 39.81
Diesel	68.82	64.65
Fuel Oil	64.56	69.45
LP Gas	1.59	3.93
Electricity	233.34	2.07
	$400.23	$179.82
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$ 24.81	$ 36.09
Non-Energy Cost	7.98	25.05
Total Cost	$ 32.79	$ 61.14
Pesticide		
Indirect Energy Cost	$ 52.26	$ 32.31
Non-Energy Cost	131.77	88.88
Total Cost	$184.03	$121.19
Total Variable Cost, per acre	$1297.89	$733.11
Total Variable Cost, per ton (excluding transportation)	62.58	87.28
Fixed Cost		
Equipment Costs		
Interest	$ 81.17	
Depreciation	76.71	$ 89.68
Irrigation	14.00	
Land Costs	110.40	80.00
Taxes	20.00	10.00
Orchard Management	56.60	35.00
Total Fixed Cost, per acre	$358.88	$214.68
TOTAL COST, per acre	$1654.67	$947.79
TOTAL COST, per ton (ex. trans.)	79.88	112.83
TRANSPORTATION COST (by truck)	43.56	4.53
TOTAL COST PER TON TO CHICAGO	$ 123.44	$117.36

Table 21.--Real Energy Input Prices: Tripled. Estimated Cost of Production, $/acre: Potatoes. Base Year, 1976.

ESTIMATED COSTS	WASH.	MICH.
Variable Cost		
1. With Energy Component		
Seed	$117.04	$112.50
Equipment Repairs	37.65	31.24
Labor	40.13	32.26
Irrigation Repairs	6.60	6.60
Irrigation Labor	6.40	6.40
	$207.82	$189.00
2. With Direct Energy (including irrigation)		
Gasoline	$ 29.76	$ 38.79
Diesel	17.01	27.21
Electricity	172.74	49.05
	$219.51	$115.05
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$100.17	$ 75.05
Non-Energy Cost	96.70	85.11
Total Cost	$196.87	$161.16
Pesticide		
Indirect Energy Cost	$ 9.00	$ 3.66
Non-Energy Cost	152.78	104.51
Total Cost	$161.78	$108.17
Total Variable Cost, per acre	$785.98	$573.38
Total Variable Cost, per ton (excluding transportation)	34.93	49.86
Fixed Cost		
Equipment Costs		
Depreciation	$ 48.07	$ 48.07
Interest	45.18	45.18
Sprinkler Irrigation		
Depreciation	27.98	27.98
Interest	34.03	34.03
Operating Capital	16.35	23.86
Land Costs	86.07	56.63
Total Fixed Cost, per acre	$257.68	$235.75
TOTAL COST, per acre	$1043.66	$809.13
TOTAL COST, per ton (ex. trans.)	46.38	70.36
TRANSPORTATION COST (by truck)	43.56	4.53
TOTAL COST PER TON TO CHICAGO	$ 89.94	$ 74.89

This correlates with the fact that Washington is relatively more energy intensive in its production of apples (Table 19); as real energy input prices rise, production costs in Washington rise at a faster pace.

On a per ton basis, Washington's total costs remain less than Michigan's, $79.88 as compared to $112.83. Yet, rather than being 69.30 percent of Michigan's cost, Washington now produces at 70.80 percent of Michigan costs: when energy prices are tripled, Washington can still produce apples at a lower cost per ton than Michigan.

Adding transportation costs does not change the cost advantage that Washington enjoys over Michigan in the base year budgets of Chapter V. As real energy prices increase, however, the cost of transportation shifts the cost advantage to Michigan's favor. Delivering apples from Washington to Chicago costs $123.44 per ton with tripled real energy prices. At the same time, Michigan can deliver apples at an estimated cost of $117.36. While the cost shift did not occur when examining just production prices, it did occur when the cost of transportation was added. It is evident therefore that the crucial factor in any regional change in competitive positions due to real energy input price increases is related to the distance from the production site to the market. It can be concluded that given two states competing in the same market, with one having an advantage even with a longer distance to ship, an increase in real energy input prices, holding all other costs constant, at some point will change the competitive balance that existed before the cost increase.

The estimated potato budget, with real energy prices tripled, holding all other costs constant (Table 21), shows total farm cost of production as $1043.66 per acre and $809.13 per acre in Washington and Michigan respectively, 1976 prices. On a total cost per acre basis, Washington's costs are higher than in Michigan, representing 128.99 percent of Michigan's potato production costs. Yet as a proportion of Michigan's costs they are less expensive than for apple production, producing a threshold price in potato production lower than in apple production. As real energy prices rise, Michigan potato growers will experience a shift in the competitive cost balance before Michigan apple producers.

When costs are taken on a per ton basis, the cost advantage that Michigan enjoyed on a per acre basis disappears. In Washington, a ton of potatoes can be produced at a cost of $46.38 when real energy input prices are tripled, while Michigan's costs go to $70.36. The increase in real energy prices has made Washington costs go up 26.55 percent while Michigan costs have risen only 19.01 percent per ton.

When transportation costs are added, Michigan gains a cost advantage. Prior to raising real energy input prices, even including transportation, Washington could deliver potatoes to Chicago cheaper than Michigan. Now, Michigan can deliver a ton of potatoes to Chicago at a cost of

$74.89, while Washington's costs have risen to $89.94. In both apples and potatoes Michigan gains this advantage when real energy input prices are tripled, due to the cost of transportation, yet potatoes are proportionally cheaper to deliver from Michigan than are apples. The above information is summarized in Table 22. The information on the

Table 22.--1976 Total Cost-Variable Cost-Relative Cost Comparisons With and Without Transportation Costs to Chicago: Real Energy Prices Tripled.

Cost Category	Apples		Potatoes	
	Mich.	Wash.	Mich.	Wash.
TC per acre--no transportation	$ 947.79	1656.77	809.13	1043.66
VC	$ 733.11	1297.89	573.38	785.98
VC/TC · %	77.35	78.34	70.86	75.31
Relative Total Cost, per acre · %	57.21	174.80	77.53	128.99
Yield per ton	8.40	20.74	11.50	22.50
TC per ton	$ 112.83	79.88	70.36	46.38
Relative Total Cost, per ton · %	141.25	70.80	151.70	65.92
Transportation Cost per ton to Chicago	$ 4.53	43.56	4.53	43.56
TC per ton--with transportation	$ 117.36	123.44	74.89	89.94
Relative Total Cost, per ton, Delivered · %	95.07	105.18	83.27	120.10

proportion of real energy costs to variable and total costs is summarized in Table 23. When the cost of transportation

Table 23.--1976 Energy Cost/Total Cost Comparisons: Real Energy Input Prices Tripled With and Without Transportation Costs to Chicago.

Cost Category	Apples Mich.	Apples Wash.	Potatoes Mich.	Potatoes Wash.
1. <u>No Transportation</u>				
VC/acre	$ 733.11	1297.89	573.38	785.98
VC/ton	$ 87.28	62.58	49.86	34.93
Var. E./acre	$ 248.22	477.30	194.76	328.68
Var. E./ton	$ 29.55	23.01	16.95	14.61
Var. E./VC	% 33.86	36.77	34.00	41.83
TC/acre	$ 947.79	1656.77	809.13	1043.66
TC/ton	$ 112.83	79.88	70.36	46.38
Var. E./TC	% 26.19	28.81	24.09	31.50
2. <u>With Transportation</u>				
TC/ton	$ 117.36	123.44	74.89	89.94
Var. E. + Trans. Energy	$ 34.08	66.57	21.48	58.17
Relative Energy Cost, per ton	% 29.04	53.93	28.68	64.68

is included, the energy cost/total cost ratio changes both between states and between commodities. The percentage of energy cost to total cost goes up to 64.68 percent in Washington potatoes and 53.93 percent in apples. The figures in Michigan when transportation costs are added are 29.04 percent for apples and 20.68 percent for potatoes.

<u>Threshold Prices at Which Competitive Advantage Changes</u>

To this point, the purpose has been to lay out the relative direction of the impact of rising real energy prices when Michigan's and Washington's commodities compete in just one market. The last section has shown that a shift in the competitive cost structure does take place when real energy prices are increased 300 percent. The focus of this section will be to see where this shift actually takes place--the threshold price. Threshold prices will be sought in each of the ten apple markets and four potato markets introduced in Chapter IV.

In order to find a threshold price at which the cost differentials in apples and potatoes shift between Michigan and Washington, the price of energy inputs will be increased by 30.6 percent, 300 percent, and 400 percent. The 30.6 percent increase is an estimate of how much energy prices will increase in 1979 (before the latest OPEC price increase). The 30.6 percent figure comes first from the estimated energy cost escalation projection developed by the U.S. Army Corps of Engineers,* of an average of seven percent next year. The 1978 yearly rate of inflation of 9.1 percent was added to that (the annual rate of inflation as of August 1, 1979 is actually about 13 percent), along with the 14.5 percent increase in oil prices due to OPEC decisions made at its December meeting (which was further increased in June 1979). The 300 percent figure comes from U.S. Department of Energy's

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*Cited in: Smith, Hindman, and Grylls Assoc., Inc., "Solar Feasibility Study for CATA Bus Storage and Maintenance Facility." Prepared for the State of Michigan, Bureau of Urban and Public Transportation, Department of State Highways and Transportation, Lansing, Michigan, 1978.

estimation of increases in natural gas due to the Carter Administration's phased deregulation policies; a policy of decontrol of domestic oil prices went into effect June 1, 1979. While this DOE study was only with regard to natural gas, it is felt this is a useful benchmark, given a price rise due to deregulation in the future. Finally, the 400 percent figure was chosen as a third point to be graphed so that the difference between costs becomes wide enough to force one or the other states to shift production to the next best production possibility. Tables 24 through 29 show the estimated costs of production for apples and potatoes given a 30.6 percent, 300 percent, and 400 percent energy input price increase, with all other costs of production held constant.

When a threshold price is sought in each of the markets in which Michigan and Washington compete in both commodities, it will be the distance over which products are shipped that will be different in each market area. Therefore, along with the 1976 base figures of Chapter V, the total farm cost of production per ton will be the same under each price increase across markets. The total farm costs per ton will be added to the various costs of transportation (Table 30), and Table 31 gives the distance from the producing area to the market and the cost of transportation in the base budgets, as real energy costs are increased.

Table 24.--Estimated Cost of Production, $/acre: Potatoes: 30.6 Percent Increased Real Energy Prices.

ESTIMATED COSTS	WASH.	MICH.
Variable Cost		
1. Without Energy Component		
Seed	$117.04	$112.50
Equipment Repairs	37.65	31.24
Labor	40.13	32.26
Irrigation Repairs	6.60	6.60
Irrigation Labor	6.40	6.40
	$207.82	$189.00
2. With Direct Energy (including irrigation)		
Gasoline	$ 12.96	$ 16.89
Diesel	7.41	11.85
Electricity	75.20	21.35
	$ 95.57	$ 50.09
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$ 43.61	$ 33.11
Non-Energy Cost	96.70	85.11
Total Cost	$140.31	$118.22
Pesticide		
Indirect Energy Cost	$ 3.92	$ 1.59
Non-Energy Cost	152.78	104.51
Total Cost	$156.70	$106.10
Total Variable Cost, per acre	$600.40	$463.41
Total Variable Cost, per ton (excluding transportation)	26.68	40.30
Fixed Cost		
Equipment Costs		
Depreciation	$ 48.07	$ 48.07
Interest	45.18	45.18
Sprinkler Irrigation		
Depreciation	27.98	27.98
Interest	34.03	34.03
Operating Capital	16.35	23.86
Land Costs	86.07	56.63
Total Fixed Cost, per acre	$257.68	$235.75
TOTAL COST, per acre	$858.08	$699.16
TOTAL COST, per ton (ex. trans.)	38.14	60.80
TRANSPORTATION COST (by truck)	18.96	1.97
TOTAL COST PER TON TO CHICAGO	$ 57.10	$ 62.77

Table 25.--Real Energy Input Prices: Tripled. Estimated Cost of Production, $/acre: Potatoes.

ESTIMATED COSTS	WASH.	MICH.
Variable Cost		
1. Without Energy Component		
Seed	$117.04	$112.50
Equipment Repairs	37.65	31.24
Labor	40.13	32.26
Irrigation Repairs	6.60	6.60
Irrigation Labor	6.40	6.40
	$207.82	$189.00
2. With Direct Energy (including irrigation)		
Gasoline	$ 29.76	$ 38.79
Diesel	17.01	27.21
Electricity	172.74	49.05
	$219.51	$115.05
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$100.17	$ 75.05
Non-Energy Cost	96.70	85.11
Total Cost	$196.87	$161.16
Pesticide		
Indirect Energy Cost	$ 9.00	$ 3.66
Non-Energy Cost	152.78	104.51
Total Cost	$161.78	$108.17
Total Variable Cost, per acre	$785.98	$573.38
Total Variable Cost, per ton (excluding transportation)	34.93	49.86
Fixed Cost		
Equipment Costs		
Depreciation	$ 48.07	$ 48.07
Interest	45.18	45.18
Sprinkler Irrigation		
Depreciation	27.98	27.98
Interest	34.03	34.03
Operating Capital	16.35	23.86
Land Costs	86.07	56.63
Total Fixed Cost, per acre	$257.68	$235.75
TOTAL COST, per acre	$1043.66	$809.13
TOTAL COST, per ton (ex. trans.)	46.38	70.36
TRANSPORTATION COST (by truck)	43.56	4.53
TOTAL COST PER TON TO CHICAGO	$ 89.94	$ 74.89

Table 26.--Real Energy Input Prices: Quadrupled. Estimated Cost of Production, $/acre: Potatoes.

ESTIMATED COSTS	WASH.	MICH.
Variable Cost		
1. Without Energy Component		
Seed	$117.04	$112.50
Equipment Repairs	37.65	31.24
Labor	40.13	32.26
Irrigation Repairs	6.60	6.60
Irrigation Labor	6.40	6.40
	$207.82	$189.00
2. With Direct Energy (including irrigation)		
Gasoline	$ 39.68	$ 51.72
Diesel	22.68	36.28
Electricity	230.32	65.40
	$292.68	$153.40
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$133.56	$101.40
Non-Energy Cost	96.70	85.11
Total Cost	$230.26	$186.51
Pesticide		
Indirect Energy Cost	$ 12.00	$ 4.88
Non-Energy Cost	152.78	104.51
Total Cost	$164.78	$109.39
Total Variable Cost, per acre	$895.54	$638.30
Total Variable Cost, per ton (excluding transportation)	39.80	55.26
Fixed Cost		
Equipment Costs		
Depreciation	$ 48.07	$ 48.07
Interest	45.18	45.18
Sprinkler Irrigation		
Depreciation	27.98	27.98
Interest	34.03	34.03
Operating Capital	16.35	23.86
Land Costs	86.07	56.63
Total Fixed Cost, per acre	$257.68	$235.75
TOTAL COST, per acre	$1153.22	$874.05
TOTAL COST, per ton (ex. trans.)	51.25	75.68
TRANSPORTATION COST (by truck)	58.08	6.04
TOTAL COST PER TON TO CHICAGO	$ 109.33	$ 81.72

Table 27.--Estimated Cost of Production, $/acre: Apples: 30.6 Percent Increased Real Energy Prices.

ESTIMATED COSTS	WASH. 217 trees/acre	MICH. 108 trees/acre
Variable Cost		
1. Without Energy Component		
Labor	$576.22	$304.38
Equipment Repairs	23.72	28.79
Materials	48.40	37.79
Irrigation Labor	32.50	
	$680.84	$370.96
2. With Direct Energy		
Gasoline	$ 13.90	$ 17.33
Diesel	29.96	28.11
Fuel Oil	28.11	30.23
LP Gas	.69	1.71
Electricity	101.58	.90
	$174.24	$ 78.28
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$ 10.80	$ 15.71
Non-Energy Cost	7.98	25.05
Total Cost	$ 18.78	$ 40.76
Pesticide		
Indirect Energy Cost	$ 22.75	$ 3.30
Non-Energy Cost	131.77	88.88
Total Cost	$154.52	$ 92.18
Total Variable Cost, per acre	$1028.38	$582.18
Total Variable Cost, per ton (excluding transportation)	49.58	69.31
Fixed Cost		
Equipment Costs		
Interest	$ 81.17	
Depreciation	76.71	$ 89.68
Irrigation	14.00	
Land Costs	110.40	80.00
Taxes	20.00	10.00
Orchard Management	56.60	35.00
Total Fixed Cost, per acre	$358.88	$214.68
TOTAL COST, per acre	$1387.26	$796.86
TOTAL COST, per ton (ex. trans.)	66.89	94.86
TRANSPORTATION COST (by truck)	18.96	1.97
TOTAL COST PER TON TO CHICAGO	$ 85.85	$ 96.83

Table 28.--Real Energy Input Prices: Tripled. Estimated Cost of Production, $/acre: Apples.

ESTIMATED COSTS	WASH. 217 trees/acre	MICH. 108 trees/acre
Variable Cost		
1. Without Energy Component		
Labor	$576.22	$304.38
Equipment Repairs	23.72	28.79
Materials	48.40	37.79
Irrigation	32.50	
	$680.84	$370.96
2. With Direct Energy		
Gasoline	$ 31.92	$ 39.81
Diesel	68.82	64.56
Fuel Oil	64.56	69.45
LP Gas	1.59	3.93
Electricity	233.34	2.07
	$400.23	$179.82
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$ 24.81	$ 36.09
Non-Energy Cost	7.98	25.05
Total Cost	$ 32.79	$ 61.14
Pesticide		
Indirect Energy Cost	$ 52.26	$ 32.31
Non-Energy Cost	131.77	88.88
Total Cost	$184.03	$121.19
Total Variable Cost, per acre	$1297.89	$733.11
Total Variable Cost, per ton (excluding transportation)	62.58	87.28
Fixed Cost		
Equipment Costs		
Interest	$ 81.17	
Depreciation	76.71	$ 89.68
Irrigation	14.00	
Land Costs	110.40	80.00
Taxes	20.00	10.00
Orchard Management	56.60	35.00
Total Fixed Cost, per acre	$358.88	$214.68
TOTAL COST, per acre	$1654.67	$947.79
TOTAL COST, per ton (ex. trans.)	79.88	112.83
TRANSPORTATION COST (by truck)	43.56	4.53
TOTAL COST PER TON TO CHICAGO	$ 123.44	$117.36

Table 29.--Real Energy Input Prices: Quadrupled. Estimated Cost of Production, $/acre: Apples.

ESTIMATED COSTS	WASH. 217 trees/acre	MICH. 108 trees/acre
Variable Cost		
1. Without Energy Component		
Labor	$576.22	$304.38
Equipment Repairs	23.72	28.79
Materials	48.40	37.79
Irrigation Labor	32.50	
	$680.84	$370.96
2. With Direct Energy		
Gasoline	$ 42.56	$ 53.08
Diesel	91.76	86.08
Fuel Oil	86.08	92.60
LP Gas	2.12	5.24
Electricity	311.12	2.76
	$533.64	$239.76
3. With Indirect Energy		
Fertilizer		
Indirect Energy Cost	$ 33.08	$ 48.12
Non-Energy Cost	7.98	25.05
Total Cost	$ 41.06	$ 73.17
Pesticide		
Indirect Energy Cost	$ 69.68	$ 43.08
Non-Energy Cost	131.77	88.88
Total Cost	$201.45	$131.96
Total Variable Cost, per acre	$1456.99	$815.85
Total Variable Cost, per ton (excluding transportation)	70.25	97.13
Fixed Cost		
Equipment Costs		
Interest	$ 81.17	
Depreciation	76.71	$ 89.68
Irrigation	14.00	
Land Costs	110.40	80.00
Taxes	20.00	10.00
Orchard Management	56.60	35.00
Total Fixed Cost, per acre	$358.88	$214.68
TOTAL COST, per acre	$1815.87	$1030.53
TOTAL COST, per ton (ex. trans.)	87.55	122.68
TRANSPORTATION COST (by truck)	58.08	6.04
TOTAL COST PER TON TO CHICAGO	$ 145.63	$ 128.72

Highlighting what has been said about transportation costs, Table 30 reveals that at all real energy price rates, Washington produces both apples and potatoes at a cheaper cost than does Michigan. This occurs even when energy prices are quadrupled. Thus, it is due to increased transportation costs that the competitive cost structure changes.

Table 30.--Total Farm Costs, per ton, Apples and Potatoes, Varying Real Energy Input Prices.

State/Commodity	Base Year, 1976	Increase in Real Energy Input Prices		
		30.6%	300%	400%
Mich. Apples	$93.13	$94.86	$112.83	$112.68
Wash. Apples	64.54	66.89	79.88	87.55
Mich. Potatoes	59.07	60.80	70.36	75.68
Wash. Potatoes	36.65	38.14	46.38	51.25

When the total costs of production per ton (Table 30) are added to the transportation costs to the various markets (Table 31), the total costs of delivering to each market area are shown in Table 32. In Table 32, at each real energy input price, the state's costs which are lower are starred. Prior to any increase in real energy prices, that is in the base year figures, Washington's costs to deliver both potatoes and apples is less than Michigan's to every city. When real energy input prices are increased 30.6 percent, this pattern remains.

Table 31.--Transportation Costs to Varying Markets: Varied Real Energy Input Prices.

Production Area to Representative Market City	Miles	Base	30.6%	300%	400%
Apples					
Mich-Chicago	200	$ 1.51	$ 1.97	$ 4.53	$ 6.04
Wash-Chicago	1900	14.52	18.96	43.56	58.08
Mich-Detroit	148	1.12	1.46	3.36	4.48
Wash-Detroit	2236	17.15	22.40	51.45	68.60
Mich-St. Louis	513	3.87	5.05	11.61	15.48
Wash-St. Louis	2037	15.56	20.32	46.68	62.24
Mich-Cleveland	325	2.45	3.20	7.35	9.80
Wash-Cleveland	2310	17.65	23.05	52.95	70.60
Mich-Houston	1368	10.31	13.46	30.93	41.24
Wash-Houston	2283	17.44	22.78	52.32	69.76
Mich-Minneapolis	538	4.06	5.30	12.18	16.24
Wash-Minneapolis	1559	11.91	15.55	35.73	47.64
Mich-Cincinnati	414	3.12	4.07	9.36	12.48
Wash-Cincinnati	2235	17.08	22.31	51.24	68.32
Mich-Buffalo	402	3.03	3.96	9.09	12.12
Wash-Buffalo	2507	19.15	25.01	57.45	76.60
Mich-Dallas	1125	8.48	11.07	25.44	33.92
Wash-Dallas	2042	15.59	20.36	46.77	62.36
Mich-Milwaukee	300	2.26	2.95	6.78	9.04
Wash-Milwaukee	1889	14.43	18.85	43.29	57.72
Potatoes					
Mich-Chicago	200	1.51	1.97	4.53	6.04
Wash-Chicago	1900	14.52	18.96	43.56	58.08
Mich-Philadelphia	728	5.49	7.17	16.47	21.96
Wash-Philadelphia	2588	19.77	25.82	59.31	79.08
Mich-Dallas	1125	8.48	11.07	25.44	33.92
Wash-Dallas	1902	14.53	18.98	43.59	58.12
Mich-Denver	1208	9.11	11.90	27.33	36.44
Wash-Denver	1122	8.57	11.19	25.71	34.28

Somewhere between a 30.6 percent change and a 300 percent change in real energy prices, Michigan's costs to deliver apples becomes less to seven out of ten market areas: in Chicago, Detroit, St. Louis, Cleveland, Cincinnati, Buffalo, and Milwaukee, Michigan's costs are less than

Table 32.--Total Costs of Delivery to Various Markets at Varied Real Energy Input Prices.

Production Area to Representative Market City	Base	30.06%	300%	400%
Apples				
Mich-Chicago	$ 94.64	$ 96.83	$117.36*	$128.72*
Wash-Chicago	79.06*	85.85*	123.44	145.63
Mich-Detroit	94.25	96.32	116.19*	127.16*
Wash-Detroit	81.69*	82.29*	131.33	156.15
Mich-St. Louis	97.00	99.91	124.44*	138.16*
Wash-St. Louis	80.10*	87.21*	125.56	149.79
Mich-Cleveland	95.58	98.06	120.18*	132.48*
Wash-Cleveland	82.19*	89.94*	132.83	158.15
Mich-Houston	103.44	108.32	143.76	163.92
Wash-Houston	81.98*	89.67*	132.20*	157.31*
Mich-Minneapolis	97.19	100.16	125.01	138.92
Wash-Minneapolis	76.45*	82.44*	115.61*	135.19*
Mich-Cincinnati	96.25	98.93	122.19*	135.16*
Wash-Cincinnati	81.62*	89.20*	131.12	155.87
Mich-Buffalo	96.16	98.82	121.92*	134.80*
Wash-Buffalo	83.69*	91.90*	137.33	164.15
Mich-Dallas	101.61	105.93	138.27	156.60
Wash-Dallas	80.13*	87.25*	126.65*	149.91*
Mich-Milwaukee	95.39	97.81	110.61*	131.72*
Wash-Milwaukee	78.97*	85.74*	123.17	145.27
Potatoes				
Mich-Chicago	60.58	62.77	74.89*	81.72*
Wash-Chicago	51.17*	57.10*	89.94	109.33
Mich-Philadelphia	64.56	67.97	86.83*	97.64*
Wash-Philadelphia	56.42*	63.96*	105.69	130.33
Mich-Dallas	67.55	71.15	95.80	109.60
Wash-Dallas	51.18*	57.12*	89.97*	109.37*
Mich-Denver	68.18	72.70	97.69	112.12
Wash-Denver	45.22*	49.33*	72.09*	85.53*

Washington's. On the other hand, even with a 300 percent real energy price increase, Washington delivers at less cost to Houston, Minneapolis, and Dallas. In potato production, a 300 percent increase in real energy prices results in a change in two out of the four market areas. To

Chicago and Philadelphia, Michigan's costs are less, while Washington can still deliver at a less costly rate to Dallas and Denver. The results remain the same when real energy prices are quadrupled. A pattern here is obvious. When real energy input prices rise as much as 300 percent, Michigan's costs are less than Washington's in all market areas east of the Mississippi (including St. Louis), while Washington's costs are less west of the Mississippi.

Figures 7 through 15 show in graphic form the effects of real energy input price increases on the total cost of delivering apples and potatoes from Michigan and Washington. As was seen from Table 32, in each of the seven apple markets and two potato markets, an increase in real energy input prices somewhere between 30.6 percent and 300 percent, causes the total cost curves to cross, producing a threshold price at which it becomes less costly to deliver from Michigan. Table 33 summarizes, in approximate form, the information in the following graphs. These threshold figures, while expressed in specific values, are only approximate estimates.

In all cases, the percentage increase in real energy input prices that causes total costs to shift, occurs substantially above the 30.6 percent figure and below the 300 percent real price increase. In apple production and shipping, a real energy input price increase of approximately 120 percent would cause the threshold cost of about $106 per ton to occur in the Buffalo market; the range goes to

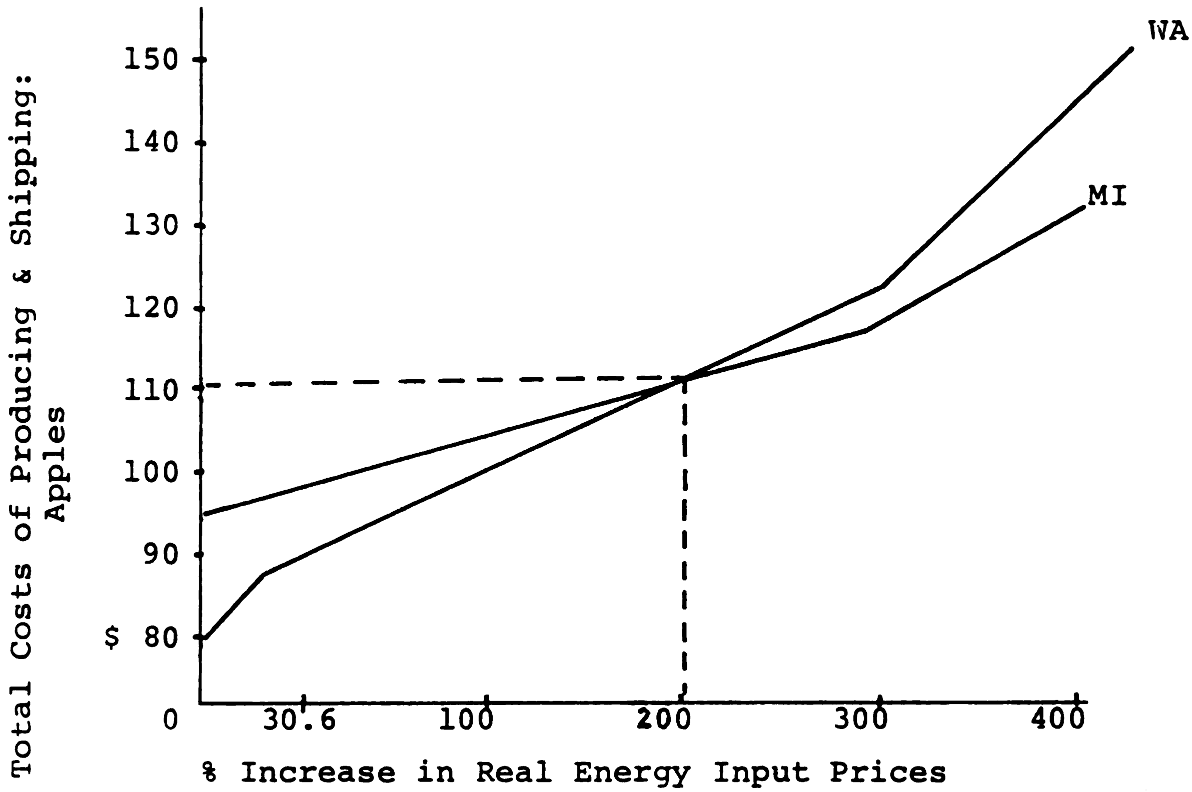

Figure 7.--Threshold Price: Apples to Chicago Market.

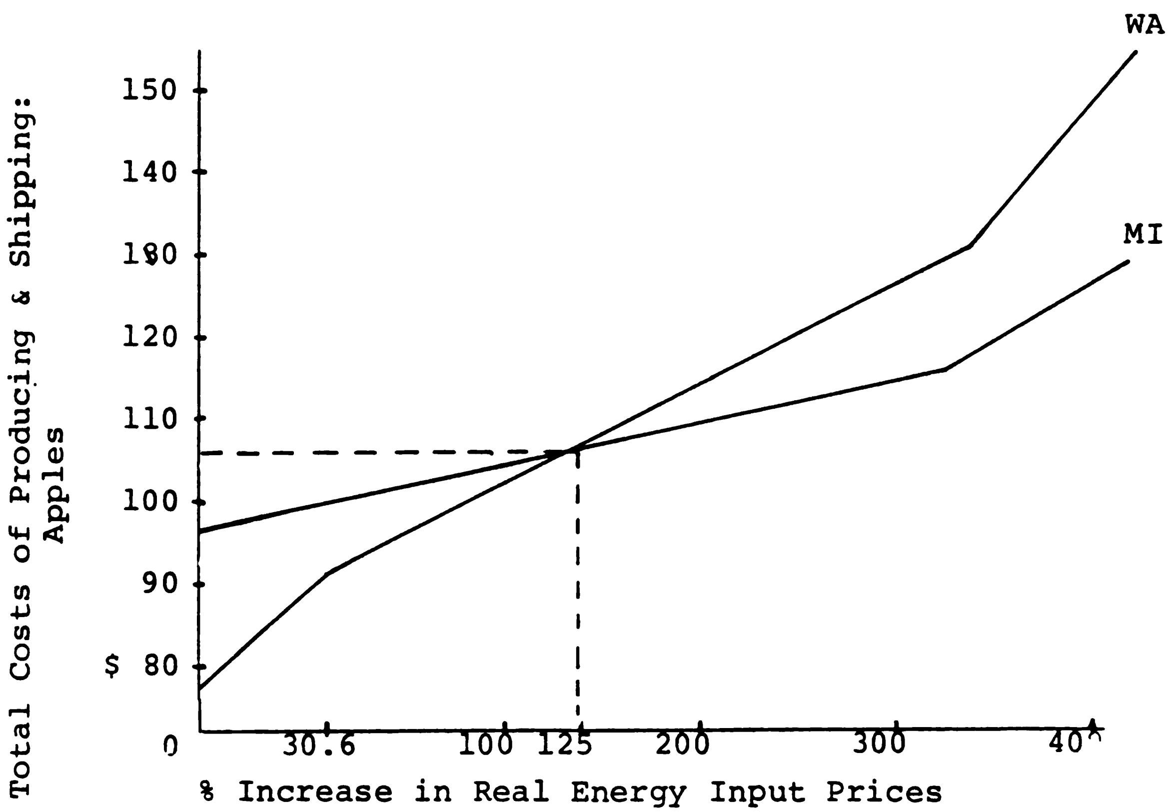

Figure 8.--Threshold Price: Apples to Detroit Market.

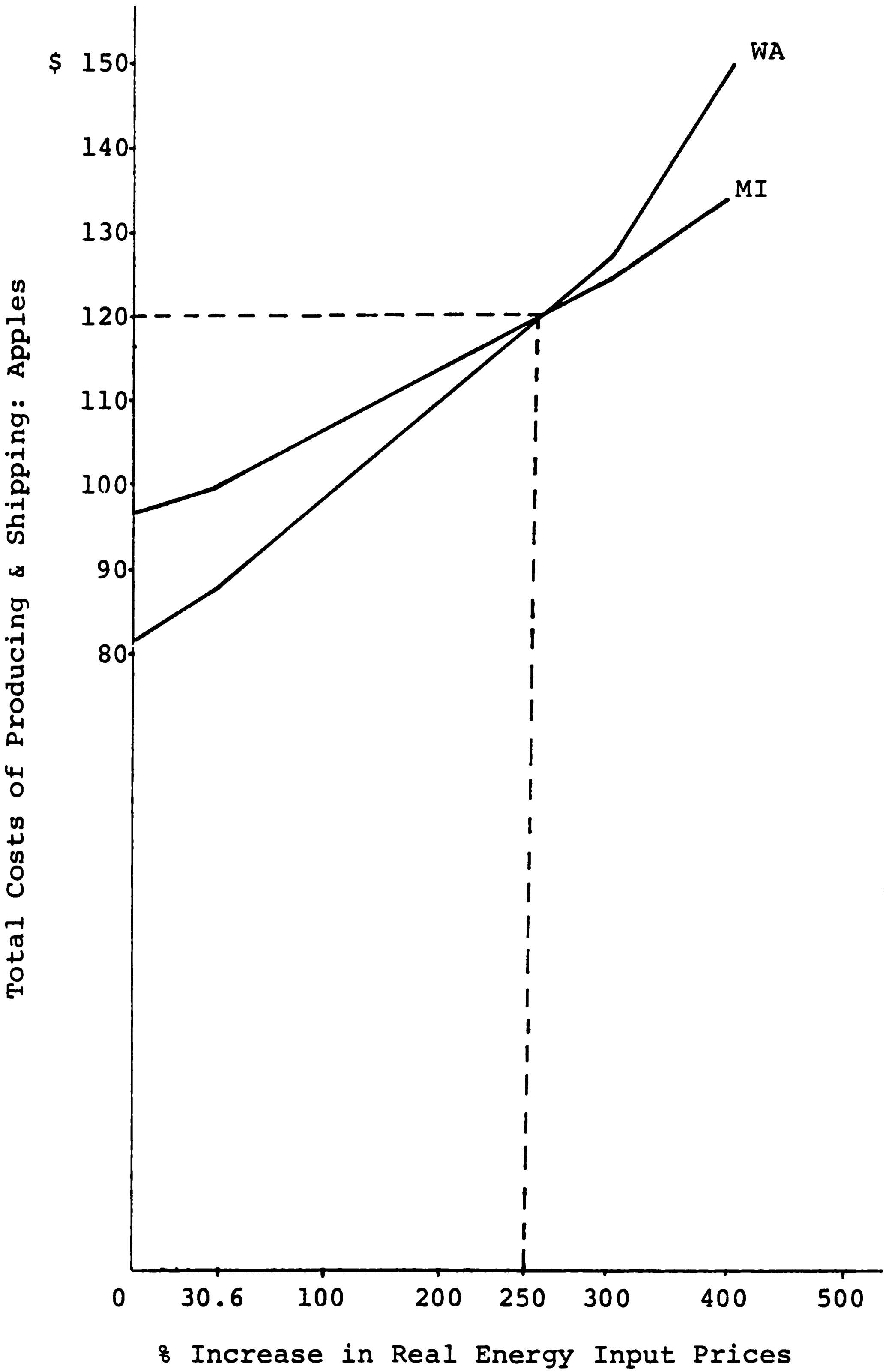

Figure 9.--Threshold Price: Apples to St. Louis Market.

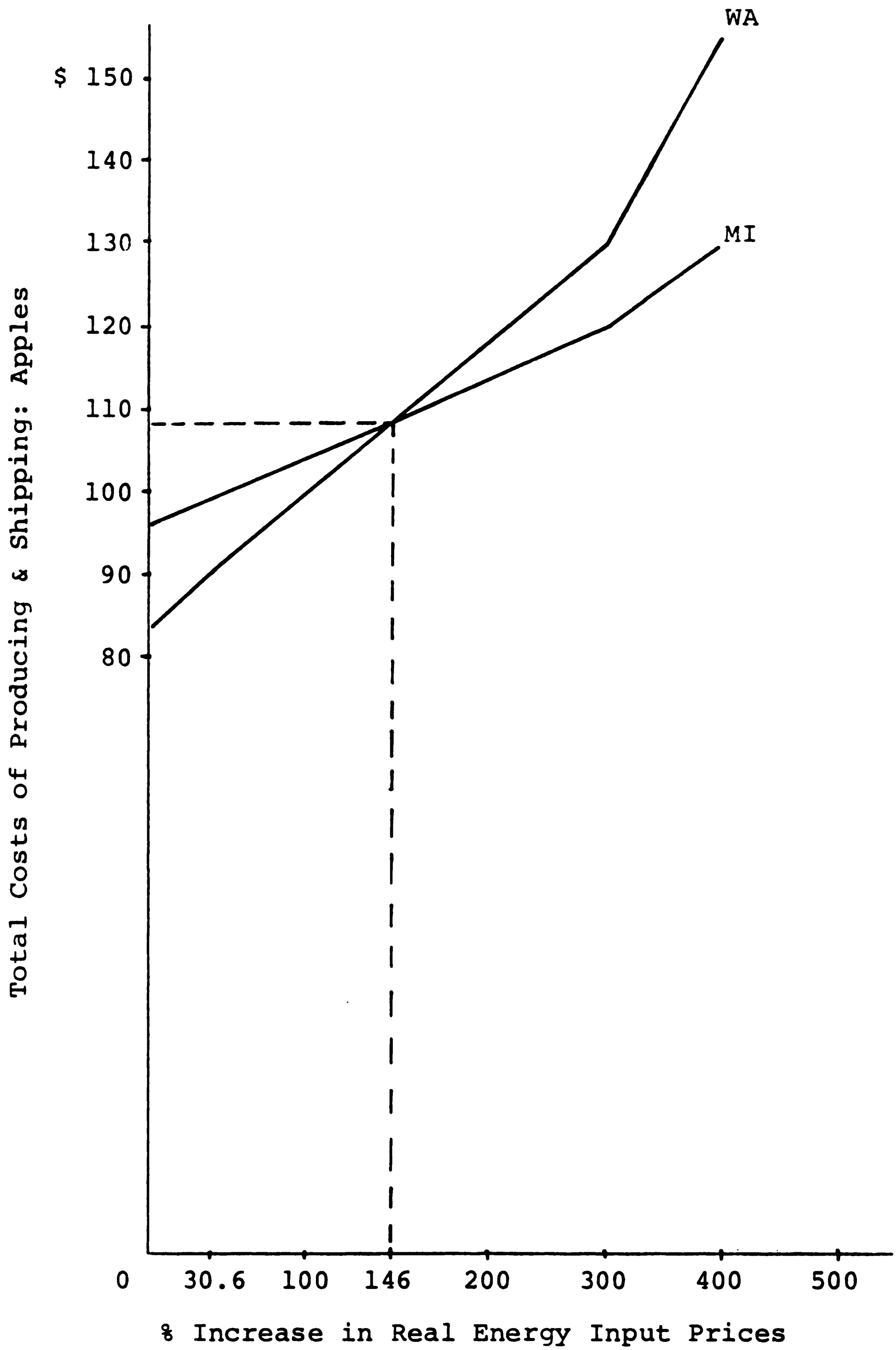

Figure 10.--Threshold Price: Apples to Cleveland Market.

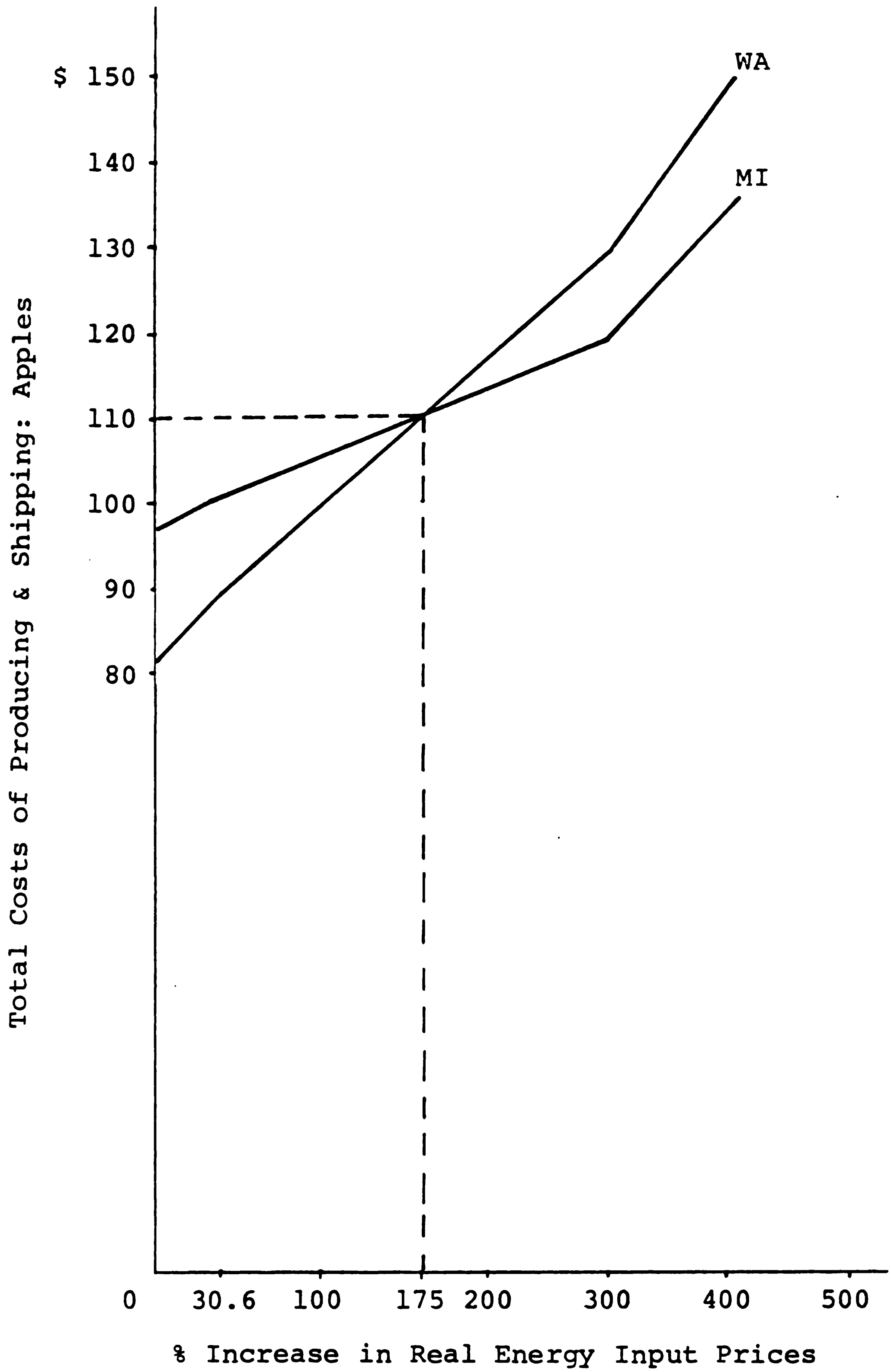

Figure 11.--Threshold Price: Apples to Cincinnati Market.

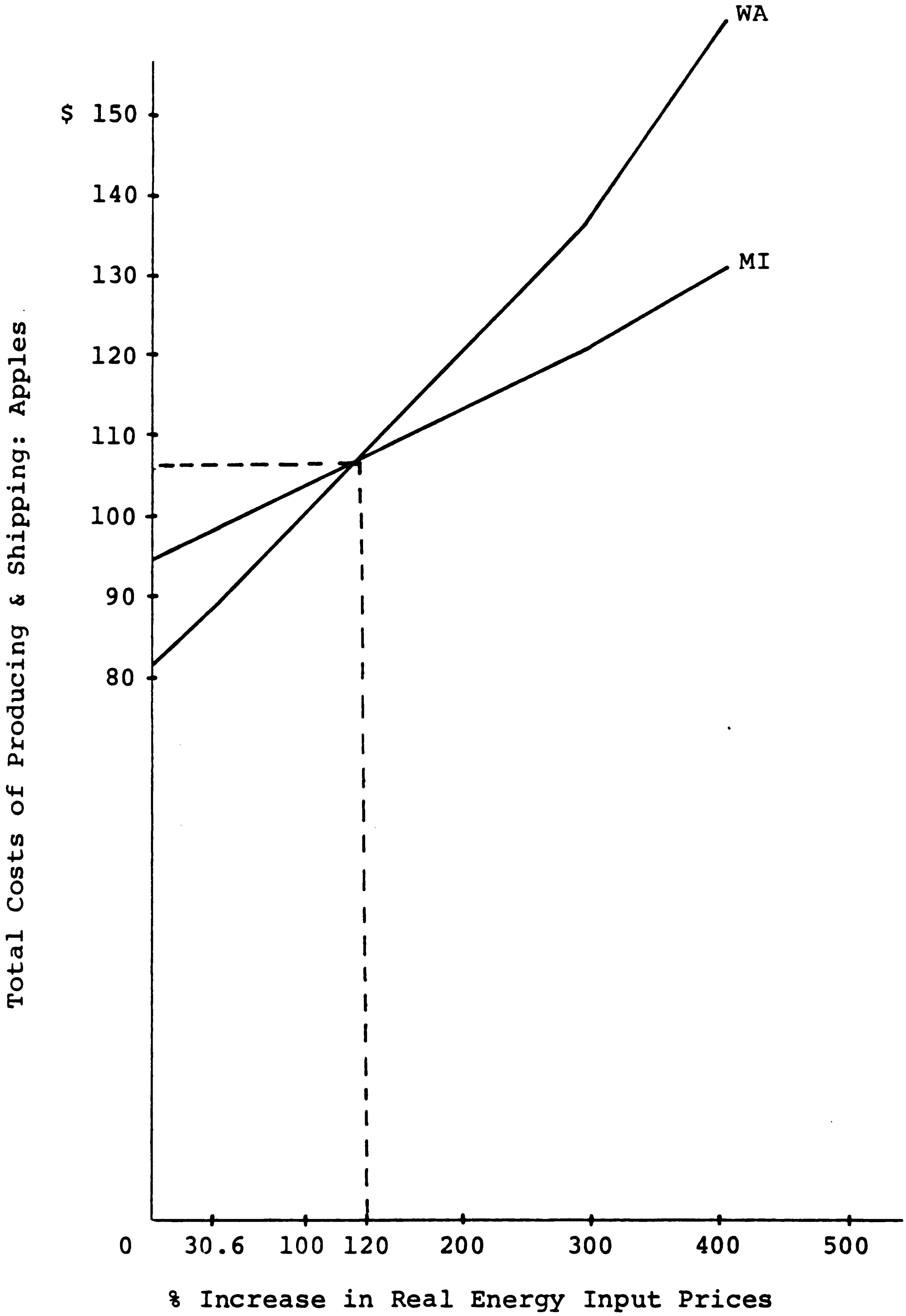

Figure 12.--Threshold Price: Apples to Buffalo Market.

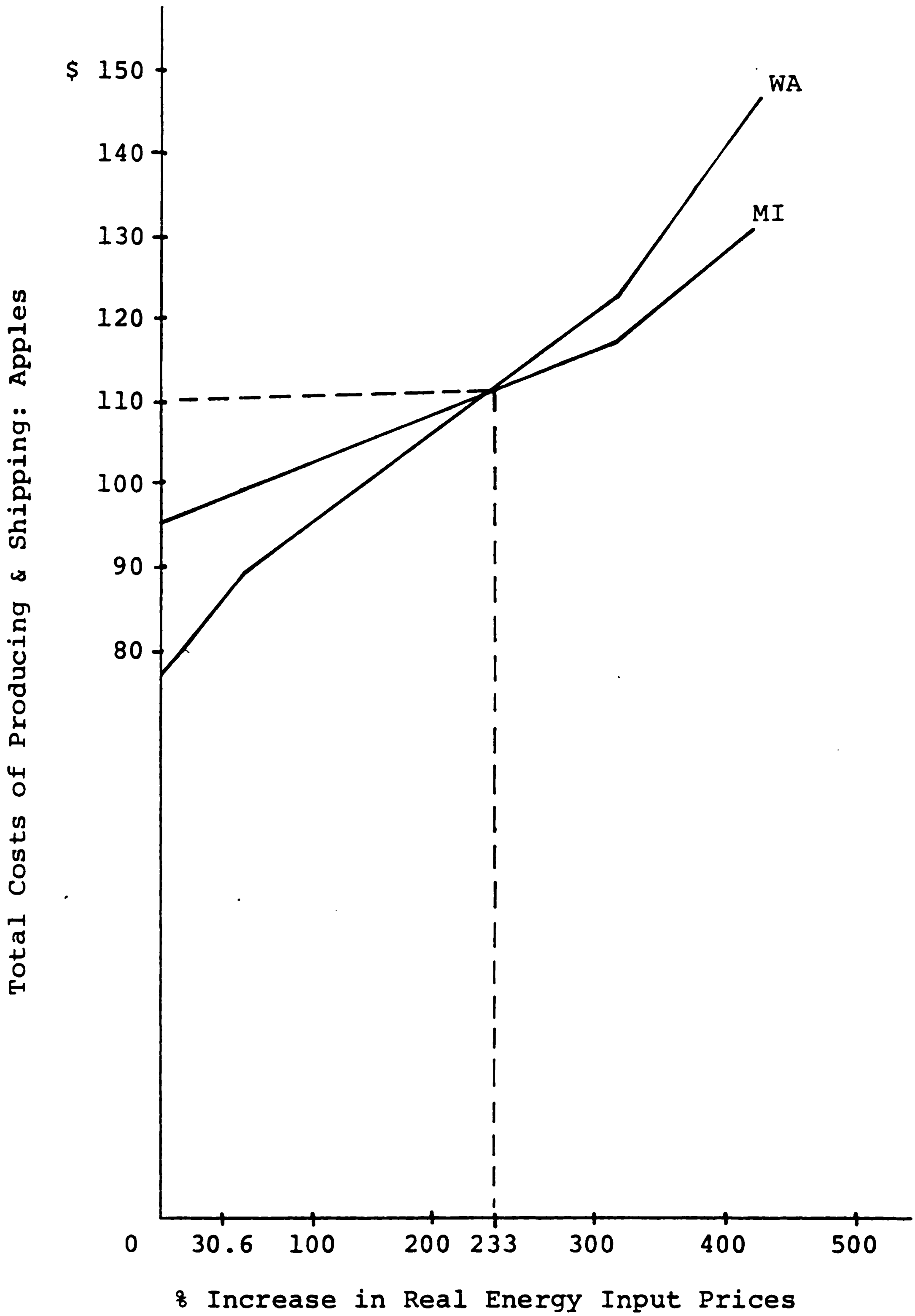

Figure 13.--Threshold Price: Apples to Milwaukee Market.

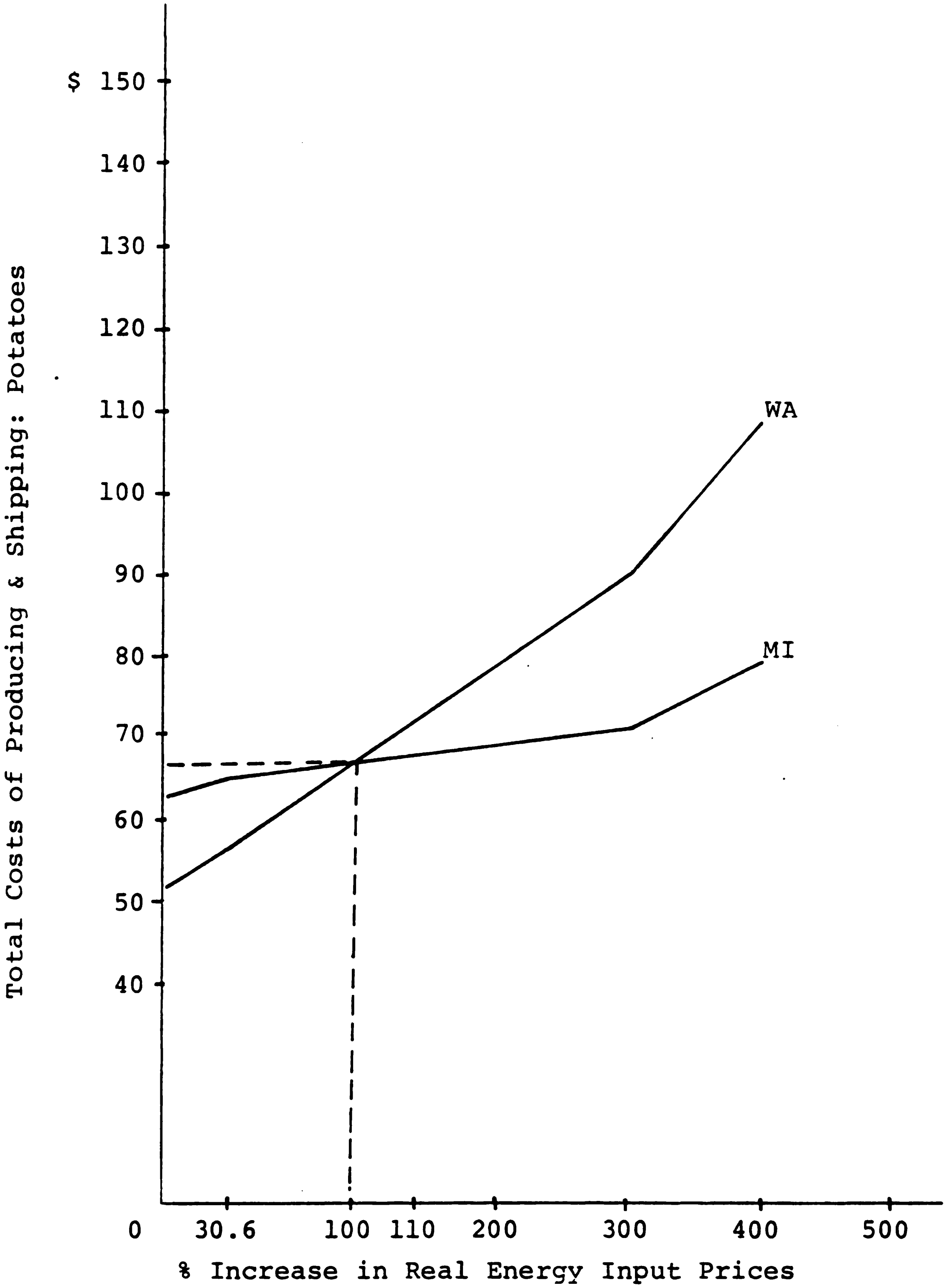

Figure 14.--Threshold Price: Potatoes to Chicago Market.

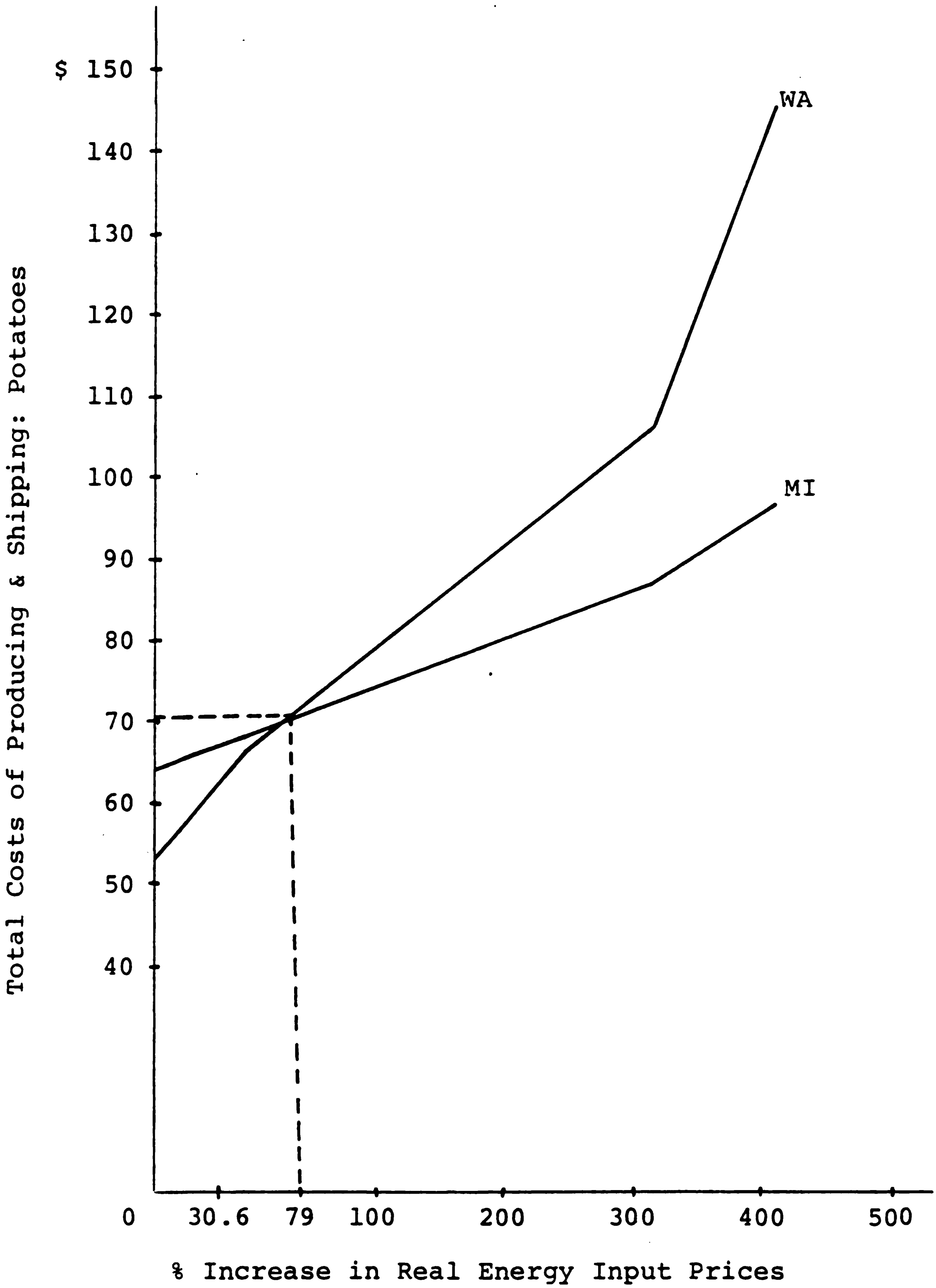

Figure 15.--Threshold Price: Potatoes to Philadelphia Market.

Table 33.--Percent Real Energy Price Increase that Switches Origins of Potatoes and Apples in Major Markets.

Representative Market Price	Increase in Energy Input Prices at Which Threshold Occurs
Apples	
Chicago	200%
Detroit	125
St. Louis	258
Cleveland	146
Cincinnati	175
Buffalo	120
Milwaukee	233
Potatoes	
Chicago	110%
Philadelphia	79

258 percent in the St. Louis market. In potato production and shipping, a real energy price increase of approximately 79 percent causes the shift in the Philadelphia market, and a 110 percent increase shifts costs in Chicago. What is evident in these ranges is that, in apple production, the lowest increase in energy prices that causes the threshold price to occur is to the Buffalo market, the farthest that Washington must ship apples. On the other hand, the highest energy prices would have to go up is to the St. Louis market, the city which Michigan must ship farthest, compared to the other six market areas. The same holds true in potatoes: it is the increase in transportation costs due to higher diesel fuel prices that is the most significant factor.

In potato production, a 79 percent increase in real energy input prices produces a threshold price. The lowest increase at which apples become less costly to deliver from Michigan is at 120 percent. Furthermore, the 110 percent increase in costs that produces a shift in the Chicago market is both below the lowest apple increase, and substantially below the approximate 200 percent increase necessary to produce the shift to the same market. Therefore, as real energy prices increase, potato growers will be affected sooner than apple producers.

Since transportation costs represent the crucial factor of the impact of rising real energy prices, it would be useful to find a set of "threshold miles". That is, the farthest west Michigan can ship its products in competition with Washington, at lower costs. Given that Michigan's commodities become less costly relative to Washington's as products are shipped east, a threshold mile in that direction would not tell us anything. However, it should be noted that as Michigan ships products east, while less costly than Washington, they compete with eastern producers, notably New York, Maine, Virginia and South Carolina.

Two sets of mileage and total costs figures are presented. For apples, one goes east to west given the direction in the trade to Chicago, the other goes southwest in the direction of St. Louis. For potatoes, the directions are first through Chicago and also west through Denver. In apple production, given a 300 percent real energy input

Table 34.--Approximate Threshold Miles Given 300 Percent Real Energy Price Increase.

Commodity	Michigan Miles West	Commodity TC	Washington Miles East	Commodity TC
Apples-Chicago	325	$120.18	1772	$120.50
Apples-St. Louis	560	125.49	1990	125.48
Potatoes-Chicago	530	82.36	1520	82.38
Potatoes-Denver	645	84.94	1685	84.99

price increase, Michigan can ship approximately 325 miles west toward Chicago and 560 miles toward St. Louis, before Washington costs are less. In potatoes, Michigan can ship approximately 530 miles west toward Chicago and 645 miles toward Denver. As with the threshold prices, these distance figures, while expressed in specific values, are only estimates of the market radius. What these figures tell is the outer limits of a market radius under which each state can produce at less cost than the other. Obviously, given the yield differences and other factors that have been discussed, Washington can ship its commodities farther east than Michigan can west. Yet, the possibilities that are presented for Michigan to expand its production and shipping of apples and potatoes, vis-a-vis Washington is evident, and will be discussed in the final chapter.

CHAPTER VII

CONCLUSIONS AND IMPLICATIONS

This study has examined the impact of increases in real energy prices on interregional competition in fresh potato and apple markets. The major conclusion is, changes in the competitive position between Michigan and Washington will be related to the distance from the production site to the market: it is in transportation rate increases that real energy prices change relative costs. The distance to market is the major determinant of the regional competitive patterns in this case, not the production function differences between firms in different regions.

The study focused on two areas. First, the general objective was to examine the impact of rising real energy prices on the cost of production in Michigan. However, what is important to Michigan farmers is not simply the fact that costs go up, but the effect of those costs on their ability to sell their produce. The conceptual framework of this study has therefore been on interregional cost competition including transportation rather than on production costs alone.

The second feature has been to provide Michigan farmers information on possible adjustments when faced with rising real energy prices. In this vein, the other major conclusion of this study is that Michigan's products will be less expensive than Washington's, as real energy input prices increase. Therefore, an expansion of the market for Michigan's fresh apples and potatoes can be expected.

Summary of Contributing Conclusions

In 1976 prices, Washington can deliver both fresh apples and potatoes at a lower cost to all markets in which they compete with Michigan. Michigan's total costs are lower on a per acre basis, however Washington, given a much greater yield per acre in both commodities, is able to ship their produce to Chicago and compete at lower cost with Michigan. In fresh potatoes, Washington's total costs are only 85 percent those of Michigan's; $51.17 per ton as compared to Michigan's $60.32 per ton to the Midwest. In fresh apples, Washington can deliver to the Midwest at 84 percent of Michigan's costs; $79.06 in Washington versus $94.64 per ton in Michigan. The central task then was to find at what increase in real energy prices shifts the costs in favor of Michigan. Not only were a set of threshold prices calculated, but more generally, the study indicated how the cost differentials, on a per ton basis, change between states as real energy prices increase.

To find a set of threshold real energy prices to each market at which the cost advantage of Washington changes, the real price of energy was increased 30.6, 300, and 400 percent, holding all other costs constant. The conclusion that it is transportation costs which represent the most crucial factor stems from the observation that at all real energy price increases, Washington's farm costs remain lower than Michigan's in both commodities. When the cost of transportation is added to production costs, an increase in real energy prices between 30.6 and 300 percent makes Michigan's cost to deliver apples less in seven of ten market areas (to areas represented by Chicago, Cincinnati, Buffalo, Detroit, St. Louis, Cleveland, and Milwaukee), and two of four potato market areas (Chicago and Philadelphia).

If real energy prices are increased from 120 percent to 258 percent above 1976 prices, all other costs held constant, Michigan can deliver apples at a lower cost to seven of ten apple markets (see Table 33). In the two potato markets at which a threshold price occurs, a 79 percent increase in real energy prices, above 1976 prices, makes Michigan's costs less than Washington's to the Philadelphia market, while a 110 percent real energy price increase produces such a shift to the Chicago market. What is evident is that potato growers in Michigan will be affected sooner than apple producers when real energy prices increase. A 79 percent real price increase will cause the first shift in costs for Michigan potato growers, while apple producers will not find their costs less than

Washington's in any market until real energy costs increase 120 percent over 1976 prices.

Finally, this study computes a "threshold distance" which is how far west Michigan's apples and potatoes can be shipped and still remain less costly as compared to Washington. Given a 300 percent real energy price increase over 1976 prices, Michigan can ship apples approximately 355 miles west and approximately 560 miles toward St. Louis, before Washington's costs are less. For apples, miles are measured from Michigan's southwestern production area and from the Yakima Valley in Washington. In potatoes, Michigan can ship approximately 530 miles west toward Chicago and 645 miles toward Denver. The distance from Michigan is measured from the Southwest potato region and from the Columbia River Basin in Washington. These figures represent the outer limits of a market radius under which each state can deliver at less cost than the other. Therefore, as real energy prices increase, a shift in the pattern of supply in these commodities may take place.

Implications for Further Research

The conclusions are based on a short-run, static economic analysis. As the planning horizon facing Michigan farmers is lengthened, additional issues need to be addressed as the dynamic adjustment process is considered. As the adjustments to higher real energy prices begin, fixed assets and transportation equipment become variable as the machinery and trucks currently in place require replacement. A more thorough accounting of the indirect energy requirements in the production of farm machinery and transportation equipment needs to be considered.

As real energy input prices rise, other factors of production (notably labor and energy substitutes such as synthetic fuels) become cheaper relative to energy and it pays to substitute these other factors for energy input. Furthermore, as real energy input prices increase, marginal cost also increases and therefore output declines. Research on the cost of substituting other inputs for energy, as well as the strength of the output reduction would be useful information for Michigan's farmers.

Four other areas of research are suggested by this study:

1. Since it was found that the cost of truck transportation is the factor that changes the competitive cost structure, research should proceed on the economics of alternative transportation modes, particularly rail transport. Given recent plans to cut U.S. regulation of railroads as announced on March 26, 1979, this may reduce the cost of rail use.

2. To better understand how rising real energy prices affect crop production, the next best production possibility facing farmers should be empirically determined. The relative rental price of land is established by finding what its earnings are in the next best crop. There is a need

to further clarify what is the next best crop. The energy prices suggested here may force Washington producers to shift to another crop, leaving more of the market available for Michigan's farmers.

3. When considering possible substitutes for fossil fuel energy inputs, the nearest substitute appears to be coal. But as the Michigan Transportation Research Program illustrates,* to utilize coal within the framework of the present energy production, consumption and distribution system, solid coal must be refined to fluid or gas. The conversion of coal to refined fluids under the best of conditions can take place only at efficiencies of 55 to 65 percent. Further, the capital costs of the conversion technology is extremely high and water resources to support the process represents a serious limitation. The report concludes that synthetic fuels derived from coal will cost, in real prices, three to five times as much as current natural fuels. Uncertainty exists about the impact on costs and efficiency of synthetic fuels due to the Administration's current commitment of $142 billion to expand synthetic fuel use. That the coal liquefication program will cost at least 300 percent more than current fuels, appears to legitimize the bounds of a 300 percent increase

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*"Coping with Energy Limitations in Transportation: Proposals for Michigan." A Draft Public Policy Discussion Paper with Recommendations for State Action. The Michigan Transportation Research Program, December 21, 1978.

in real energy prices utilized throughout this study. Further research on the costs and efficiencies of coal liquefication is warranted.

4. As real energy prices go up, in an increasing number of markets Michigan's apples and potatoes will undercut Washington's produce. Yet, the final price of apples and potatoes to the consumer will go up regardless of the supplier. When the price of produce changes, it will be necessary to look at the cross elasticities of demand between Michigan and Washington products to find how much change in consumption will take place. The conclusion however, is that since Michigan's products will be less expensive than Washington's, as real energy input prices increase, an expansion of the market for Michigan's products can be expected.

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