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EQUILIBRIUM LOCATION OF VERTICALLY LINKED INDUSTRIES UNDER FREE TRADE: CASE STUDIES OF ORANGE JUICE AND TOMATO PASTE IN THE WESTERN HEMISPHERE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the Degree Doctor of Philosophy in the Graduate School of the Ohio State University

By

Darcy Ann Hartman, M.S.

*****

The Ohio State University 1998

Dissertation Committee:
Professor Luther Tweeten, Adviser
Professor Ian Sheldon
Professor Douglas Southgate

Approved by

Adviser
Graduate Program in Agricultural Economics and Rural Sociology
ABSTRACT

Analysis of agricultural trade has typically treated raw commodities in isolation from their processed products. As industrialization of agriculture continues, models that incorporate multiple-stage processing provide more realistic analyses of the trade liberalization effects. Frequently, tariff structures target value-added products with higher tariff rates than the raw good utilized in processing. With trade liberalization, trade flows might change substantially in a vertically inter-related production system.

A model developed by Venables (1993) utilizes a two-stage system of production under varying levels of openness to trade. Using Venables' model, this dissertation analyzes effects of free trade in the Western Hemisphere for the case of the orange juice and tomato paste industries. Breaking production into two stages, the model assumes that both stages are imperfectly competitive and subject to increasing returns. The approach is location-oriented, and analyzes the final location of both raw and processed production given trade liberalization. Demand and supply linkages exist to incorporate the role of consumers and the connection between the two stages of production.

Trade liberalization is represented as a reduction in transportation costs. High transportation costs encourage production in multiple locations. Lowering transportation costs creates an agglomerative effect. Under current conditions, orange juice and tomato
paste production in the Western Hemisphere are exemplified by the first scenario, indicating trade costs could be high enough to prevent agglomeration.

Using representative firm data, parameter values are established for the current scenario. With these parameter values, transportation costs are decreased to represent the elimination of trade barriers. A system of equations is then solved to yield information on firm and grower locations given free trade.

Generally, the results indicate that for both industries production will be skewed toward the US locations - Florida for orange juice, California for tomato paste - as tariffs are reduced in the Western Hemisphere. While the results might seem counterintuitive given production cost comparisons, the results emphasize the importance of the consumer base in the model, as well as the desire for multiple varieties of the same good. Agglomeration benefits are maximized by locating in the country where the vast majority of consumption takes place.
Dedicated to my family

past, present and future
ACKNOWLEDGMENTS

I would like to thank my adviser, Luther Tweeten, for his continued faith in me, and for giving me the freedom to pursue my interests. I wish to thank my other committee members as well, Ian Sheldon and Douglas Southgate, for the intellectual and emotional support throughout this endeavor.

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In addition to the many that I have forgotten to mention by name, I would like to thank my husband, Brian Vaeth, for his eternal friendship and patience. Also, thanks to my family for the push to finish. Much love and thanks to Monkey, Nico, Ollie and Pablo for being so thrilled to see me no matter how bad my day was. Most important of all, thanks to the upcoming addition to our household for giving me the final inspiration.
VITA

January 14, 1967 .................................................. Born - Berlin Hts., Ohio, USA


1989 ..................................................................... B.S. Agriculture with Distinction in Agricultural Economics, summa cum laude, The Ohio State University.

1990 ................................................................. Economist - intern, Foreign Agricultural Service, USDA.

1990-1993 .......................................................... Graduate Research Associate and Research Associate, NC-194, The Ohio State University.

1992 ................................................................. M.S. Agricultural Economics, The Ohio State University.

1993-present ....................................................... Graduate Research Associate and Research Associate, The Ohio State University.


PUBLICATIONS

Research Publication

FIELDS OF STUDY

Major Field: Agricultural Economics
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CHAPTER 1
INTRODUCTION

1. A Background

On January 1, 1994 the United States, Mexico and Canada entered into the North American Free Trade Agreement (NAFTA). Despite all the heated political debates regarding free trade with Mexico, both Mexico and the US already traded with each other at relatively low tariff levels. Nevertheless, the agreement on such a major document required much research into the costs and benefits, expected losses and gains in each country, and in the various sectors within each country. The horticultural sector was no exception. Many government and private organizations performed analyses that were quite instrumental in developing appropriate liberalization policies for the individual products that make up this sector, such as a study sponsored by the American Farm Bureau Research Foundation (Cook et al., 1991) providing detailed cost comparisons between Mexican and US producers of fresh and processed fruits and vegetables. Overall, the policies within NAFTA that were developed have been determined by well respected economists to be a sound approach to liberalization and integration (Hufbauer and Schott, 1993).
It is time once more to renew this type of research. In June 1990, President Bush announced the Enterprise for the Americas Initiative (EAI) which envisions the economic integration of the Western Hemisphere or a Western Hemisphere Free Trade Agreement (WHFTA). At the 1994 summit meeting of the Americas in Miami, it was decided that a WHFTA would be in operation by the year 2005. While there was a great rush to bring Chile into the NAFTA, these talks have been continually postponed due to the refusal of Congress to allow President Clinton fast-track authority.

Despite this setback, the trend toward regionalism in economic integration, as opposed to multilateralism, is obvious. According to a World Bank working paper (Fernández, 1997), regional trade agreements have proliferated in the last ten years. “By the time the World Trade Organization was established on 1 January 1995, almost all GATT members (notable exceptions include Japan and Hong Kong) were signatories to at least one such agreement” (p.1). Smaller groups of countries have an easier time reaching agreement on controversial issues; the GATT, on the other hand, has been tedious in deriving policies that meet with general approval. In addition, regional trade groups have more bargaining power than individual countries, so their existence might facilitate an overall liberalization effort.

In a recent *Economist* article, Bergsten (1997) outlines the importance of US participation in future trade initiatives, and hence, the importance of fast track authority. Bergsten still sees the US as the most likely leader of any significant trade-liberalizing agreement. He cites the Clinton administration as having been instrumental in concluding the Uruguay Round of the GATT and, of course, completing NAFTA. He
predicts that lack of fast track authority for at least the next four years will greatly diminish the perception of the US as a free trader. Indeed, by eliminating the ability of the president to negotiate free trade agreements for the short-term future, the anti-trade faction will have gained new momentum in its protectionist efforts. Finally, despite the fact that regional trade agreements deviate from true “free trade” policies, the US is likely to use them judiciously and strategically in an effort to eventually broaden free trade areas.

In response to Bergsten's article, the Economist subsequently published the viewpoint of Bhagwati (1997). Bhagwati does not question giving fast track authority to the president, but he does question the president's goals. While the administration maintains that the authority is needed for both regional and global negotiations, "(t)he truth is that the president seeks it for regional agreements only. To be more precise, he wants to add Chile to the North American Free Trade Agreement and to move further towards creating a Free-Trade Agreement of the Americas" (p.21). Bhagwati finds regional trade agreements to be counter to the notion of free trade due in large part to trade diversion caused by such agreements. Neither Bergsten nor Bhagwati would dispute that free trade is the first-best solution; their disagreement lies in the ultimate purpose of a regional trade agreement.

While the purpose of this study is not to argue the merits of trade liberalization with Latin America, it is worthwhile to note the potential importance that the rest of the hemisphere has with respect to the US and its NAFTA partners. "Reflecting growth in the region, US merchandise exports to Latin America have picked up over the past three
years. US exports in 1992 were $35.1 billion against $24.1 billion in 1989, and Latin America now accounts for 7.9 percent of total US merchandise exports, up from 6.6 percent in 1989 … However, while trade gains have already been achieved, even greater gains remain to be realized with dramatic reforms of Latin American trade policy” (Hufbauer and Schott, pp.19-20). Overall economic reforms in these countries will impact the value of trade between the US and Latin America, as well.

Even though a WHFTA seems to be a long way off, there is no time like the present to begin examining the implications of such an occurrence. The Economic Research Service, USDA has begun an initiative to look into various aspects of a WHFTA. Among its interests are the fruit and vegetable fresh and processing sectors. The US fruit and vegetable industry is quite substantial in size. The value of production for fresh market and processing vegetables in 1995 was $14.8 billion (USDA, November 1996); in 1993, the value of fruit and nut production was $9.84 billion (USDA, September 1994). US producers face major competition from the countries in the southern half of this hemisphere. While a large portion of production in Latin America occurs during the off-season of US production, extensive overlap of seasons still exists, particularly given improvements in harvesting and storage techniques. Additionally, a large portion of fruit and vegetable production ends up being traded as processed goods. Seasonality is far less important once processing has taken place. Given expectations that developing countries have lower costs, US industries might be adversely affected. It is with this thought that the following dissertation is written.
1.B Objectives of the Study

The general objective of this study is to determine the effect of a WHFTA on fruit and vegetable processing location in the Western Hemisphere. Specifically, the objectives of this study are as follows:

1) To examine the differences in costs of production and processing for tomato paste and orange juice, and use these cost comparisons to determine where production would occur under free trade based on cost advantages alone;

2) To adapt a model of industry location for empirical analysis of expected outcomes in the orange juice and tomato paste industries;

3) To utilize this model to determine future locations of these processing industries;

4) To compare the outcomes from the location analyses with the outcomes from the cost comparisons;

5) To suggest policy implications based on the conclusions from the analyses.

The method explained in the pages that follow is not a traditional economic approach for determining impacts of changes in trade policy. It makes unconventional assumptions by economic standards, but conventional assumptions from a geography-based perspective. By determining where processing firms will locate under a WHFTA, the model provides insight into the impact on growers and processors. With this information, policy makers can prepare growers, processors and consumers for changes from the current state.
1.C Significance of the Study

The study has both academic and practical significance. On the practicality of this study, the results of this research can be utilized by the Economic Research Service and other USDA agencies in planning and promoting optimal liberalization policies for the fruit and vegetable sectors in future trade negotiations with various countries of the Western Hemisphere. The results can be incorporated into other ERS research to facilitate understanding of various liberalization schemes.

Academically, the study will utilize a relatively new set of economic theories focusing on agglomeration economics. The theories, predominantly advanced by Krugman and Venables, have strong theoretical ties to previous work in trade theory. Little empirical analysis exists in the literature, and no previous empirical applications of the model used for this dissertation have been found in literature searches. Interestingly, the primary authors in this literature tend to exclude agriculture in their theoretical workings, so that use of this model for horticultural products should break new ground.

1.D Organization of the Dissertation

The remainder of this dissertation is organized as follows: Chapter 2 provides cost comparisons for processing tomatoes and tomato paste for the US versus Argentina, Brazil and Chile. Chapter 3 suggests an alternative methodology for determining a free trade outcome, and provides a theoretical background. Chapter 4 details the methodology used in the research. Chapter 5 presents the results of the analyses for tomato paste along with conclusions for the tomato paste industry. Chapter 6 moves to orange juice and
presents cost comparisons for the US and Brazil. Chapter 7 describes the analyses and results for orange juice, along with conclusions specifically pertaining to this product. Chapter 8 summarizes the key findings and implications of the model. Recommendations for further research are also offered.
CHAPTER 2
COST COMPARISONS FOR TOMATO PASTE

Given the diversity of fruits and vegetables, a manageable study dictates selection of only a few representative commodities. Due to the relative scarcity of data compared to that which exists for other types of agricultural products, the products chosen for this dissertation are prominent in the world economy. They also are products that have both a fresh and processed market. In addition, they were selected for being economically important crops in the US, and being economically important to at least one of the major players in the rest of the Western Hemisphere. The preexistence of tariffs on the fresh and/or processed product was also important. In light of all these needs, tomatoes and oranges were selected for analysis.

The first product under consideration for this dissertation is tomatoes. "Tomatoes rank second to potatoes in dollar value among all vegetables produced in the US and in other parts of the world where they are grown. In terms of per capita consumption tomatoes are the leader of processed vegetables. The average American now consumes over 25 lbs. of processed tomatoes exclusive of catsup and sauces per year compared with a total of 60 lbs. for all commercially processed vegetables" (Gould, 1992, p.3).
The primary product of interest for this study is tomato paste. While paste represents less than 20% of processed tomato utilization, it is a very important commodity in world trade. South American competition is significant in paste production. Both Chile and Brazil are major producers with some production occurring in Argentina.

In the US, California is the leading state in processing tomato production. In fact, California produces approximately one-fourth of all processing tomatoes in the world. In 1989, California had 480 growers and 30 processing firms (Sims, 1992). Processed tomato products are primarily intended for domestic consumption.

In terms of tomato paste production, Chile is the seventh largest producer in the world. Its tomato processing industry is largely geared toward the export market with tomato paste accounting for over half of all canned fruit and vegetable exports. According to Roberts (1995), Chile has 14 processing plants. Chile is an important paste supplier to the US market, but interestingly canned tomatoes play a larger role in US imports from Chile.

In Argentina, the Mendoza region is a prominent producer of processing tomatoes. While it is not a major player in the world, the proximity of the Mendoza region to Chile’s production regions makes Argentina important in light of agglomeration economies; economies of agglomeration are an important component of location theory, so this fact will become useful later on. According to Cuevas and Davila (1992), 70% of Argentine processed tomato products were produced in Mendoza by 32 firms.
Brazil is cited as the sixth largest tomato producer in the world. Tomato production takes place in three distinct regions: the Northeast, predominantly the submiddle São Francisco River Valley; the Southeast, predominantly São Paulo and Minas Gerais; Central Brazil, predominantly Goiás state and Brasilia. Tomato paste is the most important product. Four firms control most of the market (90%) (Tavares de Melo, 1992).

While the ultimate purpose of this dissertation is to determine the future location of processing tomato and tomato paste production given free trade between the three South American countries and the US based on a model of agglomeration, a basic comparison of costs in the four countries can also provide useful information. Economic theory, particularly agglomeration theory, would have costs and prices endogenous to the system; nonetheless, it is helpful to first see the direct cost differences among these producing nations.

The most detailed cost breakdown for US production is provided in an extension document on costs to produce processing tomatoes in the San Joaquin Valley (Le Strange et al., 1992). The following is a general breakdown of expenses:
<table>
<thead>
<tr>
<th>Cost Type</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural Costs</td>
<td>$22.88</td>
</tr>
<tr>
<td>Harvest Costs</td>
<td>5.89</td>
</tr>
<tr>
<td>Postharvest Costs</td>
<td>0.26</td>
</tr>
<tr>
<td>Interest Charges</td>
<td>0.98</td>
</tr>
<tr>
<td>Cash Overhead</td>
<td>8.08</td>
</tr>
<tr>
<td>Non-cash Overhead</td>
<td>5.78</td>
</tr>
<tr>
<td><strong>TOTAL COST/MT</strong></td>
<td><strong>$43.88</strong></td>
</tr>
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Table 2.1: California tomato production costs.
Costs for producing tomatoes in Argentina are higher than for the US. The following cost information was obtained for this country (JICA, 1996):

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Seed</td>
<td>$2.60</td>
</tr>
<tr>
<td>Labor</td>
<td>24.68</td>
</tr>
<tr>
<td>Fertilizer</td>
<td>3.90</td>
</tr>
<tr>
<td>Pesticide</td>
<td>8.44</td>
</tr>
<tr>
<td>Fuel</td>
<td>3.25</td>
</tr>
<tr>
<td>Electricity</td>
<td>3.90</td>
</tr>
<tr>
<td>Maintenance</td>
<td>3.25</td>
</tr>
<tr>
<td>Tax</td>
<td>1.95</td>
</tr>
<tr>
<td>Depreciation</td>
<td>3.90</td>
</tr>
<tr>
<td>Interest</td>
<td>6.49</td>
</tr>
<tr>
<td>Others</td>
<td>1.30</td>
</tr>
<tr>
<td>Gathering Cost</td>
<td>11.04</td>
</tr>
<tr>
<td><strong>TOTAL COSTS/MT</strong></td>
<td><strong>$74.00</strong></td>
</tr>
</tbody>
</table>

Table 2.2: Argentina tomato production costs.
In Brazil, a sample of costs estimated by an agronomist in 1989 produced a mid-range estimate of costs compared to other available estimates. The cost breakdown, converted into 1994 prices, shows Brazil to have the highest cost of production out of the four countries in this study (Moulton and Garoyan, 1991). This is unsurprising given problems with soaring inflation, high interest rates, and impediments to a free market economy.

Land preparation & irrigation $4.55
Labor, including harvest 18.34
Pesticides and chemicals 8.28
Fertilizers, seeds 67.76
Overhead 17.08
TOTAL COSTS/MT $116.01

Table 2.3: Brazil tomato production costs.

For Chile, the estimate of costs that appeared most reasonable, given anecdotal information, is not very detailed. An average of direct costs, or variable costs, in 1994 prices is estimated to be $34.39/MT. Typical harvest costs are estimated to be $14.86/MT. Overhead costs are estimated to be 20% of direct costs; this results in overhead expenses of $6.90/MT (Moulton and Garoyan, 1991). With total costs of
$56.15, Chile can compete with California tomato producers. In fact, interviews with industry experts in Chile suggest that Chile could already be a competitive producer of tomatoes.

Trade costs are difficult to establish for processing tomatoes. The fresh product is traded in very insignificant amounts between the US and these three South American countries. Current trade costs could be based on those used for oranges in a later chapter. The US currently has phytosanitary restrictions on imports of fresh tomatoes from several countries, Chile in particular (FAS). In addition, a US import fee of 38 cents/25lb. carton of fresh tomatoes for Mexico was reported in the Farm Bureau NAFTA report. The main impediment to trade in this product, beyond the phytosanitary restriction, however, would have to be the actual cost of shipping such a great distance.

One issue to be resolved for later analysis (in Chapter 5) is whether or not producers of tomatoes face increasing returns. While definitive proof is unavailable due to data limitations, several factors suggest that an assumption of increasing returns cannot be rejected. First, the existence of fixed costs indicates that an increase in production over some range would result in declining average costs. Determining where producers are producing on their average cost curves is not possible given data limitations.

In addition, studies done in Argentina explicitly discuss ways to decrease average costs by increasing yields and, hence, production (JICA, 1996, and Condiciones de Rentabilidad, 1996). While it seems likely that producers in Argentina and Brazil have a greater possibility of reducing average costs than Chile and California, continued developments in tomato growing technology, as well as expansion in production area,
would allow fixed costs to be lowered. California is more likely to be using the most advanced technology, which suggests that California producers are producing far down on their average cost curves; however, they have a greater ability to procure financing for any additional technological improvements. This would allow them to continue decreasing their average costs.

Turning now to tomato paste processing costs, both high cost and low cost estimates were available for California production (Moulton, 1991). The low cost estimates that follow are based on an assumption of a plant specialized in production of tomato paste. The high cost estimates, thus, assume a variety of products is being produced in one location.
<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
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<tbody>
<tr>
<td>Raw Product</td>
<td>$454.02</td>
</tr>
<tr>
<td>Aseptic Drum</td>
<td>98.19</td>
</tr>
<tr>
<td>Fuel</td>
<td>9.5</td>
</tr>
<tr>
<td>Electricity</td>
<td>8.45</td>
</tr>
<tr>
<td>Direct Labor</td>
<td>190.05</td>
</tr>
<tr>
<td>Indirect Labor</td>
<td>88.69</td>
</tr>
<tr>
<td>Depreciation</td>
<td>40.12</td>
</tr>
<tr>
<td>Plant Interest</td>
<td>40.12</td>
</tr>
<tr>
<td>Working Interest</td>
<td>44.35</td>
</tr>
<tr>
<td><strong>TOTAL COSTS/MT</strong></td>
<td><strong>$973.50</strong></td>
</tr>
</tbody>
</table>

Table 2.4: California paste production costs I.
## Low Cost Estimate

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Product</td>
<td>$454.02</td>
</tr>
<tr>
<td>Tank Car Fill</td>
<td>36.95</td>
</tr>
<tr>
<td>Ingredients</td>
<td>1.06</td>
</tr>
<tr>
<td>Fuel and Electricity</td>
<td>17.95</td>
</tr>
<tr>
<td>Maintenance and Repair</td>
<td>11.61</td>
</tr>
<tr>
<td>Disposal</td>
<td>4.22</td>
</tr>
<tr>
<td>Direct Labor</td>
<td>88.69</td>
</tr>
<tr>
<td>Fees, Labor, Taxes, Etc.</td>
<td>88.69</td>
</tr>
<tr>
<td>Depreciation</td>
<td>33.79</td>
</tr>
<tr>
<td>Plant Interest</td>
<td>33.79</td>
</tr>
<tr>
<td>Working Interest</td>
<td>36.95</td>
</tr>
<tr>
<td><strong>TOTAL COSTS/MT</strong></td>
<td><strong>$807.70</strong></td>
</tr>
</tbody>
</table>

Table 2.5: California paste production costs II.
For Argentina, two cost estimates were available, as well. The Argentine costs are comparable in total to the California costs. The two sets of estimates are as follows (JICA, 1996, and Moulton and Garoyan, 1991):

**Estimate #1**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Product</td>
<td>$518.00</td>
</tr>
<tr>
<td>Labor</td>
<td>45.45</td>
</tr>
<tr>
<td>Electricity</td>
<td>77.27</td>
</tr>
<tr>
<td>Packaging</td>
<td>109.09</td>
</tr>
<tr>
<td>Others</td>
<td>4.55</td>
</tr>
<tr>
<td>Depreciation</td>
<td>65.64</td>
</tr>
<tr>
<td>Administrative</td>
<td>27.27</td>
</tr>
<tr>
<td>Interest</td>
<td>13.64</td>
</tr>
<tr>
<td><strong>TOTAL COSTS/MT</strong></td>
<td><strong>$859.10</strong></td>
</tr>
</tbody>
</table>

Table 2.6: Argentina paste production costs I (JICA, 1996).
Table 2.7: Argentina paste production costs II (Moulton and Garoyan, 1991).
One set of estimates was available for Brazilian production of tomato paste. This estimate fell within the low and high estimates for both California and Argentina. The estimates are as follows (Moulton and Garoyan, 1991):

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>$468.21</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>156.07</td>
</tr>
<tr>
<td>Packaging</td>
<td>72.83</td>
</tr>
<tr>
<td>Indirect Cost</td>
<td>218.50</td>
</tr>
<tr>
<td>TOTAL COSTS/MT</td>
<td>$915.65</td>
</tr>
</tbody>
</table>

Table 2.8: Brazil paste production costs.
Finally, one set of estimates is available for Chilean production. The total costs for Chile are the lowest of all four countries under study. The costs are estimated to be as follows (Moulton and Garoyan, 1991):

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Product</td>
<td>311.07</td>
</tr>
<tr>
<td>Container</td>
<td>91.63</td>
</tr>
<tr>
<td>Energy</td>
<td>33.76</td>
</tr>
<tr>
<td>Labor (direct and indirect)</td>
<td>18.09</td>
</tr>
<tr>
<td>Interest Charges</td>
<td>150.71</td>
</tr>
<tr>
<td>Depreciation</td>
<td>84.40</td>
</tr>
<tr>
<td>Other Overhead</td>
<td>30.14</td>
</tr>
<tr>
<td><strong>TOTAL COSTS/MT</strong></td>
<td><strong>719.77</strong></td>
</tr>
</tbody>
</table>

Table 2.9: Chile paste production costs.

Comparing the figures for the US versus the South American countries, it seems as though there is not much difference in total. One must pay attention, however, to the efficiency of the Chilean industry. Of the South American countries, it is by far the most advanced in tomato paste production. Chile is also the only one of the three that produces primarily for the export market. Argentina and Brazil produce mostly for internal markets, and have only recently been exposed to much competition. If investment took
place in these two countries to bring their efficiency to that of the Chilean industry, the entire bloc could be a strong international competitor in the production of paste.

With this in mind, the following examination of trade costs focuses on the cost to ship paste from South America to the US. All of the trade cost information can be found in Moulton and Garoyan (1991).

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight to Port</td>
<td>$83.86</td>
</tr>
<tr>
<td>Freight to US</td>
<td>159.34</td>
</tr>
<tr>
<td>Duty</td>
<td>172.74</td>
</tr>
<tr>
<td><strong>TOTAL TRADE COSTS/MT</strong></td>
<td><strong>$415.94</strong></td>
</tr>
</tbody>
</table>

Table 2.10: Argentina trade costs.

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freight to Port</td>
<td>$33.99</td>
</tr>
<tr>
<td>Freight to US</td>
<td>107.41</td>
</tr>
<tr>
<td>Duty</td>
<td>139.88</td>
</tr>
<tr>
<td><strong>TOTAL TRADE COSTS/MT</strong></td>
<td><strong>$281.28</strong></td>
</tr>
</tbody>
</table>

Table 2.11: Brazilian trade costs
Freight to Port $69.81
Freight to US 161.39
Duty 113.36
TOTAL TRADE COSTS/MT $344.56

Table 2.12: Chilean trade costs.

Shipping costs to the US are much cheaper from Brazil than from Argentina or Chile. Improvements in infrastructure, including planned transcontinental links, could decrease these costs substantially. For all three countries, the duty paid on paste definitely hinders the competitiveness of their products. If Chilean producers had no duty to pay, they could have landed their product in the US at a total cost of $950 - a price that falls within the range for California production, but much higher than California’s lower cost estimate. If Brazilian production efficiencies were the same as those of Chile, Brazilian paste could, theoretically, have landed in the US at a total cost of $861, still within the range for California. Table 2.13 provides a comparison of landed costs in the US with and without duties.
<table>
<thead>
<tr>
<th></th>
<th>US II</th>
<th>Argentina II</th>
<th>Brazil</th>
<th>Chile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production</td>
<td>$807.70</td>
<td>$859.10</td>
<td>$915.65</td>
<td>$719.77</td>
</tr>
<tr>
<td>Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landed Cost</td>
<td>807.70</td>
<td>1275.04</td>
<td>1196.93</td>
<td>1064.33</td>
</tr>
<tr>
<td>w/duty</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landed Cost</td>
<td>807.70</td>
<td>1102.30</td>
<td>1057.05</td>
<td>950.97</td>
</tr>
<tr>
<td>w/o duty</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.13: Comparison of landed costs for tomato paste.

With the costs presented here, an obvious winner under free trade does not emerge based on absolute advantage. California and Chile are operating at similar levels in terms of efficiency. While Chile could not competitively land paste in the US based on the second set of cost estimates, neither could California competitively land paste in South America. In all countries, marginal costs are less than average costs. The ratio of these two values is the measure of economies of size. When this ratio is less than one, the industry exhibits increasing returns to size, which means that a more efficient level of production could be reached by increasing production. Determining where firms are producing on their average cost curves is virtually impossible due to the unavailability of such private firm-level data. The US tends to have higher fixed cost proportions, suggesting larger returns from size are possible; however, the fixed versus variable cost breakdowns were difficult to establish, and, hence, not very reliable. Since all four countries exhibit increasing returns to size, a clear cut winner does not exist based on this measure, either.
As with tomato production, for the analysis that follows in Chapter 5, it is important to ascertain whether tomato paste processors face increasing returns. The best evidence for this is contained in Moulton, Garoyan and Hetland (1994). In a study looking at installed processing capacity, the authors found that overcapacity existed in the industry. "(W)e cannot escape the reality that since 1989, processing capacity in California has expanded more rapidly than paste production, even with recent closures. This creates the potential for expanding production of raw product in the state by 1.3 million tons beyond the level expected in 1993 without a significant increase in investment"(p.11). In fact, for the world as a whole, the authors predicted an overcapacity in 1993 equal to 30% of operating capacity. With this in mind, the assumption is plausible that average costs of producing tomato paste would decline with an increase in production.

An alternative way of determining where production will occur under free trade is to utilize a model based on location theory. "Location theory and comparative advantage are closely tied. Location theory emphasizes that firms locate where they can make the greatest profit on their investment" (Tweeten and Brinkman, 1976). The following chapter serves as an introduction to location theory, which will ultimately be used to predict where tomato paste production will take place with free trade in the Western Hemisphere.
"Since the beginning of analytical economics, the concept of comparative advantage has been the starting point for virtually all theoretical discussion of international trade. Comparative advantage is a marvelous insight: simple yet profound, indisputable yet still (more than ever?) misunderstood by most people, lending itself both to theoretical elaboration and practical policy analysis. What international economist, finding himself in yet another confused debate about US 'competitiveness', has not wondered whether anything useful has been said since Ricardo? Yet is has long been clear that comparative advantage ... is not the only possible explanation of international specialization and exchange. As Ricardo doubtless knew, and as modern theorists from Ohlin on have reemphasized, countries may also trade because there are inherent advantages in specialization, arising from the existence of economies of scale" (Krugman, 1990, p.63).

In the world of agriculture, the belief exists that traditional trade theory will fully explain location of production. However, "few would argue that natural resources explain more than a fraction of the observed unevenness of economic activity across space ... And indeed even the distribution of agricultural production is dictated as
much by access to urban markets as by the underlying quality of the soil” (Krugman, 1995, p.36). Certainly, one cannot ignore the limitations of climate and growing conditions on the location of agricultural production; however, for the products that are examined herein, production of the raw material is already taking place in the locations of concern. This is especially important to note for the US. California is estimated to be the world’s largest producer of processing tomatoes, by far. Florida, as well, is one of the world’s leading producers of juice oranges, second only to Brazil. These locations are being examined because they already have some agglomeration of the industries of concern; it would be foolish to examine them otherwise for purposes of this dissertation.

The previous chapter’s cost comparisons for tomato paste were an attempt to determine absolute and competitive advantage in paste production. To determine comparative advantage would require examination of other products. All that aside, however, what the previous quotes emphasize is that another approach to location of production might be more appropriate or provide a stronger conclusion. The literature review that follows summarizes definitions and theoretical developments in location theory and agglomeration. This review builds to the model, described in Chapter 4, that will be used in this dissertation for analysis of tomato paste and orange juice.

3. A General Definition of Agglomeration

Traditional economic theory holds that firms compete for resources and consumers so that firms improve their competitiveness by dispersing themselves over a geographic area. New theoretical developments suggest the contrary - that in an industry
with increasing returns, internal and external to the firm and the industry, agglomeration of firms may sensibly occur. Such agglomeration has been cited extensively in the literature in regard to US production (see Krugman (1991) among others). While agglomeration has not occurred to the same extent in other parts of the world, the recent trend of economic integration is expected to create more opportunities for increasing returns in industries, and hence, increasing agglomeration.

Many attempts have been made to define agglomeration economies. Useful definitions for the purposes of this dissertation include:

i) "Nothing else but the existence of increasing returns to scale - using that term in the broadest sense - in processing activities. These are not just the economies of large-scale production, commonly considered, but the cumulative advantages accruing from the growth of industry itself" (Kaldor, 1970, p.340 as quoted in Selting et al., (1994)).

ii) "An agglomerative factor, for purposes of our discussion is an "advantage" of cheapening of production or marketing which results from the fact that production is carried on at some considerable extent at one place" (Weber, 1956, p. 126).

iii) "Agglomeration confers advantages to firms by either stimulating consumption (such as providing better access to markets) or decreasing the costs of production. Agglomeration economies are a form of external economies, and this distinction is important" (Selting et al., 1994, p.3).
The rest of this chapter will be used to present a general overview of agglomeration. Section 3.B will provide extensive rationales for the existence of agglomeration. Section 3.C will present economic theory regarding agglomeration in general. Section 3.D will look at theoretical developments regarding agglomeration of a particular industry.

3.B Rationale for Agglomeration

Among the several possible explanations for the agglomeration of industries, one possibility that must be eliminated from the outset is comparative advantage. As Krugman (1991) states, "by comparative advantage I mean the general idea that countries trade in order to take advantage of their differences. The increasing returns approach asserts instead that countries trade because there are inherent advantages to specialization, even for initially similar countries" (p.6). Models using comparative advantage assume constant returns to scale and perfect competition; of interest here are industries with imperfect competition and increasing returns to scale. Increasing returns are a necessary condition for the existence of agglomeration; average costs must diminish with the clustering of vertically linked firms in order for that clustering to take place. If increasing returns exist, some form of imperfect competition must exist in any modeling, the logical limit being a monopoly.

Comparative advantage certainly played a role in the initial development of the locations being studied since they are well suited for production of the goods of interest relative to other locations. Certain conditions must be met for oranges and tomatoes to be
grown. However, given similarities that exist among the current locations for both products, location theory might be useful in determining future growing and processing sites under alternative trade conditions.

Before delving into location theory, it might be useful to review the effects of trade barriers under the neoclassical assumptions. In particular, a review of the effects of an import tariff will serve for comparison purposes with the model used in this study. The following figure (3.1) portrays the effects of a tariff.

![Figure 3.1: Effects of an import tariff under neoclassical assumptions (Tweeten, 1992, p.80).](image)

The importing country is represented by the diagram on the left. The exporting country is represented by the diagram on the right. The middle diagram portrays the world market. If the importing country imposes a tariff on the good, a lower world price
is obtained. This results in the exporting country producing less and consuming more.
The importing country produces more and consumes less than it would under a free trade
scenario. The tariff results in a gain to producers in the importing country at the expense
of its own consumers and the exporting country's producers. Removal of the tariff would
increase production in the exporting country. The price they receive would be higher, but
consumers in the importing country are better off. Construction of the above diagrams
for tomato paste and orange juice would require constructing supply and demand curves
in order to exactly estimate what losses and gains would be, and what the ultimate world
prices would be under free trade.

Returning to location theory, Krugman (1995) describes several different
approaches to the explanation of agglomeration. Within each approach, the need for a
monopolistically competitive market structure is explained. While I will not get into the
various approaches for the purposes of this dissertation, some of his comments are helpful
in understanding the need for such an approach.

In discussing central place theory, which examines the location of manufacturing
centers given an evenly distributed agricultural population, Krugman states, "(t)he idea is
simple enough: each firm faces a trade-off between economies of scale, which push
toward a limited number of production sites, and transport costs, which can be reduced by
multiplying the number of sites. But this description immediately implies that we are in a
world in which there are unexhausted economies of scale, and thus in a world of
imperfect competition" (p.41).
In a discussion of market potential theory, involving an index of purchasing power and distance to markets, he states, "(f)irms cannot exhibit constant returns to scale - otherwise one would simply establish a facility to serve every market, and there would be no reason to compute a single market potential surface ... Nor can they be producing goods that are perfect substitutes; there would be sharply defined market areas ... Thus the market potential approach seems to have an implicit monopolistic competition story lurking underneath" (p.46).

Now of course, one might think of only external economies as the cause of agglomeration. The idea of agglomeration is quite old within economic theory, however, and the original notion of external economies included more than just pure technological spillovers. Marshall (1920) was one of the first to emphasize clustering. He counted technological spillovers as one example of external economies. This form of external economy can take place within the assumptions of a competitive equilibrium. Marshall also included "the ability of a large local market to support efficient-scale suppliers of intermediate inputs" (Krugman, 1995, p.50) as an example of external economies. This form is most easily modeled using a monopolistically competitive market structure.

Obviously, the use of such an approach is not possible with every product, particularly in agriculture. The products being examined in this dissertation, however, seem to be fairly good candidates for such an approach. As mentioned before, while there are certainly limits on where agricultural production can take place, the products of interest here are produced on a large scale in the locations being considered in this dissertation. Of course, the model that is ultimately used is not a perfect representation of
the real world - no model would be. This will become clearer in Chapter 4 where the model is described. The very nature of economic modelling requires a simplification of the real world. The industries examined in this dissertation seem to be examples of clustering. The branch of economic theory explained in this chapter, and the model explained in the next chapter provide a simplified portrayal of real world agglomeration based on certain assumptions. As with any economic model, these assumptions are subject to criticism; however, application of the model to these industries should provide helpful insights.

While several non-economic rationales for agglomeration have been offered by the literature, these will be saved for last, as the economic rationales are those of interest for this dissertation. Economic explanations have generally been divided into three categories.

3.B.1 Internal economies

Internal economies are nothing more than increasing returns within a company; that is, spreading fixed costs over a larger output might substantially reduce average costs. Related benefits to increased production are increased specialization of labor, potential for adapting cost-saving technology, reduced per unit costs through bulk purchasing of inputs or sale of products, and improved organizational structure. It is important to note that internal economies refer to factors that are under the direct control of the individual firm.
3.B.ii External economies - intra-industry

"External economies of scale that are internal to the industry but external to the firm occur when many firms in the same industry locate in an area to capture the external benefits of clustering" (Selting et al., 1994, p. 4). This concept is also referred to as localization economies. These economies come about through utilization of a specialized labor pool, increased opportunities for firm specialization within an industry, access to raw materials at a lower cost for all firms, and increased opportunity for cooperation in research and development that might not be possible at an individual firm level. Economies can also accrue to consumers in that there is increased opportunity for comparison shopping and increased competitiveness for their business with many firms of an industry clustered.

3.B.iii External economies - inter-industry

As firms within an industry begin to cluster, upstream and downstream industries are attracted to the same region, adding to the external economies already present. Having input suppliers and output users nearby cuts down on transportation costs and allows for better communication among the vertical linkages. This phenomenon is also referred to as urbanization economies. As an area is built up with industries, governments will provide support services and infrastructure. Once again, these gains are external to an individual firm, but also external to individual industries. As industrial growth continues, more labor becomes available in the region allowing for even greater specialization and competitive labor pricing. An implicit limit to such gains exists, however. When a region becomes too developed, firms and industries have to compete
for increasingly scarce resources; likewise, intangible costs arise from being located in big cities due to negative externalities such as greater congestion, pollution and crime.

3.B.iv Physical factors

As the discussion herein moves to horticultural products, climate will play a major role in determining location of industries. While this might be considered influential in determining comparative advantage for primary horticultural products, increasing returns and imperfect competition will be important in processing. In addition, recalling Krugman’s quote from the beginning of this chapter, location of agricultural production is determined in part by access to markets. (See Hopman and van Niejenhuis, 1993.)

3.B.v Social and political factors

Social and political factors might be associated with external economies to the industry, but additional issues become important when looking at agglomeration from an international perspective. Politically, a potential area of concentration should be stable. Provision of supportive public services with minimal government intervention and low taxation rates is always preferable. Socially, the business climate including law, order and absence of predatory behavior are conducive to growing industries. The cultural attitudes favorable to business can promote enterprise. Considering the countries of interest for this research, these factors are important to keep in mind.

3.B.vi Transfer economies

To finalize this discussion, it should be emphasized that the primary motivation for this proposal is the potential for transfer economies. While transportation costs were mentioned in relation to external economies, they were not singled out for inspection.
Transfer economies result from agglomeration since vertically linked industries and end consumers are located near each other, thereby reducing shipping costs. In location theory, a key component of maximizing profit for an industry is minimizing transportation costs.

3.C Economic theory for general agglomeration

The previous section presents some logical rationales for the existence of agglomeration, but a few theoretical models might prove more enlightening. Krugman (1991) presents a very elementary model. Much more elaborate ones have followed. For the purposes of this paper, this section will describe Krugman’s simpler model and then summarize two models by Krugman and Venables that facilitate understanding of general industrial agglomeration. Section 3.D will feature a model by Venables that looks at an individual industry.

3.C.i Krugman’s model of geographic concentration

In Krugman (1991), he develops a simplistic model to illustrate the potential consequences of increasing returns, demand, and transportation costs on industry location. Two locations exist - East and West. Two sectors are used, an agricultural sector and a manufacturing sector. The agricultural sector has constant returns to scale and relies on a location-specific factor of production. Agricultural workers are evenly divided between the two locations. Assuming this economy has 10 workers and 60 percent are agricultural workers, then three agricultural workers are located in each location. Four manufacturing workers are left to locate.
Assuming increasing returns in the manufacturing sector, the owners of manufacturing would prefer to exist in one location. With the existence of transportation costs, however, three possible equilibrium solutions exist. Using fixed costs to incorporate the concept of increasing returns, Krugman assumes a fixed cost of four dollars for each plant. Transportation costs are assumed to be one dollar per unit. Establishing a demand of one unit of manufactured good per worker, the possible equilibrium solutions can be explored by utilizing the following chart from Krugman.

<table>
<thead>
<tr>
<th>Distribution of Manufacturing Employment</th>
<th>Costs of typical firm if it produces in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>East</td>
</tr>
<tr>
<td>East only</td>
<td>Fixed</td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>Fifty-fifty split</td>
<td>Fixed</td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
<tr>
<td>West only</td>
<td>Fixed</td>
</tr>
<tr>
<td></td>
<td>Transportation</td>
</tr>
<tr>
<td></td>
<td>Total</td>
</tr>
</tbody>
</table>

Table 3.1: Summary of costs under several scenarios.
A quick perusal of Table 3.1 shows that if all four manufacturing workers are located in the East, the optimal solution is to manufacture in the East. If two manufacturing workers live in each location, then the optimal solution is to manufacture in both locations. Finally, if all four workers are located in the West, manufacturing should be wholly located in the West.

To portray this model algebraically, let $\pi$ represent the percentage of the population in manufacturing, $s_N$ West’s share of the total population, and $s_M$ West’s share of manufacturing workers. Then,

$$s_N = \frac{1 - \pi}{2} + \pi s_M; \quad (1)$$

in other words, the more manufacturing West has, the greater its share of the population will be. This denotes a circularity in agglomeration: manufacturers want to locate near a large population in order to find customers, and people want to live near manufacturing in order to find work.
Graphically, this model can be represented in the following manner:

![Graphical representation of Krugman’s model.](image)

The line PP represents the relationship between West’s share of population and share of manufacturing as stated algebraically in the first equation. The line MM reflects the equilibrium solutions based on PP. For example if the majority of the population is in West, it would not make sense to incur the costs to move manufacturing to East; therefore, manufacturing would take place in West which is represented by the number 3 in Figure 3.1. The other previously described equilibrium solutions are represented by 1 and 2 above.

Now the question remains as to how much fixed costs have to be relative to transportation costs to determine manufacturing location. If $x$ is defined as sales of a firm, $F$ is defined as the fixed costs of opening a manufacturing plant, and $t$ is defined as the per unit transportation cost, then manufacturing will take place in East whenever
In the same manner, manufacturing will take place in West if \( (1-s_N)t < F \); otherwise, manufacturing will occur in both places. Referring back to Figure 3.1, the dynamics of the system are represented by the arrows. History matters in this depiction; the starting position determines what equilibrium solutions are possible.

The possibility exists of having only one equilibrium solution. If the dispersion of agriculture is stronger than the pull of manufacturing’s circularity, then it is possible that the only equilibrium is to manufacture in both East and West. A requirement for the possibility of manufacturing in just one location is to have fixed costs large enough.

Specifically, concentration of production in one region requires the following:

\[
F > \frac{1 - \pi}{2} t \alpha .
\]  

Without this requirement, agriculture determines the location of manufacturing.

"We can immediately see that a key role for history depends on three parameters: large \( F \), i.e., sufficiently strong economies of scale; small \( t \), i.e., sufficiently low costs of transportation; and large \( \pi \), i.e., a sufficiently large share of "footloose" production not tied down by natural resources" (pp. 21-22).

3.C.ii Krugman and Venables (1993) - Model of Integration

Krugman and Venables were concerned with the level of manufacturing concentration in the US relative to Europe. Specifically, they wanted to know if the economic integration of Europe would result in the level of agglomeration witnessed in the US. They hypothesized that by lowering \( t \) through a reduction in tariffs and administrative hassles at the borders, the integration of Europe would result in
interindustry specialization, i.e., integration would effectively make the countries of Europe less similar.

To model this, they relied on several simplifications of the world. They assumed two symmetric countries (which again can be East and West). Both countries have similar states for two types of products. Utility is represented as follows:

\[ U = C_1^{0.5} C_2^{0.5}, \quad (3) \]

where 1 and 2 represent the two types of goods. The aggregate C is made up of differentiated goods:

\[ C_i = \left[ \sum_j C_{ij}^{(\sigma - 1)/\sigma} \right]^{\sigma/(\sigma - 1)}. \quad (4) \]

The only factor of production is labor, but intermediate goods can be used in production, as well. The intermediate input is represented by:

\[ Z_i = L_i^{1-\mu} M_i^\mu \quad (5) \]

where \( \mu \) is a measure of the relative importance of intermediate inputs. \( L_i \) represents the labor input. The authors make the simplifying assumption that the aggregate input \( M_i \) is defined identically to the aggregate consumption good.

They also assume that the differentiated good \( j \) is produced with economies of scale; this is demonstrated once again by the use of fixed and marginal costs in terms of the composite input \( Z_i \).

\[ Z_i = \alpha + \beta Q_{ij}, \quad (6) \]

where \( Q_{ij} \) can be used as either an intermediate input or a final good.
The setup presented above allows for the existence of external economies of scale through the inclusion of intermediate inputs. The larger a company is, the more cheaply it can produce the intermediate input for its final good. This effect is compounded for the industry.

The economy can be described as monopolistically competitive, with profits driven to zero through free entry. Firms face a constant elasticity of demand, thereby resulting in a Dixit and Stiglitz (1977) type economy. In such an economy, “the possibility of product differentiation arises from the desire of every individual to consume a variety of goods” (Helpman and Krugman, 1989, p.134). Trade is allowed, but iceberg transport costs, represented by $r>1$, are incorporated. Iceberg transport costs are such that for every unit shipped, only $1/r$ arrives. Labor is immobile, and each country has a labor force of 1 for simplification of this model. To facilitate the illustration of adjustment under integration, the authors impose a rule that transfer of a worker from one industry to another takes place gradually.

In an effort to avoid complete retelling of the article by Krugman and Venables, the results of this setup will be summarized. The model allows the determination of a short and long-run equilibrium, and can be solved analytically given various parameter values. The main conclusion of the model, however, echoes that of Krugman’s much simpler model. “At high levels of transport cost there is never agglomeration; there is a range of transport costs for which agglomeration may but need not occur; and at sufficiently low transport costs only agglomerated equilibria are stable” (p.16).
The authors discuss what this conclusion means specifically for Europe after it has fully adjusted for integration. The possibility remains that, despite the reduction in tariffs and administrative border policies, cultural barriers that are included in transport costs will still remain at high enough levels as to discourage agglomeration. Regardless, the reduction in $\tau$ still might not be enough to force agglomeration on the continent. If agglomeration does occur, there will be very serious real adjustment costs to be dealt with, despite the long-run improvement in efficiency.


In yet another paper on the subject, the authors turn their attention to the question of whether integration between developed and developing countries leads to a greater division between the rich and the poor or the great “sucking sound” predicted by 1992 presidential candidate Ross Perot. Applying a version of their agglomeration model to such a scenario results in justification of both views. A brief summary of this model seems in order as the topic of concern herein is integration between NAFTA and the rest of the Western Hemisphere.

The authors return to the characterization of a constant-returns-to-scale agricultural sector and an increasing-returns-to-scale manufacturing sector. As in the model in Section 3.C.ii, the manufacturing sector produces both final goods and intermediate goods as inputs for other manufactured goods.

"The interaction between transport costs and trade in intermediates creates country-specific external economies, which may lead to agglomeration of industrial activity. These externalities are similar to those which arise from the interaction between
transport costs and labor mobility in recent models of economic geography (e.g. the model in section A). However, our model differs from these in important ways. The mechanism creating the externalities is linkages between firms (through the input-output structure), rather than linkages between firms and worker/customers... Since we do not assume labor mobility the model is applicable to international as well as to interregional economics” (pp.4-5).

The important ramification for this setup is that the labor immobility allows for redirection of manufacturing to the low wage, lesser developed country. With transportation costs low enough, the manufacturing sector does not have to locate where the consuming public is; it might be cheaper to ship the finished goods from the developing country depending upon the values of all other parameters.

Their model is able to make sense of both outcomes predicted by the “experts”. By combining increasing returns to scale and transportation costs, various stages of integration are demonstrated. “The world economy must achieve a certain critical level of integration before the forces that cause differentiation into core and periphery can take hold; and when that differentiation occurs, the rise in core income is partly at peripheral expense. As integration proceeds further, however, the advantages of the core are eroded, and the resulting rise in peripheral income may be partly at the core’s expense” (pp.25-26). It is important to keep in mind that integration will still lead to overall improvement through more efficient use of resources.
3.D Economic Theory for Specific Industry Agglomeration

While the above models are interesting from a general point of view, they do not answer the question of what will happen to a specific industry. As an example, if Chile were to join NAFTA, what would happen to the tomato paste industry? Would there still be production in both Chile and California, or would the industry agglomerate in one location with the reduction in transport costs of the finished product? Venables (1993, 1995) has developed some models to deal with these more specific questions although no applications have been performed. Two models are presented here. The first (Venables, 1995) is a very simplified version that will be presented to facilitate understanding. The second (Venables, 1993) is more fully developed and will be explained in greater detail in the chapter that follows.

As with the models in Part 3.C, Venables (1995) relies on a model of imperfectly competitive industries producing both intermediate and final goods. The firms of the particular industry are monopolistically competitive, i.e., they produce a differentiated good under increasing returns. Once more, two locations are used, which for our purposes can be referred to as North and South (America). The object of the model is to determine the ratio of firms in each location, $n_1$ and $n_2$.

The firms are characterized as identical within each location. Firms in North can supply South and vice versa. Price is characterized as $p$ with the location-specific subscript. The transportation costs are represented by $t$ and follow the aforementioned iceberg form. A CES aggregate of the differentiated products is used so that the unit
expenditure function in North (assuming North is represented by the subscript 1) is as follows:

$$q_1 = \left[ n_1 p_1^{1-\sigma} + n_2 (p_2 t)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{7}$$

where $\sigma$ represents product differentiation and exceeds unity. Venables describes $q_i$ as the location-specific price index. The variable $p_i$ is the consumer price in location $i$.

Expenditure in each location is represented by $e_i$. Individual firm sales are depicted as:

$$p_i x_i = e_1 \left( \frac{p_1}{q_1} \right)^{1-\sigma} + e_2 \left( \frac{p_2 t}{q_2} \right)^{1-\sigma} \tag{8}$$

where the first term measures domestic sales for North and the second term measures North's international sales.

Again, increasing returns are incorporated by utilizing fixed and constant marginal costs in production. For now, expenditures, costs, and, therefore, prices are exogenous. Figure 3.2 presents the loci of zero-profit for this model, i.e., the level of production at which fixed costs are just covered given free entry. The figure assumes non-infinite trade costs so that the numbers of firms in each location are dependent on one another; thus, each locus has a negative slope.
To the right of the locus for an individual location, too many firms exist to be profitable, so exit of firms takes place in that location; similarly, to the left of a location's locus, entry of firms occurs. The equilibrium point for the two locations is exhibited at E; E is a stable location for this model as the path diagram indicates. With the introduction of cost and demand linkages, there exists the possibility of agglomeration so that E becomes unstable. Depending on the cost and demand linkages specified, \( \frac{dx}{dn} \) could be negative or positive. (Note: \( dx = dx_1 = -dx_2 \), and \( dn = dn_1 = -dn_2 \).) With a negative change in quantity with a change in number of firms, the equilibrium will be stable; however, if \( dx/dn \) is positive E becomes unstable.

To illustrate this process, the author totally differentiates the first two equations around E and, dropping out the terms for \( dq \), arrives at:
\[ \frac{dx}{dn} = -\tau^2 + \tau \frac{de}{dn} - \left[ \sigma(1 - \tau^2) + \tau^2 \right] \frac{dp}{dn}. \]  

(9)

The number of firms in each location and the price levels in each location are all set equal to unity. \( \tau = (1 - t^{1-\sigma}) / (1 + t^{1-\sigma}) \), so that free trade is represented when \( \tau = 0 \), and autarky is represented when it equals unity. The first term of \( dx/dn \) relates to trade costs and supports the notion that firms are more competitive in their own location, thus, supporting a stable \( E \). The second term is the demand linkage, and the third term is the cost linkage. These two linkages provide the destabilizing effect. The end result is that once transport costs are reduced enough, the demand and cost linkages can lead to agglomeration of the industry.

In order to incorporate the intermediate good concept into this model, Venables assumes that all goods can be used as inputs. In this manner, \( q \), represents “not only the cost to consumers of generating utility from differentiated products, but also the cost to firms of using an aggregate of differentiated products as an intermediate” (p.298). The author then incorporates a Cobb-Douglas cost function to illustrate the bifurcation that occurs. Figure 3.3 illustrates this point.
Point $C$ is a bifurcation point or crisis point, "at which the system prefers to leave the steady-state, evolving instead into some other state" (Coveney and Highfield, 1990, p.163). When transportation costs are below the bifurcation point, production will occur at either of the two locations but not at both. Beyond this point, production will occur in both locations. The dashed lines represent stable equilibria, while the solid lines are unstable.
4. A Venables’ Model

Finally, we arrive at a model that provides the demand and cost linkages, along with better defined intermediate linkages, the model appearing in Venables (1993). While this particular paper ultimately details a general equilibrium version of the agglomeration model, the version presented here is only a partial equilibrium. Given the nature of the industries for which I intend to apply the model, this version seems most appropriate. Venables indicates that if the industries are small relative to factor markets and total income, it is appropriate to treat wages and relative demand for the consumption good as exogenous.

The industry model is characterized by the Dixit-Stiglitz form of monopolistic competition. Firms produce differentiated goods with increasing returns to scale; this would suggest that, depending on the average cost curve, the most efficient number of firms might be one - a monopoly. Consumers, however, desire a wide variety of differentiated goods; this will serve to limit firm size thereby maintaining enough firms so as to remain competitive, at least monopolistically. Recall that in order to model agglomeration economies, increasing returns are a necessary condition. This eliminates
perfect competition for modeling purposes. The easiest way to model increasing returns while maintaining a competitive environment is to use this form of monopolistic competition, utilizing a technology of fixed costs and constant marginal costs.

Two vertically linked industries exist in this model along with two locations where both industries may locate; regardless of where an individual firm is located, it may provide the good for either location. Subscripts in the following equations refer to location, i.e., 1 or 2; superscripts refer to industry, i.e., a or b. A constant elasticity of substitution utility function is used to aggregate over varieties. If \( e \) refers to expenditure and \( p \) to price, demand for a particular variety is:

\[
\begin{align*}
x_{ii}^k &= (P_i^k)^{\varepsilon^k} (P_i^k)^{\varepsilon^k - 1} e_i^k, \\
x_{ij}^k &= (P_j^k t_j^k)^{\varepsilon^k} (P_i^k)^{\varepsilon^k - 1} e_j^k \\
&\quad i \neq j
\end{align*}
\]

\[ \varepsilon^k > 1 \]
\[ t^k \geq 1 \]

where the first subscript on \( x \) indicates where the good was produced and the second subscript indicates where it is sold and consumed.

The elasticity of demand for a particular product is represented by \( \varepsilon \); all goods are required to be normal. While theoretically demand elasticities are negative, it is common to refer to the absolute value of the elasticity. The elasticity of demand must be larger than one "in order to make sense of monopolistic competition (if the elasticity of demand with respect to price is smaller than one, marginal revenue is negative)" (Helpman and
Krugman, 1993, p.117). As in all the previous models, \( t \) is used to represent iceberg transport costs.

The \( P \)'s are price indices for each location. Using \( n \) to indicate the number of firms, the price indices are defined as:

\[
\begin{align*}
(P_1)_{1-\varepsilon} &= (p_{1}^{k})_{1-\varepsilon} n_{1}^{k} + (p_{2}^{k})_{1-\varepsilon} n_{2}^{k}, \\
(P_2)_{1-\varepsilon} &= (p_{1}^{k})_{1-\varepsilon} n_{1}^{k} + (p_{2}^{k})_{1-\varepsilon} n_{2}^{k}.
\end{align*}
\]

(11)

With positive trade costs, the relocation of a firm results in a decrease in the price index for the location to which that firm has moved due to a savings from the elimination of \( t \) for that firm's good.

Profits, represented by \( \pi \), are as follows:

\[
\pi_i^k = (p_i^k - c_i^k)(x_i^k + x_j^k) - c_i^k f^k
\]

(12)

with marginal costs represented by \( c \) and fixed costs represented by the last term. This equation is merely revenue less marginal and fixed costs. Note the appearance of increasing returns, once more. Assuming a profit of zero and price equal to average cost, standard assumptions for monopolistic competition, maximizing \( \pi \) with respect to price and marginal cost results in:

\[
c_i^k = p_i^k (1 - \frac{1}{\varepsilon_k}).
\]

(13)

The following is also derived from profit maximization:

\[
x_i^k + x_j^k = f^k (\varepsilon_k - 1) = \phi^k.
\]

(14)

Equations (13) and (14) are equivalent statements. Solving each one out for \( \varepsilon \), the following equation is obtained:
The term $f^k$ is calculated as the per unit fixed cost multiplied by production and divided by marginal cost, so that both sides of equation (15) result in the marginal portion of the price divided by the fixed portion of the price with price equal to average cost. The demand elasticity is determined by price and ability to substitute. This ability, of course, is dependent upon the number of varieties from which to choose, which gets us back to increasing returns. Using fixed and variable costs to calculate the demand elasticities is equivalent to using prices and substitutability, as demonstrated in equation (15). This elasticity is for a particular variety of a good.

As explained in Helpman and Krugman (1993), the demand elasticity for a CES subutility function is actually considered to be the same as its elasticity of substitution. The subutility function has the form:

$$u_i(D_{i1}, D_{i2}, \ldots) = \left( \sum_{\omega} D_{i\omega}^{\beta_i} \right)^{\gamma_i}, \beta_i = \left( \frac{1}{\sigma_i} \right), \sigma_i > 1$$

with $\sigma_i$ representing the elasticity of substitution. Of course, this elasticity must be greater than one; otherwise, marginal revenue is negative. The demand function for a particular variety is:

$$D_{i\omega} = \frac{p_{i\omega}^{-\sigma_i}}{\sum_{\omega' \in \Omega_i} p_{i\omega'}^{-\sigma_i}} E_i, \omega \in \Omega_i,$$

where $p_{i\omega}$ is the price of variety $\omega$ and $\Omega_i$ is the set of available varieties. This results in the following demand elasticity:

$$\frac{c_i^k}{p_i^k - c_i^k} = \frac{x_{ii}^k + x_{yi}^k}{f^k}. \quad (15)$$
\[ \sigma_i + \frac{p_{lw}^{1-\sigma_i}}{\sum_{\omega \in \Omega} p_{lw}^{1-\sigma_i}} (1 - \sigma_i). \]

With a large enough variety, the second term can be ignored, so that the demand elasticity is essentially equivalent to the elasticity of substitution with this particular utility function.

For algebraic simplicity, demand in Venables' model for a single variety at its home location per unit of expenditure is represented by \( 1/z^k \) where \( z^k = (p^k)^e (P^k)^{1-e} \). Relative costs and prices of two firms in the same location are represented by \( \rho^k \) which is defined as \( \rho^k = c^k_2 / c^k_1 \equiv p^k_2 / p^k_1 \). The break-even production level for a firm can be expressed as \( \phi^k \) where:

\[
\frac{e^k_1}{z^k_1} + \frac{e^k_2}{z^k_2} \left( \frac{t^k}{\rho^k} \right)^{-e^k} = \phi^k, \quad (16)
\]

\[
\frac{e^k_1}{z^k_1} \left( t^k \rho^k \right)^{-e^k} + \frac{e^k_2}{z^k_2} = \phi^k.
\]

As one last step in the simplification process, define relative expenditure to be \( \sigma \equiv e_2 / e_1 \).

Now to consider the case of vertically linked industries, let \( a \) represent the upstream industry which supplies \( b \), the downstream industry which supplies consumption goods. The demand for industry \( a \) is assumed to come solely through the downstream industry, i.e., consumers do not directly consume the goods of industry \( a \). The linkages of these two industries must now be clarified.
Assuming relative prices for the downstream industry are endogenous to the system, the division of industry \( b \) between locations 1 and 2 can be expressed as a function of relative expenditure at both locations, transport costs and relative production costs:

\[
\frac{n_2^b p_2^b}{n_1^b p_1^b} = \frac{\sigma^b (t^b)^{\epsilon'} + (t^b)^{1-\epsilon'} - (\rho^b)^{\epsilon'} (\sigma^b + t^b)}{(t^b)^{\epsilon'} + \sigma^b (t^b)^{1-\epsilon'} - (\rho^b)^{\epsilon'} (1 + \sigma^b t^b)}.
\] (17)

Note again that the firm ratio is dependent not just upon relative production costs and transport costs, but also relative expenditure. If relative expenditure were eliminated from the equation by setting \( \sigma^b = 1 \), the following equation is obtained:

\[
\frac{n_2^b p_2^b}{n_1^b p_1^b} = \frac{(t^b)^{\epsilon'} + (t^b)^{1-\epsilon'} - (\rho^b)^{\epsilon'} (1 + t^b)}{(t^b)^{\epsilon'} + (t^b)^{1-\epsilon'} - (\rho^b)^{\epsilon'} (1 + t^b)}.
\]

The numerator and denominator are identical except for the opposite signs on \( \rho^b \)'s exponent.

As stated previously, this model is a partial equilibrium where relative wages are considered to be exogenous. Labor is the only factor of production; however, industry \( b \) uses industry \( a \)'s output as an input. Labor is also considered to be immobile; this assumption is useful for examining agglomeration possibilities on an international level.

Of course, in reality the products being studied in this dissertation use more than just labor to produce the raw product; when applying this model, the price or cost ratio for aggregate inputs to produce the upstream product might work more effectively.

Comparing the wage ratios to the price and/or cost ratios provided in the analyses for the two industries reveals a substantial difference between the two. This is not surprising if
the cost breakdowns for the products are examined. Many inputs besides labor are used in the production of tomatoes and oranges. Additionally, the wage ratio would not fully account for differences in productivity. Anecdotal evidence suggests that workers in US industries are more productive than workers in the South American countries. This can be attributed to many factors: availability of complementary inputs, payment schemes, cultural differences in labor practices. Suffice it to say that the use of the wage ratio is incomplete, at best. For consistency in the model, parameterizing the raw product price ratio based on the processed product price ratio provided more reasonable results under current trade conditions.

Since industry $a$ only uses labor, the model shows relative costs and prices to be:

$$\rho^a = \omega .$$  \hspace{1cm} (18)

Industry $b$ must incorporate the inputs from $a$ into its relative costs. Labor share in industry $b$'s output is represented by $\mu$. Assuming a Cobb-Douglas production function, and utilizing the CES aggregator, industry $b$ can be characterized as follows:

$$c^b_i = w_i^\mu (P_i^a)^{1-\mu},$$
$$\rho^b = \omega^\mu \left( \frac{P_2^a}{P_1^a} \right)^{1-\mu} .$$  \hspace{1cm} (19)

Performing some algebraic manipulations, relative costs for industry $b$ can be transformed further to the following:

$$\rho^b = \omega^{1-\varepsilon} \left( \frac{P_2^a}{P_1^a} \right)^{1-\mu} \left( \frac{1 - (t^a / \omega)^{-\varepsilon}}{1 - (t^a \omega)^{-\varepsilon}} \right)^{1-\mu} .$$  \hspace{1cm} (20)
Assuming that the expenditure ratio for industry \( a \) and wage ratio are known, and using the zero profit condition, we can determine the firm allocation and the price indices for industry \( a \). Once these are calculated, we can determine the relative costs/prices for industry \( b \). Relying on the partial equilibrium nature of this model and assuming that the expenditure ratio for industry \( b \) is exogenous, we can determine expenditures for industry \( a \). Implicit in this is that industry \( b \) is the only demander of industry \( a \)’s output.

\[
e^a_i = (1 - \mu)n^b_i c^i_b (x^b_i + x^b_j + f^b) = (1 - \mu)n^b_i p^b_i \phi^b,
\]

\[
\begin{pmatrix}
  e^{a}_2 \\
  e^{a}_1
\end{pmatrix} = \frac{n^b_2 p^b_2}{n^b_1 p^b_1} \cdot \tag{21}
\]

The expenditure for industry \( a \) at a particular location is proportional to the production in the downstream industry at that location. Thus, the above two equations are the demand linkage equations for the intermediate linkage. The previous equation is the cost linkage.

Using equation (21), the following transformation can be made to facilitate understanding of \( \mu \):

\[
\mu = 1 - \frac{e^a_i}{n^b_i p^b_i (x^b_i + x^b_j)}
\]

\[
\mu = 1 - \frac{n^a_i p^a_i x^b_i + n^a_j p^a_j \phi^a x^b_i}{n^b_i p^b_i (x^b_i + x^b_j)} \tag{22}
\]

\[
\Rightarrow \mu = 1 - \frac{\text{total value of tomatoes consumed in country } i}{\text{total value of tomato paste produced in country } i}
\]

Note that units are canceled out in this equation, so the units used in the upstream industry do not necessarily have to match those of the downstream industry.
Utilizing the cost and demand linkages, we arrive at the following equilibrium condition:

$$\frac{1-(t^a/\omega)^{-\sigma^a}}{1-(t^a/\omega)^{-\sigma^a}}(\rho^a)^1-\epsilon^a \omega^{1-\mu} = \sigma^b(t^b)^{1-\epsilon^b} + (t^b)^{1-\epsilon^b} - (\rho^b)^{1-\epsilon^b} (\sigma^b + t^b).$$ \hspace{1cm} (23)

With $\sigma^b$ and $\omega$ treated as parameters, along with all the others, $\rho^b$ is now a function only of parameters. These parameters include not only relative prices or costs and trade costs, but also relative expenditure. Once this is calculated, all other variables can be identified.

Given $\rho^b$ and using equation (17), the ratio of $n^b/n^b$ can be determined. With equation (21), the expenditure ratio for industry $a$ is calculated. This is substituted into:

$$\left(\frac{z_2^a}{z_1^a}\right) = \left(\frac{e_2^a}{e_1^a}\right) \left[1-(t^a/\omega)^{-\epsilon^a}\right] \left[1-(t^a/\omega)^{-\epsilon^a}\right].$$ \hspace{1cm} (24)

The price ratio for industry $a$ remains the same. Ultimately, various permutations of $z$ ratios are equalized to obtain the ratio of firms in industry $a$ as follows:

$$\sigma^a \left[1-(t^a/\omega)^{-\epsilon^a}\right] = \frac{p_1^a n_1^a (\rho^a)^{\epsilon^a} (t^a)^{1-\epsilon^a} + p_2^a n_2^a}{p_1^a n_1^a + p_2^a n_2^a (\rho^a)^{\epsilon^a} (t^a)^{1-\epsilon^a}}.$$ \hspace{1cm} (25)

One caveat to the above is that the number of firms must be non-negative. This is met with the conditions that follow:

$$\left(\frac{\sigma^b (t^b)^{\epsilon^b} + (t^b)^{1-\epsilon^b}}{\sigma^b + t^b}\right)^{1/2} > \rho^b > \left(\frac{(t^b)^{\epsilon^b} + \sigma^b (t^b)^{1-\epsilon^b}}{1 + \sigma^b t^b}\right)^{-1/2}.$$ \hspace{1cm} (26)

$$(t^a)^{1-\mu} \omega^\mu > \rho^b > (t^a)^{\mu-1} \omega^\mu.$$ \hspace{1cm}

Venables goes on to provide numerical examples by choosing multiple parameter values. While these results will not be discussed here, the general outcome can be
summarized. As with all the previous models, the equilibrium outcome is characterized as a bifurcation. Three general outcomes are possible. First, at a high level of trade cost, production in both the upstream and downstream industries is diversified; extremely high trade costs simulate autarky. As trade costs decrease, diversification remains stable, but two other stable equilibria emerge wherein production in industry $a$ is located at only one site while industry $b$ is still diversified. Production in industry $b$ would be skewed towards the location of industry $a$. While this outcome might be mathematically possible with the products that will be examined in this dissertation, it is in reality highly implausible that fruit and vegetable production would take place just in the US or South America with processing occurring in both locations due to perishability of the products and subsequent high transport costs. As $t$ continues to decrease and approach unity, the diversified equilibria become unstable; specialization in both $a$ and $b$ becomes the equilibrium. "With high trade costs firms become tied to markets and their location decisions are much less sensitive to differences in production costs. When production is subject to increasing returns to scale, then at intermediate levels of trade costs location becomes skewed towards (although not completely concentrated in) locations with easy market access. Such locations can therefore support higher real wages than can less well placed locations" (Venables, 1993, p.1).

Venables focuses more on the general equilibrium model, but his comments are applicable to the above partial equilibrium model. "That linkages between industries create an incentive for agglomeration of activity seems unsurprising, but depends crucially on market imperfections. The linkages studied in this paper are purely market
linkages, and they derive their effect from the interaction of trade costs with increasing returns to scale and imperfect competition” (p.19).

The general findings of the above models provide an interesting contrast with previous work done in intra-industry trade (IIT). IIT theory typically states that countries with similar economic status would engage in two-way trade in differentiated products. These models typically use models of imperfect competition (see Helpman and Krugman, 1993). Agglomeration theory states that with the right combination of increasing returns, imperfect competition and transportation costs, countries that are very similar in terms of endowments might eventually specialize in completely different goods.

4.B The Solution Procedure

Given the complexity of the equations in Venables’ model, it seems obvious that a straightforward solution is unlikely. The partial equilibrium condition (23) is a nonlinear equation with respect to the unknown variable $\rho$. Solving for this variable is the key to solving for all the other variables; in particular, the relative number of firms in each location can be determined once this equation is solved.

The first step to solving this and the remaining equations will be to establish parameter values for all the exogenous variables including relative consumer demands, $\sigma^k$, and wage rates, $\omega$. These parameter values are calculated based on primary and secondary data sources.
The next issue is to solve the model given the data. As stated previously, the first equation to be solved is highly nonlinear. With Fortran programming, Newton’s method is utilized to solve for $\rho^\phi$. Newton’s method uses successive linearization which basically just replaces a nonlinear problem with a sequence of linear problems. “At each iteration of the sequence, the nonlinear problem is linearly approximated around some point, the linear problem is solved, and the solution of the linear problem is used as a point of linearization for the subsequent iteration. If properly designed and initiated, a successive linearization scheme will converge quickly to a solution of the original nonlinear problem” (Miranda, 1994, pp.29-30).

The algorithm for Newton’s method uses the following steps:

1) Initialize the procedure by making an educated guess of $x_0$ for $f(x)=0$, and set $k=0$.

2) With the $k^{th}$ iterate $x_k$, use $x_{k+1}$ as the root of the linearization problem: $f(x_k) + J(x_k)(x - x_k) = 0$. $J(\cdot)$ is the Jacobean of $f$ at $x_k$.

Letting $\delta x_k$ be the solution to $J(x_k) \delta x_k = -f(x_k)$, let

$$x_{k+1} \leftarrow x_k + \delta x_k.$$

3) If $\|\delta x_k\| < \tau$ or $\|f(x_{k+1})\| < \tau$, stop; otherwise add 1 to $k$ and perform the next iteration.

Newton’s method converges to an answer at a quadratic rate, making it a very rapid technique. The requirements are for $f$ to be continuously
differentiable in the neighborhood of \( x^* \) and for the Jacobian to be nonsingular.

Several complications arise when using this method, however. First, Newton's method is only guaranteed to be locally convergent; therefore, it is highly important to provide a good initial guess. Second, computation and programming of the Jacobian is a tedious task. Appendix B contains samples of the programs used for the analyses of Chapter 5 and Chapter 7.

4.C Application to Horticultural Products

While the primary authors of agglomeration theory seem to indicate that agricultural goods should be excluded from the possibilities of their models, recent work in agricultural economics would indicate that agriculture is characterized increasingly by industrialization and processed, differentiated final goods (see Drabenstott (1994) and Sheldon (1996) amongst others). In looking at horticultural products, or agricultural products in general, one must keep in mind the limits on production of the raw good. Obviously, any location under consideration must have the production capability for the first-stage product; otherwise, location of the consumption base will have minimal influence since transport costs for the raw products tend to be prohibitively expensive. For the products under consideration in this dissertation, however, the locations being studied have world prominence in the production of the particular good.

On thinking about horticultural products, one can immediately identify production and processing locations in the US: tomato processing in California, orange juice production in Florida. Likewise, processing locations can be identified in regions of
South America: tomato processing in Chile, Argentina and Brazil; orange juice production in the state of São Paulo in Brazil. The locations for tomato paste were the focus of cost comparisons in Chapter 2.

A few observations about these products show them to be worthy candidates for an application of the agglomeration models presented above. Typically, countries have administered lower tariff rates for unprocessed goods than for processed goods. This is the case for the US; the tariffs it charges on processed horticultural goods are higher than those for the raw commodities. Tariff rates can be incorporated into the transportation costs of the models by Krugman and Venables; in fact, they implicitly did this in their model regarding European integration.

Structural characteristics of the horticultural goods industries also make them suitable. The processing industries can generally be considered to be imperfectly competitive. While the total number of firms in existence might seem high, the market is generally controlled by just a few players. A quick glance at the grocery store shelves provides a strong indication that differentiation is occurring to some extent in tomato paste and orange juice. Whether the differences are real (such as different tastes or consistencies) or perceived (such as brand name alone), the high numbers of different varieties correspond to an assumption of differentiation. Even agricultural production might be considered imperfectly competitive given the nature of vertical integration in many food sectors and the large number of varieties. A combination of varieties of the raw product provides processors with the vital components for manufacturing a good with the desired characteristics. With the investments typically required for machinery and
storage for the goods in question, as already shown for tomato production, increasing
returns exist in both the upstream and downstream industries. Although technically all
costs are variable in the long run, the model does not contain a time element.
Furthermore, a limit exists as to the size of a firm due to the assumption of consumer
demand for variety; this means that an individual firm most likely cannot grow to the
most efficient size in terms of size economies given the constraints of the model.

A concern might exist, at least in regard to the first stage of production, as to the
shape of the supply curve. In the Venables model, a supply curve is not part of the
mechanics. Agricultural products are typically thought to have an upward-sloping supply
curve. A quick perusal of price and supply data for both tomatoes and oranges shows that
price and supply tend to move in opposite directions - as price goes down, supply goes
up. Even in a competitive system this should be unsurprising given that price is a
function of supply and demand. If an excess supply exists, price will adjust accordingly.
In a monopolistically competitive system, price and supply will also have an inverse
relationship. In such a system, an increase in supply would cause the price to go down
because firms would be producing at a lower point on their average cost curves - price
equals average cost. Of course, such a quick examination of price and supply data does
not uncover the shape of the supply curve. An upward-sloping supply curve cannot be
ruled out. Keep in mind, particularly in the case of oranges, that the ability for supply to
respond to price is quite delayed. For tomatoes, it takes a year to respond to prices. For
oranges, a response could take at least five years. Also, anecdotal evidence suggests that
producers often have very limited price knowledge when contracting with processors.
Certainly, in the long run they would exit the market if returns were consistently low. In the short run, they might still choose to operate.

Horticultural trade is an important part of the US and NAFTA trade relationship with the countries of Argentina, Brazil, and Chile. Currently, the agriculture and processing sectors exist in both NAFTA (particularly the US) and South America. With the trend toward integration, and specific interest in integration of the Western Hemisphere, transportation costs might be reduced, much as in the case of European integration. Given the models outlined above, it seems possible that further agglomeration could occur.

With these issues in mind, and given the objectives of the Economic Research Service for which this research is intended, agglomeration theory appears to have the ability to offer insights in determining effects of integration. As highlighted in the paper by Krugman and Venables (1993), possible adjustment costs from agglomeration could be substantial. By predicting in advance where certain industries would be inclined to locate, governments can prepare the structural adjustment policies necessary to soften the blows of such outcomes.
TOMATO PASTE ANALYSIS AND RESULTS

Discussing Venables’ model from a mathematical viewpoint does not prove as enlightening as applying it to real-world scenarios. The model performs quite nicely when carefully selected numbers are inserted into the equations, as demonstrated in his article. When actually using real numbers, it becomes quite obvious that the partial equilibrium equation is highly sensitive to the values of the wage ratio and the processed product expenditure ratio. The following commentary will, hopefully, provide further insight into the workings of the model, including an extensive discussion of what drives the results.

5.A Parameter Values

The cost comparisons done in Chapter 2 provide much information for calculating the necessary parameters to run Venables’ model. In order to calculate parameter values for \( \omega \) and \( \alpha \), where the \( p \) stands for paste, the following values are necessary: \( n_p, n_{p', p}, p, \alpha, \nu, \sigma, \epsilon, \varphi, \) and \( \mu \). The superscript \( t \) stands for tomatoes, and the \( u \) and \( s \) represent the US (California,
in particular) and South America, respectively. Within South America, the countries Argentina, Brazil and Chile are examined.

The number of paste processing firms is somewhat misleading. In 1993, California had 32 processing firms. While this does not account for all US production, California is where the vast majority of paste production takes place; hence, this is the number that is used for the US. Argentina had 41 plants at this time. This is a very high number given the size of the industry relative to other countries. Most of these processors are very small and/or produce several other products. Brazil had 12 processors, while Chile had 10. The South American total for this time period was 63 (Moulton et al., 1994).

The remaining data for this study are reported for 1994; this is the representative year chosen for the analyses that follow.

Price data come from several sources. For the US one source gave a paste price of $909/MT (ERS, 1996). Another listed a California price of $856/MT (JICA, 1996). (Note that some prices have been converted into 1994 prices using IMF inflation and exchange rates.) The simple average of the two US prices is $882.50/MT. The price for tomato paste in Argentina was $986/MT (JICA, 1996). In Brazil, a higher price is given of $1041/MT (Moulton and Garoyan, 1991). Finally, for Chile the reported price is $804/MT. This is the lowest price of all locations; however, for South America, a weighted average of prices is $889.68. This is just slightly higher than the average used for the US. The price ratio, with South America on the
top, is 1.008. Since Chile is the biggest competitor of California, it is useful to know that the price ratio for these two locations is 0.9110.

To calculate initial values for the trade costs factors, the $t$'s, the trade costs were added to the originating country’s price; this total was then divided by the price. Trade cost factors were calculated for all three South American countries individually. For Argentina, a $t$ of 1.422 was derived for tomato paste. Brazil has a value of 1.532. Chile’s trade factor is 1.427. The weighted average of the three is 1.465. Specific trade costs are detailed in the cost comparison section of Chapter 2. Specific information on trade costs for tomatoes proved extremely difficult to obtain since virtually no fresh processing tomatoes were shipped between the US and these three South American countries. Given information on shipping costs for similar products, I believe it is safe to use a trade cost factor of 1.9 on tomatoes; that is, trade costs almost double the price of a tomato that arrives in the US from South America, and vice versa.

Calculating the demand elasticities can be approached in several different ways, but each method boils down to a ratio of the variable portion of the cost to the fixed portion of the cost, based on price equal to average cost (see Chapter 4). Recall from Chapter 4 the explanation provided for calculating these elasticities. Comparing these elasticities with positivistic estimates from other studies is not very useful because other studies treat these products as a whole. This study is assuming that there are many horizontally differentiated
varieties so that many imperfect substitutes exist within each product category. Cost comparisons are detailed Chapter 2.

For the US, two sources were available for cost data on processing tomatoes. One source gave variable costs of $28.96/MT and fixed costs of $12.41/MT (Le Strange et al., 1992). Another source listed these costs as $42.12 and $18.05/MT (Cook et al., 1991). These result in an average demand elasticity of 3.33 for the US. The breakdown of costs for Argentina was $57.72/MT for variable costs and $16.28 for fixed costs (JICA, 1996). The resulting demand elasticity is 4.55.

In Brazil, three sets of cost data were available. One set gave variable costs of $96.76 and fixed costs of $17.08, resulting in a demand elasticity of 6.67 (Moulton and Garoyan, 1991). The second data set had variable costs at $135.81 and fixed costs at $25.75 for an elasticity of 6.27 (Moulton and Garoyan, 1991). The third set reported variable costs of $82.56 and fixed costs of $21.55 which resulted in an elasticity of 4.83 (IEA, 1996). A simple average of the three gives an elasticity of 5.92.

Estimates given for Chile have variable costs of $49.36/MT. The fixed costs are estimated to be $6.90/MT (Moulton and Garoyan, 1991). The demand elasticity calculated from these figures is 8.15. Taking a weighted average of the four countries yields a demand elasticity of 5.580 for processing tomatoes.
For tomato paste, again a cost comparison is done in the section that follows. Low and high cost estimates are given for California processing. Variable costs are $614.5/MT and $760.2/MT respectively. Fixed costs are $193.2/MT and $213.3/MT (Moulton and Garoyan, 1991). The average demand elasticity resulting from these estimates is 4.37.

Two estimates are available for Argentina, as well. The first sets variable costs at $754.5/MT with fixed costs of $104.5/MT (JICA, 1996). This results in an elasticity of 8.22. The second data set gives variable costs of $837/MT and fixed costs of $119/MT for an elasticity of 8.03 (Moulton and Garoyan, 1991). The simple average of the two elasticities is 8.125.

For Brazil, variable costs are estimated to be $696.81/MT. Fixed costs are $218.84/MT (Moulton and Garoyan, 1991). The resulting elasticity is 4.18. The Chilean processing industry has variable costs of $454.17/MT and fixed costs of $265.60/MT. The elasticity for Chile is 2.71. The weighted elasticity for all four countries is 4.067.

Finally, a calculation of the labor share of production is required. First, an assessment was needed of production of tomatoes and paste. In this case, tomato production was calculated backward from paste production using the appropriate conversion ratios (See Moulton et al., 1994). US production of tomato paste in 1994 was 1.112 million MT. Of that amount, 1043 MT was exported to South America - a very trivial amount. Processing tomato
production devoted to tomato paste is estimated to have been 6.005 million MT (FAS and NTDB). Virtually all was used within the US.

In the South American countries, paste production totaled 141,064 MT for 1994. Of that 2064 MT were produced in Argentina (Condiciones de Rentabilidad, 1996); Brazil produced 56,000 MT (FAS); Chile's share was 83,000 MT (FAS). Derived tomato production is as follows: Argentina - 14,448 MT, Brazil - 375,200 MT, Chile - 481,400 MT. These three countries sent a total of 6386 MT of tomato paste to the US, the vast majority of that coming from Chile. Domestic consumption accounts for all production except that shipped from South America to the US, or vice versa.

Based on the verbal description of $\mu$ provided in Chapter 4, the labor share for US (California) tomato paste production was 0.6200. The shares for Argentina, Brazil and Chile were 0.3468, 0.5618, and 0.6249, respectively. A weighted average for the four countries is 0.6149.

While I ultimately end up calculating values of the wage ratio and paste expenditure ratio based on all other initial data values (paste price ratio inclusive), it helps to have real values of these parameters for comparison purposes. A wage ratio, $\omega$, can be calculated using gross domestic product per capita. Using IMF data, the US figure is $26,608. Argentina has a per capita GDP of $8206. Brazil's GDP per capita is $5463. The Chilean figure is $3732. Taking a weighted average of the three South American countries, based on paste production, the wage ratio is 0.1642.
Recall from Chapter 4 that the wage ratio is used as the primary product’s price ratio. Labor is assumed to be the only input for the primary product. Looking at the cost comparisons for tomato production in Chapter 2, however, it is immediately obvious that in reality many inputs besides labor go into the production of processing tomatoes. Given this, the weighted price ratio or weighted average cost ratio would be more useful for comparison with the parameter that is calculated by the model. (Recall the assumption that price is equal to average cost in this model.) The weighted price ratio using all three South American countries is 0.9300; the ratio of Chile to the US is 0.8352. Using the cost ratio results in a number greater than one. The ratio including Argentina, Brazil and Chile versus the US is 1.7703, and using just Chile is 1.2796. The price ratios seem to be the most realistic for comparison purposes. Implicit in using these ratios is that the relative costs of the inputs for the raw product are exogenous. While this might seem to be unreasonable at first, it is merely stating that the inputs, if not used for tomatoes or oranges, would certainly be used for something else so that cost ratios are unaffected.

Expenditure on tomato paste in the US totaled $988.2 million in 1994. In South America, expenditure was $121.2 million. The resulting expenditure ratio, with the South American figure in the numerator, is 0.1226. This is a very low expenditure ratio; South American consumption, including exports to countries other than the US, is only 12% of American consumption. Obviously, looking at Chile only, that expenditure ratio is even smaller.
Remember that market potential, or the consumer base, along with the production base, plays an important role in Venables’ model and in location models generally. Such small expenditure ratios will give California producers an advantage considering that they are competitive in price with the South American producers. A strong price advantage in South America theoretically would be able to offset the consumer advantage.

5.B Analysis and Results

Using the parameter values from the previous section, several combinations of countries and values were analyzed in an effort to predict the location of tomato processing in the Western Hemisphere under free trade. The three South American countries included in the study - Argentina, Brazil and Chile - are quite different in their production technologies and capabilities. Chile’s industry closely resembles the Californian industry in technology and costs; however, it is much smaller than the Californian industry. Chile produces in large part for the export market. Argentina and Brazil have much higher costs and less advanced technologies. While their production capabilities could be greatly enhanced, they currently produce primarily for their domestic markets.

For all results reported below, the table headings have the following meanings:

\( t_p \) = trade cost factor for tomato paste, \( t_r \) = trade cost factor for tomatoes, \( p_p \) = price ratio for tomato paste, \( r_f \) = firm ratio for tomato paste, \( p_r \) = price ratio for tomatoes, \( r_f \) = firm ratio for tomatoes. In all cases, California is represented in the denominator.
Given the preceding observations, it was thought best to consider three combinations of countries and/or parameters. The first combination was an analysis of the three South American countries relative to the California industry. The number of South American firms was 63, while the number of Californian firms was 32. The initial trade cost factor for paste was 1.465 with a demand elasticity of 4.067. The initial trade cost factor for tomatoes was 1.9 with a demand elasticity of 5.5802. The labor share of production in paste processing was 0.6149.

The results are provided in Table 5.1. Using the actual paste price ratio, a tomato price ratio of 1.0609 was calculated along with a paste expenditure ratio of 1.4707. The tomato price ratio is not unreasonable compared to the average cost ratio reported in the preceding section, but the paste expenditure ratio is absurdly high. Paste consumption in the three South American countries, including their exports to countries other than the US, is extremely small relative to US consumption. The general trend in the results is overall growth in the ratio of firms in Argentina, Brazil and Chile. The high paste expenditure ratio greatly distorts the results, as does the large number of firms. The model assumes that all firms are the same size.
For this combination and the combinations which follow, it was possible to get the model to produce results using the actual wage and paste expenditure ratios reported in the preceding section. The results proved to be relatively meaningless. The scenario under current trade costs resulted in a negative number of paste-processing firms in California with the tomato grower ratio approaching zero with mixed signs.

The second case that was considered was a direct comparison of Chile and California. As mentioned previously, the Chilean industry is similar to that of California except for overall size. Chile had 10 paste processing firms compared to California’s 32. The trade cost factor for paste was 1.4270, while the trade cost factor for tomatoes was 1.9, initially. The demand elasticities for paste and tomatoes were 3.54 and 5.74,
respectively. The labor share of production was estimated to be 0.6225. The elasticities and labor share were calculated by taking the simple average of the Chilean and Californian figures.

The results for this scenario are presented in Table 5.2. The initial paste price ratio of 0.9113 yielded a tomato price ratio of 0.8399 and a paste expenditure ratio of 0.3775. The tomato price ratio is reasonable compared to the price ratio in the preceding section, although the paste expenditure ratio is very high relative to real figures. This expenditure ratio should work in Chile’s favor. Additional support for these results lie in the initial figures for the firm ratios. The firm ratios are reasonable estimates. The results indicate that the industry would agglomerate in California with minimal production occurring in Chile. Chile and California are quite competitive with each other in cost of production; therefore, once again the expenditure ratio plays a greater role in determining location outcome due to such strong similarities in production. If greater disparity existed in the price ratio, the outcome should be quite different.

\[
\begin{array}{cccccc}
\varphi & \nu & \varphi' & \eta_p & \varphi' & \eta' \\
1.427 & 1.9 & 0.9113 & 0.3109 & 0.8399 & 0.3517 \\
1.4 & 1.8 & 0.9204 & 0.2655 & 0.8399 & 0.3034 \\
1.3 & 1.7 & 0.9315 & 0.2176 & 0.8399 & 0.2496 \\
1.2 & 1.6 & 0.9441 & 0.1815 & 0.8399 & 0.2036 \\
1.15 & 1.5 & 0.9535 & 0.1499 & 0.8399 & 0.1644 \\
1.1 & 1.4 & 0.9656 & 0.0966 & 0.8399 & 0.0924 \\
1.05 & 1.4 & 0.9803 & 0.0787 & 0.8399 & 0.0588 \\
1.03 & 1.4 & 0.9875 & 0.0712 & 0.8399 & 0.0449 \\
\end{array}
\]

\[\alpha = 0.3775\]

Table 5.2: Tomato paste results with Chile only.

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The third and final scenario considered was to incorporate all of the South American production capacity, but under the assumption that production technologies were like those of Chile. In other words, this case considers the impact not only of Western Hemisphere free trade, but also integration of the South American countries through investment and mergers. The industry in Brazil and Argentina has much room for improvement. With the cooperation that exists among these three countries and with their proximity to one another, it seems likely that great advancements could be made in Brazil and Argentina so that their efficiency in paste and tomato production could be brought more in line with that of Chile.

Tables 5.3 and 5.4 highlight the results for this third scenario with slightly different parameters. Table 5.3 uses 34 as the total number of paste firms in South America. Table 5.4 uses 20 as the total. These reductions from the total actual number are meant to compensate for the unusually high number of firms in Argentina. Recall that Argentina purportedly has 41 paste processing firms. This is a highly inefficient number considering their level of production, and it tends to distort the results due to the assumption that firms are all the same size. For both tables, an initial paste price ratio of 0.9107 is used. For Table 5.3, this results in a tomato price ratio of 0.9169 and a paste expenditure ratio of 0.6460. For Table 5.4, this results in a tomato price ratio of 0.8826 and a paste expenditure ratio of 0.5093. These expenditure ratios are very high compared to the actual figure. The initial trade cost factor for paste was set at 1.465; otherwise, the other parameters are the same as for the second case.
The results for both sets of figures in case three again show an overall decline in the tomato paste industry for South America. For the first set of figures the industry declines to approximately one-fourth the size of the California industry. In the second set of figures, the industry declines to less than 20% of the size of the California industry. This occurs in spite of the artificially high paste expenditure ratios derived from the paste price ratio.

\begin{table}[h]
\centering
\begin{tabular}{llllll}
\hline
$\varphi$  & $t'$  & $\varphi'$ & $r\varphi$ & $\varphi'$ & $r\varphi'$ \\
1.465 & 1.9 & 0.9107 & 1.0669 & 0.9169 & 1.1468 \\
1.4 & 1.8 & 1.0037 & 0.2829 & 0.9169 & 0.2892 \\
1.3 & 1.7 & 0.9805 & 0.3824 & 0.9169 & 0.3982 \\
1.2 & 1.6 & 0.9789 & 0.3817 & 0.9169 & 0.3965 \\
1.15 & 1.5 & 0.9814 & 0.3551 & 0.9169 & 0.3631 \\
1.1 & 1.4 & 0.9854 & 0.3145 & 0.9169 & 0.3085 \\
1.05 & 1.4 & 0.9911 & 0.2906 & 0.9169 & 0.2732 \\
1.05 & 1.3 & 0.9913 & 0.2550 & 0.9169 & 0.2205 \\
\hline
\end{tabular}
\caption{Tomato paste results based on Chile with paste firm ratio of 1.0625.}
\end{table}

\begin{table}[h]
\centering
\begin{tabular}{llllll}
\hline
$\varphi$  & $t'$  & $\varphi'$ & $r\varphi$ & $\varphi'$ & $r\varphi'$ \\
1.465 & 1.9 & 0.9108 & 0.6266 & 0.8826 & 0.6868 \\
1.4 & 1.8 & 0.9621 & 0.2937 & 0.8826 & 0.3164 \\
1.3 & 1.7 & 0.9576 & 0.3057 & 0.8826 & 0.3316 \\
1.2 & 1.6 & 0.9635 & 0.2714 & 0.8826 & 0.2917 \\
1.15 & 1.5 & 0.9691 & 0.2365 & 0.8826 & 0.2485 \\
1.1 & 1.4 & 0.9765 & 0.1923 & 0.8826 & 0.1882 \\
1.05 & 1.4 & 0.9862 & 0.1681 & 0.8826 & 0.1496 \\
\hline
\end{tabular}
\caption{Tomato paste results based on Chile with paste firm ratio of 0.625.}
\end{table}

\( \alpha = 0.6460 \)

\( \alpha = 0.5093 \)

Table 5.3: Tomato paste results based on Chile with paste firm ratio of 1.0625.

Table 5.4 - Tomato paste results based on Chile with paste firm ratio of 0.625.
5.C Conclusions on Tomato Paste

Given the logic of Venables' model and location theory in general, the results reported in the preceding section are not surprising. While basic cost comparisons were not able to provide a clear cut winner, Venables' model strongly favors the Californian industry. The industry in California dwarfs the South American industry. Certainly, attempts could be made to expand production and increase efficiency, particularly in Argentina and Brazil. In fact, one study used in this dissertation research was financed by a Japanese agency exploring ways to increase tomato paste supplies in Argentina for export to Japan (JICA). The results from the Venables model imply that increasing the industry in South America would be uneconomical given the low demand within the region and lack of a cost advantage over California.

Although Chile's industry looks very promising, it was suggested more than once in industry interviews that tomatoes and tomato paste processing were not as profitable as other ventures might be. The opportunity costs are potentially too high for the industry to continue indefinitely. Some representatives contended that Peru would be a better location for increasing tomato production. High value fruits seem to hold more promise for Chilean agriculture based on anecdotal evidence. Additionally, many of the laborers in tomato production are already coming from Peru on a seasonal basis.

Even if the US industry could not meet demand, it has neighbors that could and do assist. Both Canada and Mexico have tomato paste industries. Mexico's industry is already competitive with Californian processors, and could be more so with efficiency advancements to bring it in line with California production (Cook et al., 1991). This only
serves to bolster the results indicating further agglomeration in California, since the processing areas in Mexico would be adjacent.

One important point to consider in the preceding analyses is the role of exchange rates. While the model is taking a static view of the industry, fluctuations in exchange rates could drastically affect cost differences in the real world, thereby offsetting the consumption advantage in California. In and around 1994, exchange rates for the countries of concern were behaving in a relatively stable fashion, so the cost ratios provided herein should be reasonably realistic. In recent times, countries with strong Asian ties might have had an exchange rate effect. Brazil would be the most likely of the three to have experienced this; however, it appears to be the least competitive of the three South American countries.

Summing up, the California tomato paste industry should feel relatively secure regarding free trade in the Western Hemisphere under the assumptions maintained in this model. The three South American countries will probably still maintain an industry, but its importance is likely to decline with the advantages from agglomeration going to California. For US purposes, trade barriers could be removed for tomatoes and tomato paste without harming US producers, benefitting consumers from freer trade not only in tomatoes but in other products as well. These results are not inconsistent with results from basic cost comparisons.
CHAPTER 6
COST COMPARISONS FOR ORANGE JUICE

The next product of interest for this dissertation is orange juice. Oranges are the third largest fruit crop in the world in production with approximately 30 MMT (Nagy et al., 1993). While California dominated in the production of oranges for many years in the US, World War II initiated the search for improved juice technology. Upon its development, the citrus industry began to be dominated by Florida as its climate is suitable for juice oranges.

"Today, Florida grows approximately twice as much citrus as California, with about 90% of its fruit going to the processed markets. Florida's hot and humid climate induces thin peels that are easily scarred and develop poor color, and these cosmetic effects generally render Florida fruit inferior in the fresh markets. However, the juice flavor from such fruit is rated as superior. In California, the fresh markets still rule supreme, generating about ten times as much profit for citrus growers as processed fruit. One Florida venture was to initiate a citrus industry in Brazil in order to avoid the economic damage of freezes in Florida. This budding industry was later sold to the Brazilians, who have, in recent times, emerged as a major contender in the international citrus juice market. With a few devastating freezes in Florida, it did not take long for the
Brazilian citrus empire to establish markets in the US and usurp Florida's previous position as king in the citrus industry. Brazil has the largest juice processing plants in the world and is a leader in citrus technology in many areas” (Kimball, 1991, pp.1-2).

Brazilian orange and orange juice production is centered on the state of São Paulo. Almost all orange production is utilized for juice. In 1989/90, there were 10 companies in the São Paulo state producing orange juice (Goncalves, 1991).

According to McClain (1989), US consumers consume approximately 40% of all juices, nectars and non-carbonated drinks, leading the world in per capita consumption. While the US is the second largest producer of oranges (second to Brazil), it is a net importer of juice (Spreen et al., 1991). More than 90% of US imports are supplied by Brazil. Due to the lobbying strength of Florida agriculture, as witnessed in NAFTA and other negotiations, the orange juice market is highly protected.

In the preceding analysis of tomato paste, cost comparisons were done initially to determine if a final outcome could be predicted based on absolute advantage. No clear winner emerged from these cost comparisons. With orange juice, this will not be the case. While the purpose of this dissertation is to determine the future location of orange and orange juice production given free trade between Brazil and the US based on a model of agglomeration, incorporating increasing returns and monopolistic competition, a basic comparison of costs in the two countries can also provide useful information. Economic theory has costs and prices endogenous to the system, so current prices and costs are a snapshot of short-term economic equilibrium at a point in time; nonetheless, it is helpful to see the differences between these two producing nations.
For orange production in Florida, two sources yielded information on costs. First looking at the Farm Bureau report on NAFTA (Cook et al., 1991), the following is obtained:

<table>
<thead>
<tr>
<th>Cultural costs</th>
<th>$2.0822</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picking</td>
<td>0.7457</td>
</tr>
<tr>
<td>Roadsiding</td>
<td>0.7138</td>
</tr>
<tr>
<td><strong>TOTAL VARIABLE COSTS/BOX</strong></td>
<td>3.5417</td>
</tr>
</tbody>
</table>

Table 6.1: Florida orange production costs I.

For total costs, the following were added in: general administrative and overhead costs, management costs, property taxes, interest. This created a total of $4.3210/box. Variable expenses were 81.96%, and fixed costs were 18.04% of the total.
A second estimate was taken from Muraro (1995). The following costs were detailed:

- **Cultural costs and other costs**: $2,274
- **Picking/collecting**: 0.755
- **Load oranges**: 0.728
- **Administrative**: 

  **TOTAL COSTS/BOX**: 3.757

Table 6.2: Florida orange production costs II.

Assuming that fixed costs were included in “other costs”, and assuming the same percentage as that from the Farm Bureau report, fixed costs are calculated to be $0.678/box, with variable costs at $3.079/box. This estimate is used in the calculations in the previous section because it is more recent.

For Brazil, the percentage breakdown of costs is based on a representative grower in São Paulo state: 33.8% of total costs were fixed, with 66.2% variable. Using data from Muraro (1995) the following breakdown is obtained:
### Cultural costs and other costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural costs and other costs</td>
<td>$1.396</td>
</tr>
<tr>
<td>Picking/collecting</td>
<td>0.432</td>
</tr>
<tr>
<td>Loading</td>
<td>0.058</td>
</tr>
<tr>
<td>Administrative</td>
<td>0.190</td>
</tr>
<tr>
<td><strong>TOTAL COSTS/BOX</strong></td>
<td>2.076</td>
</tr>
</tbody>
</table>

Table 6.3: Brazil orange production costs.

With this information, it is estimated that fixed costs in Brazil are $0.7017/box and variable costs are $1.3743/box.

Comparing Florida and Brazil costs, Brazilian producers have lower costs in oranges across the board. In fact, Florida oranges are produced at almost twice the expense of Brazilian oranges. The disparity in costs is not quite so big when costs per pound solid are compared. The quantity of oranges needed for a single strength equivalent gallon of orange juice is dependent upon the pounds solid in the oranges. Florida's costs per pound solid are approximately 1.5 times larger than Brazil's costs. A more detailed cost breakdown in Muraro (1995) shows Florida with an advantage in chemical and fertilizer costs, and Brazil with a major advantage in labor and operating costs. Including trade costs raises the overall cost of Brazilian oranges in the US or of US oranges in Brazil to levels that do not justify trade - whole fresh oranges are practically
nontraded goods. The US has a one cent per pound tariff on fresh oranges, which would add $0.90/box to the price of imported oranges.

One important issue in terms of the Venables model is whether there are increasing returns in the production of oranges and orange juice. The increasing returns assumption seems reasonable in the processing end, as the cost comparisons that follow will show. In production of oranges, however, this assumption might seem inappropriate. While definitive proof either way is not available with the data gathered for this research, some evidence in favor of increasing returns can be found.

First, the existence of fixed costs suggests that average costs would decrease with an increase in production. With available data, one cannot determine exactly how far down growers are on their average cost curves. Looking at changes that have taken place in Florida suggests, however, that average costs would have decreased in the years following the year used for this study - 1994.

In the early 1980’s, Florida suffered some devastating freezes. In response to this, orange production relocated to a more appropriate location where it was less subject to freezing. This relocation occurred from 1985 through 1994. In 1994, Florida had a record number of orange trees, a large portion of which were quite young. As these trees mature, and with the many advances made in orange production technology, Florida orange production is expected to increase dramatically. In addition to increasing yields as the trees age, expected annual losses should also be substantially lower due to the decreased likelihood of freezes (Spreen, 1996). New technological innovations should further reduce average costs; these innovations include better rootstocks, improved
irrigation systems and higher density plantings. All of these points combined provide evidence for increasing returns in orange production, at least for Florida growers.

Calculation of orange juice costs begins with the price of oranges in each location. In Florida, the price of a box of oranges was $3.50. Each box contains 6.5 pounds of solids (ps) (Muraro, 1995); therefore oranges cost $0.5344/ps. For other costs, the fixed/variable percentage breakdown is based on Muraro (1997); 57.0% of costs are considered variable, and 43.0% are fixed. According to Muraro (1995), bulk processing costs are $0.1711/ps, and other domestic costs are $0.0300/ps. Combining the cost of the oranges with these costs results in a variable cost of $0.6490/ps and a fixed cost of $0.0865/ps. A pound solid is equivalent to 0.9191 SSE gallons. Therefore, variable costs are $0.7061/SSE gallon, and fixed costs are $0.0941/SSE gallon.

For Brazil, I estimated that labor costs were half of Florida’s labor costs based on conversations with experts in the field. Excluding oranges, the breakdown of costs is 51.2% variable and 48.8% fixed. The price of a box of oranges was $1.84/box with 6.00 ps/box; hence, the price of oranges was $0.3067/ps. In discussions with industry experts in Brazil, many times it was pointed out that the price per box of oranges received by growers is causing them to operate at a loss, so the cost of oranges for juice processing in Brazil should theoretically be higher than orange prices would indicate. The bulk processing cost was $0.1534/ps, and the domestic costs were $0.0861/ps (Muraro, 1995). This provides a total of $0.4293/ps in variable costs and $0.1169/ps in fixed costs. With a pound solid equivalent to 0.8683 SSE gallons, variable costs are $0.4944/SSE gallon,
and fixed costs are $0.1346/SSE gallon. For orange juice production, Brazil has higher fixed costs, but much lower variable costs resulting in a lower average cost for Brazil.

As with production of processing oranges, some evidence of the plausibility of increasing returns is necessary in the production of orange juice. The best evidence for increasing returns in Florida relates to the decline in production resulting from the freezes. By 1994, the industry had not fully recovered, so orange juice processors would have been operating below capacity. In Brazil, processors have to compete against the fresh market. Due to problems in vertical linkages, processors face the prospect of operating at less than full capacity when they are unable to compete with the fresh price, according to interviews with processors. Exact estimates of installed capacity and operating capacity were not available.

Trade costs in orange juice were a bit easier to locate since so much juice is traded. These costs are presented in terms of the cost of shipping juice from Brazil to the US as is consistent with reality. Specifically, the breakdown is as follows:
Table 6.4: Costs to ship orange juice.

If the US eliminated its tariffs against orange juice, trade costs theoretically could fall by $0.3212/SSE gallon, which is roughly half the price of FCOJ in Brazil. Total trade costs would then fall to $0.1927/SSE gallon making the price of Brazilian FCOJ in the US $0.8900/SSE gallon; this is less than the Florida price of $0.9616/SSE gallon. This results in a seven cent difference, or a 7% difference in price. Based on absolute advantage alone, Brazil has the edge in the production of orange juice for the US. In terms of economies of size, Brazil’s cost figures show fixed costs to be a higher percentage of total costs than Florida’s. Interviews with industry experts in both Brazil
and Florida suggest, though, that Brazil is operating at a lower point on its average cost curve relative to Florida. This indicates that Florida has greater potential gains from an increase in firm size. Brazil is producing more orange juice with fewer plants.

Figure 6.1: Effects of an import tariff under neoclassical assumptions as it pertains to orange juice (Tweeten, 1992, p.80).

Returning to the three-panel diagram from Chapter 3, Figure 6.1 serves as a reminder of what would happen under the traditional assumptions. The graphs are based on the following elasticities: US supply elasticity = 0.5, US demand elasticity = -0.8, Brazil supply elasticity = 0.8, Brazil demand elasticity = -1. The Florida price for 1994 was $0.9616/SSE gallon. If the US tariffs totalled $0.3212/SSE gallon, that would give an effective world price of $0.6404/SSE gallon - Florida’s price less the tariff. If the tariff were removed, equilibrium price would be $0.8900/SSE gallon, Brazilian
production would increase from 1.525 billion SSE gallons to 2.001 billion SSE gallons
and Florida production would decrease from 1.257 billion SSE gallons to 1.210 billion
SSE gallons under these assumptions. The impact on Florida production is quite minimal
- a change of 3.7 percent. This analysis ignores the rest of the world. The question now
is whether the assumptions of the location model will result in the same conclusion that
Brazil has the advantage in juice production.
CHAPTER 7
ORANGE JUICE ANALYSIS AND RESULTS

7.A Parameter Values

In order to calculate parameter values for ω and σ, where the j stands for juice, the following values are necessary: nj, ny, pf, py, ρf, ρy, t0, v, εf, εy, and μ. The o stands for oranges, and the f and b represent Florida and Brazil, respectively.

The numbers of juice processing firms are straightforward. The number of juice processing firms in Florida was 27 (Pollack, 1997). In Brazil, the number was 20 (Amaro, 1996). These numbers are for the year 1994, as are all numbers which follow.

Due to the availability of data, 1994 was chosen as the representative year for this study.

Price data were also relatively easy to obtain. The price of frozen concentrated orange juice (FCOJ) in Florida was $0.9616 per single strength equivalent (SSE) gallon (NASS, 1996). FCOJ is the processed product being analyzed in this study, as it makes up the bulk of orange juice processing and trade, and has commodity-like qualities. The price of FCOJ in Brazil was estimated to be $0.6973/SSE gallon. This estimation was based on the '90 price and was calculated relative to the percentage change in price for Florida. Using these prices, a price ratio of 0.7251 results. (Note that all ratios use Brazilian data in the numerator and Floridian data in the denominator.) Later, in this
section, another price ratio will be calculated according to the ratio of average costs, assuming zero profits in the industry.

To calculate initial values for the trade cost factors, the $t$'s, the differences in prices between the two countries were used, based on the assumption of Dixit-Stiglitz style monopolistic competition of all firms in the study. As such, the following identity holds:

$$ p_1 t_1 = p_f' $$

therefore, $t$ has a value of 1.409. For oranges, the price in Florida was $3.50/box, while the Brazilian price was $1.84/box (NASS, 1996). This results in a $t$ of 1.902. One should expect a much higher $t$ for oranges as the product is much bulkier, and in fact is rarely traded between Brazil and the US.

Calculating the demand elasticities can be approached in several different ways, but each method boils down to a ratio of the variable portion of the cost to the fixed portion of the cost, based on price equal to average cost. Cost comparisons are detailed in the preceding chapter, including the breakdown of variable versus fixed costs. Briefly, for oranges, variable costs in Florida were $3.079/box with fixed costs of $0.678/box. This results in a Florida-specific demand elasticity of 5.547. In Brazil, variable costs are $1.3743/box with fixed costs of $0.7017/box. The Brazil-specific demand elasticity is 2.959. The model calls for a single elasticity for oranges; taking a simple average of the two results in an elasticity of 4.253.

For juice, again a cost comparison is done in the previous chapter. In Florida, the variable cost of juice was estimated to be $0.7061/SSE gallon. The fixed costs were
estimated at $0.0941/SSE gallon. (Note that units are irrelevant in this model; they cancel out in the calculation of these parameters.) The demand elasticity of Florida juice is 8.504. In Brazil, variable costs were $0.4944/SSE gallon, with fixed costs at $0.1346/SSE gallon. This results in an elasticity of 4.673 for Brazil. Again, taking a simple average, the elasticity for the model is 6.585. Based on average costs, the price ratio can be recalculated to be 0.7861. This is the price ratio that is used in the initial parameterization.

Finally, a calculation of the labor share of production is required. First, an assessment was needed of production of oranges and juice. Florida production of oranges in 1994-95 was 10,641,000 MT. Production in Brazil was 15,710,000 MT for the same time period (Spreen, 1996). At 90 pounds per box, this translates to 260.7 million boxes for Florida and 384.8 million boxes for Brazil. Orange production in the US is limited to Florida for this study because almost all oranges in Florida are used for juice production, and almost all US juice production is from Florida oranges. Of this production, only a negligible amount is shipped between the two.

Juice production in Florida was 1257.2 million SSE gallons (FAS). In Brazil, production was 1525.4 million SSE gallons (FAS). It must be noted that total production was used in both countries. Exports were considered to be anything shipped from Florida to Brazil, or vice versa. Domestic consumption was assumed to be the remainder, thus, including exports to any other country. This was particularly important in the case of Brazil, where domestic consumption is quite low. To exclude production for exports would make Brazil’s production appear to be extremely low; the exporting companies can
be considered to be domestic consumers of the products. Brazil exports predominantly to Europe. Including European consumption within Brazilian consumption seemed most appropriate given the limitations of the model. Europe does not have the ability to produce orange juice in such large quantities, so it is a consumer and not a producer. Floridian exports to Brazil were 15,685 SSE gallons; Brazilian exports to Florida were 120,705,573 SSE gallons; this amounts to approximately 8% of Brazil's total production of orange juice.

Based on the verbal description of $\mu$ provided in Chapter Three, the labor share for Florida orange juice was 0.3945, while the share for Brazil was 0.5481. Taking a simple average results in a share of 0.4713.

While I ultimately end up calculating values of the wage ratio and juice expenditure ratio based on all other initial data values (juice price ratio inclusive), it helps to have real values of these parameters for comparison purposes. The wage ratio, $\omega$, was calculated using gross domestic product per capita. Using IMF data, the Brazilian figure is $5463.21 per capita. For the US, the figure is $26,608.23 per capita. The resulting ratio is 0.2053. Basing the ratio on labor costs per box of oranges, the ratio is 0.1837 (Muraro, 1995). As with tomato paste, oranges have many inputs besides labor, so the orange price ratio or cost ratio was far better suited for comparison purposes. The price ratio for oranges is 0.5257; the cost ratio is 0.5526. Both of these ratios are much higher than the actual wage ratio, and would be higher still with pounds solid taken into account.

The juice expenditure ratio, based on the above-mentioned prices, trade costs, and production values, is 0.7379. Recall that the juice expenditure ratio is the ratio of
Brazilian expenditure (including its exports to countries other than the US) on orange juice to US expenditure on orange juice.

7.B Analysis and Results

Using the parameter values from the previous section, various analyses were done in an effort to predict the location of orange juice processing in the Western Hemisphere under free trade. Analysis required use of calculated parameters for the orange price ratio and the juice expenditure ratio. Attempts were made to use the actual wage and juice expenditure ratios, and also the actual orange price and cost ratios with the juice expenditure ratios. The model, however, is limited in what combinations of parameters will allow it to converge; thus, these attempts were unsuccessful.

As an alternative, the actual juice cost ratio was used to derive estimates of the orange price and juice expenditure ratios. Using the juice cost ratio of 0.7860, the orange price ratio was calculated to be 0.7743, and the juice expenditure ratio was calculated to be 0.2160. These ratios are quite different from actual ratios; although, the juice expenditure ratio is of greater concern. The orange price ratio is somewhat higher than the actual ratio. As stated previously, however, Brazilian orange growers appear to have been operating at a loss so that the actual price ratio should probably be higher than the ~0.55 reported. The juice expenditure ratio is much lower than the actual ratio. Nonetheless, these parameters yielded initial firm ratios for both oranges and juice that were realistic.
Many other parameters were necessary for the calculation of price and firm ratios with the decline in trade costs. The numbers of juice processors in Brazil and Florida were 20 and 27. The initial trade cost factor used was 1.409 for juice and 1.902 for oranges. Elasticities were calculated to be 6.585 for juice and 4.253 for oranges. The labor share of production in juice production was estimated to be 0.4713. The preceding section contains details of how these numbers were determined.

Table 7.1 reports the price and firm ratios as trade costs decline. For Tables 7.1-7.3, symbol definitions are as follows: \( \psi \) = trade cost factor for juice, \( \rho_o \) = trade cost factor for oranges, \( \rho_j \) = price ratio for juice, \( \eta_j \) = firm ratio for juice, \( \rho_o \) = price ratio for oranges, \( \eta_o \) = firm ratio for oranges. Brazil is always represented in the numerator. Note that the price ratio remains constant for oranges; this is an assumption of the model - that the wage ratio is exogenous.

The initial trade costs show Brazil with roughly three-fourths as many juice processors as Florida and with more orange growers than Florida; this is realistic given the actual data values for these ratios. As the trade costs decline just slightly to a trade cost factor of 1.3 for juice and 1.8 for oranges, a dramatic change takes place in firm ratios. The number of juice processors in Brazil falls to 30% that of Florida. The proportion for growers drops to 40% of Florida’s. As trade costs continue to drop, these ratios continue their decline. The price ratio for juice steadily approaches one, as would be expected with freer trade.

Reducing the trade cost factor for the raw product might seem to be pointless considering that trade of the first-stage product is unlikely to occur for processing.
regardless of unnatural trade barriers. The primary reason for reducing this factor along with the processed good’s trade cost factor is for ease in convergence. Doing so does not seem to inappropriately manipulate the results. The last five rows of Table 7.1 show that holding the raw product trade cost factor at 1.4 while continuing to reduce the processed good’s trade cost factor still results in a downward trend in firm ratios for both the raw product and the finished good.

<table>
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<th>( u )</th>
<th>( t^o )</th>
<th>( \rho )</th>
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\( \sigma = 0.2160 \)

Table 7.1: Orange juice results with juice price ratio = 0.7860.

Additional sensitivity analyses were done in an effort to raise the juice expenditure ratio and lower the orange price ratio. These parameters were most sensitive to the juice price ratio, but changes in this ratio move both parameters in the same direction. (See Appendix C for insight as to how these numbers respond to changes in
other data values.) Since the orange price ratio used in the above analysis is not as inconsistent with the data, efforts were focused on raising the juice expenditure ratio.

Table 7.2 shows the results from arbitrarily setting the initial juice price ratio at 0.8505 in an effort to raise the juice expenditure ratio. An orange price ratio of 0.9066 and a juice expenditure ratio of 0.6165 were derived from initial calculations. The initial firm ratios for juice and oranges show Brazil having more of both compared to Florida. As trade costs decrease, the general trend is a reduction in these ratios leading to greater numbers of both in Florida. The industries do not decline as much as in the first analysis.

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\( \sigma = 0.6165 \)

Table 7.2: Orange juice results with juice price ratio = 0.8505.

Table 7.3 utilizes an even higher initial juice price ratio of 0.9875. This ratio results in an orange price ratio of 0.9509 and a juice expenditure ratio of 0.7613. The juice expenditure ratio is more closely aligned with the actual juice expenditure ratio,
treating Brazilian exports to countries other than the US as domestic consumption. The initial juice firm ratio is realistic. The initial orange firm ratio is low, but appropriate measures for this were hard to find. As in the preceding cases, the general trend for firm ratios in both the raw and processed sectors is a decrease. The downward trend is not as dramatic as in the other cases, however. The Brazilian industry settles at approximately two-thirds the size of the Floridian industry. The juice price ratio again approaches one.

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$\sigma = 0.7613$

Table 7.3: Orange juice results with juice price ratio = 0.9875.

8.C Conclusions on Orange Juice

Of the two industries studied in this dissertation, the results for the orange juice industry seem surprising given the cost advantage that exists for Brazil along with its relatively high juice expenditure ratio. The US consumes large quantities of orange juice, and having an orange juice industry here appears to maximize the benefits of
agglomeration based on the model. While Brazil did have a slight cost advantage under free trade, remember that it was an advantage amounting to only 7% of the total cost.

The latter results generally show just a slight readjustment of the industry toward Florida when using higher juice expenditure ratios. While the tables show trade costs for the processed good virtually disappearing, in reality the actual costs of shipping would still exist. By locating enough of the industry in Florida to securely meet the new level of US demand, transportation costs would be minimized for the industry. Demand in the US will be greater after the relocation of the industry since prices will be lower in the US. Consumers will demand more of each variety. This means that the US firms will be producing lower on their average cost curves. The absolute advantage that Brazil has does not appear to be large enough to override the benefits of agglomeration predicted by the model using the parameter values stated with each analysis.

While the results do not correspond with those suggested by Figure 6.1, the second and third sets of results show relatively small adjustments in favor of Florida. Recall that Figure 6.1 also showed a small adjustment for the Florida industry, but in favor of Brazil. Combining the results of these two types of analyses would suggest that the impact on Florida's orange juice industry would be minimal with the removal of tariffs.

Several points of concern exist with these results however. The first is Florida's ability to maintain a steady supply of oranges. Orange production has suffered in the recent past from severe cold and other adverse growing conditions. Production has shifted southward and has recovered markedly from these losses; however, land use will
increasingly become an issue in Florida. Certainly, orange juice processors in Florida could not afford to ship oranges from Brazil. Fortunately, expansion of orange production could take place in the vicinity of Florida, providing a nearby source of oranges if necessary. Mexico has room for expansion of orange production with the proper incentives. In fact, production of oranges along the Gulf Coast has increased in recent years (Farm Bureau, 1991). With freer trade between the US and NAFTA, Mexico could become a supplier for the Florida juice industry. Of course, this brings up the question of whether the juice industry would relocate to Mexico; Brazil is the concern here, though.

The second point of concern is the diminishing of the Brazilian industry predicted by the results. The interpretation I give to the results combined with Figure 6.1 would focus mainly on the security of the US industry. The benefits of agglomeration and the strength of the consumer base in the US appear to ensure the longevity of the US industry under freer trade in the Western Hemisphere. What the model, and therefore the results, leaves out is the importance of the European orange juice market. The ability of the US industry to approach self-sufficiency in orange juice depends upon weather and market conditions. Florida processors do not have the capability to supply the rest of the world; they just approach self-sufficiency. Additionally, off years occur such that another source of FCOJ is necessary to maintain a steady supply for the US market; Brazilian producers need a backup supply as well in the event of a catastrophic year. Finally, even in ideal years, blending of concentrates is vital to achieving the appropriate sugar-to-acid ratio for consumer preferences.
The point of the preceding paragraph is that, despite the predictions of the results, the Brazilian industry is most likely safe under Western Hemisphere free trade. Brazilian firms produce FCOJ primarily for the export market to Europe. The US is unable to meet this additional demand. Brazil has room for expansion in the production of oranges. Furthermore, while domestic consumption currently is quite low relative to the US, demand within Brazil and within South America could increase dramatically as the region develops. Currently, Brazilian consumers tend to squeeze their own oranges for juice; convenience foods could become more attractive as per capita incomes rise. Anyway, the results for orange juice do not show the industry completely vacating Brazil; the industry just shifts partially toward Florida as trade costs decrease and the juice price ratio converges toward one. As was the case for tomato paste, the US appears able to remove trade barriers on processing oranges and orange juice with benefits from agglomeration economies to US consumers and perhaps to US producers.

The above-mentioned criticisms pertain to the results as obtained from the three analyses. These analyses are only as valid as the parameter values used in them. As stated earlier, Venables’ model works well with carefully selected parameter values. Using real data can be problematic. The parameter values used in the tomato paste analyses appear to work quite nicely. The orange juice parameter values did not work as well.

The most important point, then, is that while the various attempts to analyze this industry come close to correctly portraying the baseline scenario for 1994, it was impossible to obtain a realistic combination of values for the orange price ratio and juice
expenditure ratio concurrently. As stated previously, to accurately portray the real world situation, these two ratios needed to be moved in opposite directions. Appendix C highlights the effects of various parameter changes on these ratios. While theoretically some combination of changes could have resulted in the desired ratio values, only a change in the juice price ratio resulted in meaningful changes in these ratios. In an effort to avoid too much data manipulation, I was forced to use either a combination of a realistic orange price ratio and a low juice expenditure ratio, or a high orange price ratio and a more realistic juice expenditure ratio. Either combination provides Florida with an advantage. In the first case, they have a strong consumer advantage that overwhelms the Brazilian cost advantage. In the second case, their consumer advantage is somewhat decreased, but they are shown to be more cost competitive in the production of the raw good. In reality, the Brazilian industry should show a cost advantage coupled with a small disadvantage on the consumption side. The ability to replicate this would provide far more believable results. These results could be drastically different from the results provided above.

Additionally, since all firms are assumed to be the same size, Florida is given an advantage in the number of firms. This is a small problem relative to problems with the other parameters. Were the other parameters more realistic, it would be useful to adjust firm numbers a bit to see how the model reacts.

Support for the results obtained above does exist. In Spreen, Muraro, and Fairchild (1991) and in Spreen (1996), analyses done on the orange juice industry provide results suggesting that the removal of tariffs on orange juice in the US would have little
effect on the Florida industry. These authors used a much different methodology with
different assumptions; they were examining a gradual phase-out of tariffs. Taking into
account expectations of dramatic increases in Florida orange production for the next
several years, they concluded that by the time tariffs were eliminated, Florida would have
reached the point of being a net exporter. The effects of tariff protection would already
have been minimized as a result of its exposure to the world market.

Suffice it to say, the orange juice results have limitations. Strong policy
conclusions are unwarranted without refinement of the model and data beyond the scope
of this study. However, agglomeration economies appear to enable the Florida industry
to survive with free trade. The world probably benefits from having the insurance of at
least two major producers of orange juice. Florida and São Paulo combined produced
over 80 percent of the world orange juice supply in 1994-95 (Spreen, 1996). Brazil is
capable of having “off” years as well as Florida.
CHAPTER 8

GENERAL CONCLUSIONS
AND COMMENTS ON THE MODEL

8.A Observations on the Model

As stated in the introduction to Chapter 4, applying Venables’ model to a real-world scenario provided a valuable perspective to the innerworkings of the system. The primary observation made in these analyses is the sensitivity of the partial equilibrium equation to the wage ratio and processed product expenditure ratio. The behavior of the processed product price ratio is highly dependent upon these ratios.

For tomato paste, South American expenditure is quite low compared to the US. This is the case even with exports to third parties included. For the year of interest, and in general, Argentina and Brazil produced paste primarily for their domestic markets. These markets are quite small relative to the US. While Chile produced paste more for the export market, it still is a relatively small producer compared to the US. In parameterizing the value of the paste expenditure ratio for various trade scenarios, a higher ratio was derived than actual data would suggest. This would work in favor of the South American countries given the workings of the model. Even so, the assumed boost in expenditure within these countries did not protect their production share in the face of
freer trade. The South American countries would need to have a strong cost advantage to gain the agglomeration benefits with freer trade.

In the case of orange juice, the US again has the advantage with the expenditure ratio for juice. This time, Brazil has a production advantage. As discussed in the conclusions of Chapter 7, however, attempts to use realistic parameter values resulted in lack of convergence in the model. In attempting to manipulate the above two parameters, other parameters were altered. The model is not nearly as sensitive to such things as firm numbers and demand elasticities as it is to the price and expenditure ratios. This leads to a discussion of the intuition of the model based on the results herein.

Referring once more back to Chapter 2 and Chapter 6, one may recall that cost comparisons suggest certain outcomes, at least for orange juice. Certainly in the case of orange juice, the analysis of costs in the US and Brazil shows Brazil having the advantage in orange juice production. Figure 6.1 further reinforces this. With the elimination of tariffs, Brazil could supply the US at a lower price than Florida, although only 7% lower. The case for tomato paste was not clear, however.

In a world where comparative advantage is the main determinant of production location, the analysis could have ended with the conclusion of Chapter 6 for orange juice (additional analysis was necessary for the tomato paste industry), but the assumptions underlying comparative advantage are not the assumptions being made in this dissertation. The model assumes increasing returns to scale, monopolistic competition among firms, free entry and exit, and consumers’ desire for variety.
"In a world characterized by increasing returns and by transportation costs, there will obviously be an incentive to concentrate production of a good near its largest market, even if there is demand for the good elsewhere. The reason is simply that by concentrating production in one place one can realize the scale economies, while by locating near the larger market, one minimizes transportation costs. This point - which is more often emphasized in location theory than in trade theory - is the basis for the common argument that countries will tend to export those kinds of products for which they have relatively large domestic demand" (Krugman, 1990, p.30). Keeping this in mind, the results obtained for tomato paste are certainly credible.

A key factor that Krugman does not address in the above quote and in his discussion of location theory generally is the relative costs of shipping the various stages of production. In particular, if the cost of shipping the raw product is so much more expensive than shipping the processed product, then processing will take place where production of the raw product occurs regardless of where consumption takes place. With orange juice and tomato paste, it is the case that the costs of shipping the raw product are prohibitively expensive. Very little trade takes place between the US and its South American counterparts in processing oranges and processing tomatoes. The locations chosen for this study are major players in the production of both the raw products and the processed products. If they were not, tomato paste and orange juice processing would not suddenly move to these locations just because a large consumer base existed there. If the result had been obtained indicating transport of the raw product would take place, that would automatically have rendered the result to be not credible for these products.
The country with the larger consumer base will have an advantage in a world based on the assumptions of the Venables model, assuming the countries being compared have equal production capabilities. As trade costs are reduced, the industry will have increased incentive to take advantage of the increasing returns due to agglomeration economies. As an industry grows in one location, the average costs of production will decrease. The consumers in the country where the industry is located will gain utility by having more varieties available to them at the lower cost, since price equals average cost. Note that the results of the model report only firm ratios, not actual firm numbers. The price of the goods will be lowered as agglomeration economies result for the industry. The demand curve will shift as demand elasticities incorporate the new fixed/variable cost ratios. Since a customer in the US will have more varieties available at the local price, that customer will be able to demand more of each variety. This results in a production increase for each firm allowing that firm to produce at a lower point on its average cost curve. This demonstrates the incorporation of agglomeration economies internal to the firm. Since this comes about as a result of several firms choosing that location, the overall lower transportation costs that ensue demonstrate agglomeration economies external to the individual firm but internal to the industry or intra-industry economies. The effect on both the upstream and downstream sectors demonstrates inter-industry agglomeration economies. The vertically linked industries minimize already lower transportation costs by exporting to the other location with the smaller consumption base.
It is interesting to note that regardless of who gains in a particular industry, costs/prices should decrease in both locations with a reduction in tariffs. Assuming overall expenditure remains the same for a particular country, if the average price for a good decreases due to a reduction in trade costs (the average being based on domestic purchases and imports), then consumers will be able to buy more of each variety. This alone allows each firm to move further down its average cost curve regardless of location, further reducing the price for the good. In terms of iceberg transport costs, more of the imported good arrives - less melts away during transport.

Why would the industry exist in both locations to begin with? The agglomeration advantages are offset initially by the higher transportation costs and the consumers' desire for a variety of products. With transportation costs low enough, the industry can afford to ship a larger variety of products to the other location while taking advantage of the reduced costs of producing in one cluster near the larger consumer base.

This does correspond to what is witnessed currently. The US has an enormous economy; it is the largest producer and consumer in the world. The percentage of production that is exported, and the percentage of consumption that is imported is quite small relative to other countries, particularly developing countries. The US is a relatively open market, so trade barriers are not severely impeding the flow of goods. Production and trade patterns witnessed here in the US could be attributed in part to of an enormous consumption base creating agglomeration economies by producing here.

What is required to obtain the result that Brazil would produce orange juice and South America would produce tomato paste? Within the Venables model, a strong
production/cost advantage would have to exist for the southern countries. In the case of orange juice, Brazil does have a slight advantage; however, getting the model to accommodate the most realistic set of parameter values was not possible. While the results can still be justified, they are not as convincing as they could be due to the parameter values used. Additionally, if location were ignored, Brazil would gain the orange juice industry. Ignoring location would eliminate the importance of the location of the consumer base. The whole purpose of using Venables' model is to combine demand location with production capabilities and transportation costs.

Other limitations exist in the model that have not been discussed. They relate to the simplifying assumptions of the model. Perhaps the biggest limitation relates to symmetry. Firms in both countries are assumed to face identical elasticities and labor shares of production. They are all assumed to be the same size and to face the same trade costs. Additionally, no allowance is made for third countries or the rest of the world, and the possibility of a consumer market for the raw product is not permitted.

8.B Conclusions Based on Results

The findings reported in Chapter 5 and Chapter 7 suggest that the US tomato paste and orange juice industries will be retained in the face of freer trade within the Western Hemisphere. Orange juice results are least reliable, however. While the results presented here might at first seem counterintuitive based on conventional thinking, when one uses assumptions other than those for comparative advantage these results can be rationalized to some extent. Certainly, the results of the analysis on tomato paste are
credible given that the cost ratio for tomato paste was quite close to one. The results for orange juice conflict with the results based on a simple cost comparison; however, Brazil’s advantage was minimal, and the three panel diagram showed insubstantial effects for the Florida industry given a reduction in tariffs. The results provided using Venables’ model show that the potential agglomeration economies might be large enough to outweigh Brazil’s slight cost advantage; although, realistically these results should be considered inconclusive due to parameter limitations.

In the tradition of comparative advantage the US and other Western Hemisphere countries would produce and trade to take advantage of their differences. Comparative advantage analyses rely on the assumptions of constant returns to scale and perfect competition. The model used in this dissertation emphasizes increasing returns to scale and monopolistic competition. These assumptions can be justified with the products analyzed here. Of course, each of the assumptions used in this model are subject to challenge, as well. Definitive proof is not offered here as to what set of assumptions is more appropriate; valid arguments can be offered for either approach. In fact, comparative advantage and location theory are just a subset of the possibilities available for analysis.

The model does not perfectly correspond to the tomato paste and orange juice industries. Neither would a model utilizing perfect competition or any other set of assumptions. That is the nature of modelling - it is a simplification of the real world used to further one’s understanding of various relationships. Nonetheless, if one takes the assumptions of Krugman and Venables as valid and applicable to orange juice and tomato
paste, the results herein are what is obtained given limitations on parameter values. As noted below, refinement of the assumptions and models with better data, over time, will provide improved predictions of outcomes and more plausible results.

8.C Suggestions for Further Research

Possible extensions to this research are numerous. Attempts to make the model more accommodating of various parameter value combinations would certainly be helpful. The lack of a strong conclusion on orange juice is disappointing.

Certainly many other products would be interesting to analyze given sufficient data. Analysis that involves products and countries where the processed product expenditure ratios are closer to one would be interesting to examine. Products produced and consumed in both the US and Europe would most likely meet this need.

One extension that would have been extremely useful in the case of orange juice is incorporating a third party that does not produce but consumes, as in the case of orange juice and Europe. History matters in determining where agglomeration is going to take place. Agglomeration theory might suggest that the orange juice industry should relocate from Brazil to Europe, but the production capability for oranges does not exist there.

Another extension to the model that would be useful is to make it dynamic. It is difficult to picture the shifting of an entire industry to one location. Accounting for this change over time would lend credibility to the results.
APPENDIX A

MATHEMATICS OF THE MODEL

A.1 Term Definitions

\( e_i^k \) expenditure at location \( i \) on industry \( k \)'s output

\( x_{ij}^k \) quantity of industry \( k \) output produced in \( i \) and sold in \( j \)

\( p_i^k \) price of product from industry \( k \) produced in \( I \)

\( e^k, e^k > 1 \) elasticity of demand for a single industry

\( p_i^k t_i^k, t_i^k > 1 \) effective price of good exported from \( i \)

\( P_i \) price index at location \( i \)

\( n_i^k \) number of firms of industry \( k \) in location \( i \)

\( \pi_i^k \) profits of a single firm located in \( i \)

\( c_i^k \) marginal cost

\( c_i^k f_i^k \) fixed cost

\( 1 / z_i^k \) demand for a single variety at home location per unit expenditure

\( \rho^k \) relative costs of suppliers in both locations

\( \phi^k \) break-even output level

\( \sigma^k \) location 2 expenditure relative to 1 in industry \( k \)
\( \kappa \) some positive constant

\( w^i \) wage at location \( i \)

\( \omega \) relative wages

\( \mu \) labor share of production

A.2 Model Mathematics

demand equations

\[
x_n^k = (p_i^k)^{1-\epsilon} (p_i^k)^{\epsilon-1} e_i^k
\]

\[
x_y^k = (p_i^k t^k)^{1-\epsilon} (p_i^k)^{\epsilon-1} e_i^k
\]

\( i \neq j \)

price indices

\[
(p_i^k)^{1-\epsilon} = (p_1^k)^{1-\epsilon} n_1^k + (p_2^k t^k)^{1-\epsilon} n_2^k
\]

\[
(p_1^k)^{1-\epsilon} = (p_1^k t^k)^{1-\epsilon} n_1^k + (p_2^k)^{1-\epsilon} n_2^k
\]

\[
x_{11}^k = \frac{(p_i^k)^{1-\epsilon} e_i^k}{(p_1^k)^{1-\epsilon} n_1^k + (p_2^k t^k)^{1-\epsilon} n_2^k}
\]

\[
\Rightarrow x_{12}^k = \frac{(p_1^k t^k)^{1-\epsilon} e_i^k}{(p_1^k t^k)^{1-\epsilon} n_1^k + (p_2^k)^{1-\epsilon} n_2^k}
\]

\[
dn_i^k = -dn_2^k > 0 \Rightarrow \frac{d(P_i^k)}{dP_2^k} < 0
\]

profit equation

\[
\pi_i^k = (p_i^k - c_i^k)(x_u^k + x_y^k) - c_i^k f^k
\]

\[
\frac{\partial \pi}{\partial p_i^k} = 0 = x_u^k \frac{\partial x_u^k}{\partial p_i^k} + x_y^k \frac{\partial x_y^k}{\partial p_i^k}
\]

\[
\frac{\partial \pi}{\partial c_i^k} = -x_u^k - x_y^k - f^k = 0
\]
\[ p_i^k \left( 1 - \frac{1}{\varepsilon^k} \right) = c_i^k \]

\[ x_{ii}^k \frac{\partial x_{ii}^k}{\partial p_i^k} + x_{ij}^k \frac{\partial x_{ij}^k}{\partial p_i^k} = -x_{ii}^k - x_{ij}^k - f^k \]

\[ \left( \frac{\partial x_{ii}^k}{\partial p_i^k} + 1 \right) x_{ii}^k + \left( \frac{\partial x_{ij}^k}{\partial p_i^k} + 1 \right) x_{ij}^k = -f^k \]

\[ 0 = \left( p_i^k - p_i^k \left( 1 - \frac{1}{\varepsilon^k} \right) \right) (x_{ii}^k + x_{ij}^k) - p_i^k \left( 1 - \frac{1}{\varepsilon^k} \right) f^k \]

\[ 0 = p_i^k \left( \frac{1}{\varepsilon^k} \right) (x_{ii}^k + x_{ij}^k) - p_i^k \left( 1 - \frac{1}{\varepsilon^k} \right) f^k \]

\[ \left( 1 - \frac{1}{\varepsilon^k} \right) f^k = \frac{1}{\varepsilon^k} (x_{ii}^k + x_{ij}^k) \]

\[ \frac{\varepsilon^k - 1}{\varepsilon^k} f^k = \frac{1}{\varepsilon^k} (x_{ii}^k + x_{ij}^k) \]

\[ f^k (\varepsilon^k - 1) = x_{ii}^k + x_{ij}^k \]

Define

\[ z_i^k = (p_i^k)^{\phi^k} (p_i^k) \]

\[ \rho^k = c_2^k / c_1^k = p_2^k / p_1^k \]

\[ \frac{e_1^k}{z_1^k} + \frac{e_2^k}{z_2^k} \left( \frac{t^k}{\rho^k} \right)^{-\phi^k} = f^k (\varepsilon^k - 1) = \phi^k \]

\[ \frac{e_1^k}{z_1^k} (t^k \rho^k)^{-\phi^k} + \frac{e_2^k}{z_2^k} = f^k (\varepsilon^k - 1) = \phi^k \]

\[ \frac{e_1^k}{z_1^k} + \frac{e_2^k}{z_2^k} \left( \frac{t^k}{\rho^k} \right)^{-\phi^k} = \frac{e_1^k}{z_1^k} (t^k \rho^k)^{-\phi^k} + \frac{e_2^k}{z_2^k} \]

\[ \frac{e_1^k}{z_1^k} (1 - (t^k \rho^k)^{-\phi^k}) = \frac{e_2^k}{z_2^k} \left( 1 - \left( \frac{t^k}{\rho^k} \right)^{-\phi^k} \right) \]

\[ e_1^k z_2^k (1 - (t^k \rho^k)^{-\phi^k}) = e_2^k z_1^k \left( 1 - \left( \frac{t^k}{\rho^k} \right)^{-\phi^k} \right) \]
\[
\begin{align*}
\frac{e_1^k z_2^k (1 - (t^k \rho^k)^{-\varepsilon^k})}{e_2^k \left( 1 - \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} \right)} &= z_1^k \\
\frac{e_1^k e_2^k \left( 1 - \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} \right)}{e_1^k z_2^k (1 - (t^k \rho^k)^{-\varepsilon^k})} + \frac{e_2^k \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k}}{z_2^k} = \phi^k \\
\frac{e_2^k \left[ 1 - \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} \right]}{(1 - (t^k \rho^k)^{-\varepsilon^k})} + \frac{\left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k}}{\phi^k} = \phi^k \\
\frac{e_2^k \left( 1 - \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} \right) + (1 - (t^k \rho^k)^{-\varepsilon^k}) \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k}}{(1 - (t^k \rho^k)^{-\varepsilon^k})} = z_2^k
\end{align*}
\]

\[
\begin{align*}
\frac{e_1^k}{z_1^k} + \frac{e_2^k \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} \phi^k (1 - (t^k \rho^k)^{-\varepsilon^k})}{e_2^k \left( 1 - (t^k)^{-2\varepsilon^k} \right)} &= \phi^k \\
\frac{\phi^k \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} - (t^k)^{-2\varepsilon^k}}{(1 - (t^k)^{-2\varepsilon^k})} = \phi^k \\
\frac{e_1^k}{z_1^k} &= \phi^k \left[ 1 - \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} \right] \left[ 1 - (t^k)^{-2\varepsilon^k} \right] = \phi^k \left[ \frac{1 - (t^k)^{-2\varepsilon^k} - \left( \frac{t^k}{\rho^k} \right)^{-\varepsilon^k} + (t^k)^{-2\varepsilon^k}}{(1 - (t^k)^{-2\varepsilon^k})} \right]
\end{align*}
\]
\[ z^k_1 = \frac{e^k_1}{\phi^k_1} \frac{(1-(t^k)^{-2\epsilon^k})}{\left(1-\left(\frac{t^k}{\rho^k}\right)^{\epsilon^k}\right)} \]

\[ (p^k_1)^{\epsilon^k} (P^k_1)^{-\epsilon^k} = (p^k_1)^{-\epsilon^k} n^k_1 + p^k_1^{\epsilon^k} (p^k_2 t^k)^{-\epsilon^k} n^k_2 = z^k_1 \]

\[ z^k_1 = p^k_1 n^k_1 + p^k_2 n^k_2 (\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k} \]

\[ (p^k_2)^{\epsilon^k} (P^k_2)^{-\epsilon^k} = (p^k_2)^{-\epsilon^k} (p^k_2 t^k)^{-\epsilon^k} n^k_1 + (p^k_1)^{-\epsilon^k} n^k_2 = z^k_2 \]

\[ z^k_2 = p^k_1 n^k_1 (\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k} + p^k_2 n^k_2 \]

\[ p^k_1 n^k_1 = z^k_1 - p^k_2 n^k_2 (\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k} \]

\[ p^k_2 n^k_2 = z^k_2 - p^k_1 n^k_1 (\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k} \]

\[ \Rightarrow p^k_1 n^k_1 = z^k_1 - (z^k_2 - p^k_1 n^k_1 (\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k})(\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k} \]

\[ p^k_1 n^k_1 = z^k_1 - z^k_2 (\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k} + p^k_1 n^k_1 (t^k)^{2(1-\epsilon^k)} \]

\[ p^k_1 n^k_1 (1-(t^k)^{2(1-\epsilon^k)}) = z^k_1 - z^k_2 (\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k} \]

\[ p^k_1 n^k_1 = \frac{z^k_1 - z^k_2 (\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k}}{1-(t^k)^{2(1-\epsilon^k)}} \]

\[ p^k_2 n^k_2 = z^k_2 - (\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k} \left(\frac{z^k_1 - z^k_2 (\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k}}{1-(t^k)^{2(1-\epsilon^k)}}\right) \]

\[ p^k_2 n^k_2 = z^k_2 - \frac{(\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k} z^k_1}{1-(t^k)^{2(1-\epsilon^k)}} + \frac{(\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k} z^k_2 (\rho^k)^{-\epsilon^k} (t^k)^{-\epsilon^k}}{1-(t^k)^{2(1-\epsilon^k)}} \]

\[ p^k_2 n^k_2 = \frac{z^k_2 (1-(t^k)^{2(1-\epsilon^k)}) - z^k_1 (\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k} + z^k_2 (t^k)^{2(1-\epsilon^k)}}{1-(t^k)^{2(1-\epsilon^k)}} \]

\[ p^k_2 n^k_2 = \frac{z^k_2 - z^k_1 (\rho^k)^{\epsilon^k} (t^k)^{-\epsilon^k}}{1-(t^k)^{2(1-\epsilon^k)}} \]
APPENDIX B

FORTRAN PROGRAMS

B.1 Program to Calculate Parameters

double precision tolx
integer n, maxit, i, it
parameter (n=2, tolx=1.d-10, maxit=500)
integer ipvt(n), njb, njf
double precision x(n), fjac(n,n), fval(n), delx(n), errx
real pjb, pjf, tj, epsj, rhoj
real to, epso, mu
print *, 'What is the number of juice processors in Brazil?'
read *, njb
print *, 'What is the number of juice processors in Florida?'
read *, njf
print *, 'What is the price of juice in Brazil?'
read *, pjb
print *, 'What is the price of juice in Florida?'
read *, pjf
print *, 'What is the trade cost factor for juice?'
read *, tj
print *, 'What is the elasticity for juice?'
read *, epsj
print *, 'What is the trade cost factor for oranges?'
read *, to
print *, 'What is the elasticity for oranges?'
read *, epso
print *, 'What is the labor share of production?'
read *, mu

rho=pjb/pjf
x(1)=0.7952
x(2)=1.0608
do 10 it=1, maxit
fval(1)=rho*njb/njf-(x(1)**(epsj)+tj**((1-epsj)-

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```fortran
&(rho***(epsj))*(x(l)+tj))/
&(tj**epsj+x(1)*(tj***(1-epsj))-(rho***(epsj))*
&(1+x(1)*tj))

fjac(1,1)=-(tj**epsj-rho**epsj)*(tj**epsj+x(1)*
&j***(1-epsj)-rho***(epsj)*x(l)-(tj)**
&(1-epsj)-rho***(epsj)*tj)*(x(1)*tj**epsj+tj**
&(1-epsj)-rho***(epsj)*(x(1)+tj))/(tj**epsj+x(1)*
&tj***(1-epsj)-rho***(epsj)*(1+x(1)*tj))**2

fjac(1,2)=0

fval(2)=rho*njb/njf-(1-(to^x(2))**(eps0))*rho**((1-eps0)
&(1-mu))x(2)**((eps0-mu)/(1-mu))/((1-x(2))**(eps0)-

fjac(2,1)=0

fjac(2,2)=-(eps0-mu)/(1-mu))*((1-(eps0-x(2))**(eps0))/(1-(to
&x(2))**(eps0)))*rho**((eps0-x(2))**(eps0)-
&(1-mu)-rho**((eps0-x(2))**(eps0)-
&((eps0-x(2))**(eps0)-1)*(1-(to/x(2))**(eps0)+
&((eps0-x(2))**(eps0)-1)*(1-(to/x(2))**(eps0)))/

do 11 i=l,n

delx(i)=-fval(i)

11 continue

call ludcomp(fjac, n, n, ipvt, info)
call lusolve(fjac, delx, n, n, ipvt)
errx=0

do 12 i=l,n

errx=errx+dabs(delx(i))
x(i)=x(i)+delx(i)

12 continue

print *, it, (x(i), i=l,n)

print *, njb, njf

print *, pj, pjf

print *, t, epsj

print *, to, epso

print *, mu

if (errx.le.tolx) stop

10 continue

print *, 'failure to converge'

stop

end
```

```fortran
&\{(p\rho^{\epsilon_j})(x(l)+tj)/
&\{(tj^{\epsilon_j}+x(1)^{(1-\epsilon_j)})-(\rho^{\epsilon_j})*
&(1+x(1)^{\epsilon_j})\}

fjac(1,1)=-(\{tj^{\epsilon_j}-\rho^{\epsilon_j}\}+(tj^{\epsilon_j}+x(1)^{\epsilon_j})-\{tj^{\epsilon_j}\})*
&(x(1)^{\epsilon_j}+tj^{\epsilon_j})*(x(l)^{\epsilon_j}+tj^{\epsilon_j})*(1-\epsilon_j)

fjac(1,2)=0

fval(2)=\rho*njb/njf-(1-(to^{x(2)}))^{(\epsilon_0)})*\rho^{((1-\epsilon_0)
&(1-\mu))x(2)^{((\epsilon_0-\mu)/(1-\mu))}/((1-x(2))^{(\epsilon_0)-

fjac(2,1)=0

fjac(2,2)=-(\epsilon_0-\mu)/(1-\mu))*((1-(\epsilon_0-x(2))^{(\epsilon_0)})/(1-(to
&x(2))^{(\epsilon_0)}))*\rho^{((\epsilon_0-x(2))^{(\epsilon_0)-
&(1-\mu)-\rho^{((\epsilon_0-x(2))^{(\epsilon_0)-
&((\epsilon_0-x(2))^{(\epsilon_0)-1})*(1-(to/x(2))^{(\epsilon_0))}+
&((1-(to/x(2))^{(\epsilon_0)-1})*(1-(to/x(2))^{(\epsilon_0))}/

do 11 i=l,n

delx(i)=-fval(i)

11 continue

call ludcomp(fjac, n, n, ipvt, info)
call lusolve(fjac, delx, n, n, ipvt)
errx=0

do 12 i=l,n

errx=errx+dabs(delx(i))
x(i)=x(i)+delx(i)

12 continue

print *, it, (x(i), i=l,n)

print *, njb, njf

print *, pj, pjf

print *, t, epsj

print *, to, epso

print *, mu

if (errx.le.tolx) stop

10 continue

print *, 'failure to converge'

stop

end
```

B.2 Program to Calculate Price Ratio and Firm Location

double precision tolx
integer n, maxit
parameter (n=1, tolx=1.d-10, maxit=500)
integer i, it, ipvt(n)
double precision x(n), fjac(n,n), fval(n), delx(n), errx
real tj, epsj, omega, sigmaj, upperj, lowerj, nuo
real to, epso, mu, sigmao, nu, zee, rhoo, uppero, lowero
integer njb, njf

print *, 'What is the number of juice processors in Brazil?'
read *, njb
print *, 'What is the number of juice processors in Florida?'
read *, njf
print *, 'What is the trade cost factor for juice?'
read *, tj
print *, 'What is the elasticity for juice?'
read *, epsj
print *, 'What is the trade cost factor for oranges?'
read *, to
print *, 'What is the elasticity for oranges?'
read *, epso
print *, 'What is the labor share of production?'
read *, mu
print *, 'What is the wage ratio?'
read *, omega
print *, 'What is the expenditure ratio?'
read *, sigmaj

x(1)=1.008

10 do 10 it=1, maxit
fval(1)=((1-(to*omega)**(-epso))/(1-(to/omega)**(-epso)))
&*x(1)**((1-epso)/(1-mu))*omega**((epso-mu)/(1-mu))
&-(sigmaj*tj**epsj+tj**(-epsj)-
&x(1)**epsj*(sigmaj+tj))/
&(tj**epsj+sigmaj*tj**(1-epsj)-x(1)**(-epsj)*
&(1+sigmaj*tj))
fjac(1,1)=((1-epso)/(1-mu))*((1-(to*omega)**(-epso))/
&(1-(to/omega)**(-epso)))*omega**((epso-mu)/(1-mu))*x(1)**
&(mu-epso)/(1-mu)+(epsj*x(1)**(epsj-1)*(sigmaj+tj)*
&(tj**epsj+sigmaj*tj**(1-epsj)-x(1)**(-epsj)*(1+sigmaj*tj))+
&epsj*x(1)**(-epsj-1)*(1+sigmaj*tj)*(sigmaj*tj**epsj+tj**)
&(1-epsj)-x(1)**epsj*(sigmaj+tj))/((tj**epsj+sigmaj*tj)**2)
do 11 i=1,n
delx(i)=fval(i)
do 11 continue
call ludcomp(fjac, n, n, ipvt, info)
call lusolve(fjac, delx, n, n, ipvt)
errx=0
do 12 i=1,n
errx=errx+dabs(delx(i))
x(i)=x(i)+delx(i)
do 12 continue
print *, it
print *, njb, njf
print *, tj, epsj
print *, to, epso
print *, mu
lowero=(to**(mu-1))*(omega**mu)
uppero=(to**(1-mu))*(omega**mu)
lowerj=(((tj**epsj)+sigmaj*(tj**(1-epsj)))/(1+sigmaj*(tj**epsj))^(l/epsj))
upperj=(((tj**epsj)+sigmaj*(tj**(1-epsj)))/(1+sigmaj*(tj**epsj))**(-l/epsj))
nu=(l/x(l))*(sigmaj*(1j**epsj)+(ti**(l-epsj))-(x(l)**epsj)*(sigmaj+tj))/((tj**epsj)+sigmaj*(tj**(l-epsj))-(x(l)**(-epsj))*(l+sigmaj*tj))
sigmao=nu*x(l)
zee=sigmao*(1-(to/omega)**(-epso))/(1-(to*omega)**(-epso))
&(-epso)
rhoo=((x(l)/omega**mu)**((l-epso)/(l-mu))*(l/zee)**(-l/epso)
&(-epso))
uo=(sigmao*(l-(to/rhoo)**(-epso))-(l-(to*rhoo)**(-epso))*rhoo**epso*to**(l-epso))/(((l-(to*rhoo)**(-epso))-sigmao*(l-(to/rhoo)**(-epso))*rhoo**(-epso)*to**(l-epso))*rhoo)
print *, 'The lower limit for nfb>0 is', lowerj
print *, 'The upper limit for nbj>0 is', upperj
print *, 'The lower limit for nfo>0 is', lowero
print *, 'The upper limit for nbo>0 is', uppero
print *, 'The juice price ratio is', x(l)
print *, 'The ratio of juice firms is', nu
print *, 'The orange price ratio is', rhoo
print *, 'The ratio of orange growers is', nuo
if (errx.le.tolx) stop
10 continue
   print *, 'failure to converge'
   stop
end

C$include c:\fortran\miranda\scal.sub
C$include c:\fortran\miranda\axpy.sub
C$include c:\fortran\miranda\ludcomp.sub
C$include c:\fortran\miranda\lusolve.sub
APPENDIX C

EFFECTS OF PARAMETER CHANGES

The following table illustrates the effects of a 10 percent change in each parameter value individually on the values of the processed product expenditure ratio, the product price/cost ratios and the firm ratios. The values used in this table are data values for tomato paste. The first line of values represents the original analysis, and is included for comparison purposes. Changes in firm numbers, trade cost factors, elasticities and labor shares do not yield dramatic changes in price and firm ratios. As stated in the main text, however, the model is quite sensitive to the initial tomato price ratio and paste expenditure ratio. The last four rows show the model’s sensitivity to 10 percent changes in these parameter values, particularly for \( \rho \). Recall that base values for these parameters were calculated by using the actual paste price ratio. These calculated base values were reasonable estimates compared to actual data.
<table>
<thead>
<tr>
<th>Change</th>
<th>OP</th>
<th>OP'</th>
<th>OP''</th>
<th>OP'''</th>
<th>OP''''</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASE</td>
<td>0.3775</td>
<td>0.8399</td>
<td>0.9113</td>
<td>0.3517</td>
<td>0.3109</td>
</tr>
<tr>
<td>n_ρ = 9</td>
<td>0.3638</td>
<td>0.8337</td>
<td>0.9108</td>
<td>0.3212</td>
<td>0.2825</td>
</tr>
<tr>
<td>n_ρ = 11</td>
<td>0.3907</td>
<td>0.8457</td>
<td>0.9108</td>
<td>0.3888</td>
<td>0.3452</td>
</tr>
<tr>
<td>n_ρ = 29</td>
<td>0.3912</td>
<td>0.8459</td>
<td>0.9109</td>
<td>0.3896</td>
<td>0.3460</td>
</tr>
<tr>
<td>n_ρ = 35</td>
<td>0.3658</td>
<td>0.8346</td>
<td>0.9110</td>
<td>0.3248</td>
<td>0.2859</td>
</tr>
<tr>
<td>μ = 1.284</td>
<td>0.3334</td>
<td>0.8399</td>
<td>0.9111</td>
<td>0.3531</td>
<td>0.3121</td>
</tr>
<tr>
<td>μ = 1.570</td>
<td>0.3834</td>
<td>0.8399</td>
<td>0.9108</td>
<td>0.3545</td>
<td>0.3134</td>
</tr>
<tr>
<td>μ = 1.71</td>
<td>0.3775</td>
<td>0.8431</td>
<td>0.9114</td>
<td>0.3654</td>
<td>0.3107</td>
</tr>
<tr>
<td>μ = 2.09</td>
<td>0.3775</td>
<td>0.8383</td>
<td>0.9113</td>
<td>0.3459</td>
<td>0.3112</td>
</tr>
<tr>
<td>σ_ρ = 3.186</td>
<td>0.3967</td>
<td>0.8399</td>
<td>0.9112</td>
<td>0.3526</td>
<td>0.3117</td>
</tr>
<tr>
<td>σ_ρ = 3.894</td>
<td>0.3607</td>
<td>0.8399</td>
<td>0.8922</td>
<td>0.4713</td>
<td>0.4143</td>
</tr>
<tr>
<td>σ_ρ = 5.166</td>
<td>0.3775</td>
<td>0.8329</td>
<td>0.9111</td>
<td>0.3589</td>
<td>0.3123</td>
</tr>
<tr>
<td>σ_ρ = 6.314</td>
<td>0.3775</td>
<td>0.8459</td>
<td>0.9116</td>
<td>0.3448</td>
<td>0.3093</td>
</tr>
<tr>
<td>μ = 0.5603</td>
<td>0.3775</td>
<td>0.8301</td>
<td>0.9111</td>
<td>0.3619</td>
<td>0.3120</td>
</tr>
<tr>
<td>μ = 0.6848</td>
<td>0.3775</td>
<td>0.8503</td>
<td>0.9040</td>
<td>0.3924</td>
<td>0.3544</td>
</tr>
<tr>
<td>σ_ρ = 0.7559</td>
<td>0.3775</td>
<td>0.7559</td>
<td>0.9805</td>
<td>0.0258</td>
<td>0.0256</td>
</tr>
<tr>
<td>σ_ρ = 0.9239</td>
<td>0.3775</td>
<td>0.9239</td>
<td>0.7913</td>
<td>7.9745</td>
<td>13.5502</td>
</tr>
<tr>
<td>σ_ρ = 0.3397</td>
<td>0.3397</td>
<td>0.8399</td>
<td>0.8233</td>
<td>1.2331</td>
<td>1.4709</td>
</tr>
<tr>
<td>σ_ρ = 0.4153</td>
<td>0.4153</td>
<td>0.8399</td>
<td>0.9602</td>
<td>0.1532</td>
<td>0.1688</td>
</tr>
</tbody>
</table>

Table C.1: Sensitivity analysis based on tomato paste.
Additionally, analysis was done on orange juice to see the effect of a change in firm numbers. The Table C.2 shows the results for various firm ratios based on orange juice parameter values. Changes in firm numbers do not result in dramatic changes in other variables.

<table>
<thead>
<tr>
<th>( \eta ) actual</th>
<th>( \phi )</th>
<th>( \eta ) calculated</th>
<th>( \rho )</th>
<th>( \eta )</th>
<th>( \sigma )</th>
</tr>
</thead>
<tbody>
<tr>
<td>20/27</td>
<td>0.7860</td>
<td>0.7413</td>
<td>0.7743</td>
<td>1.1576</td>
<td>0.2160</td>
</tr>
<tr>
<td>22/27</td>
<td>0.7861</td>
<td>0.8150</td>
<td>0.7833</td>
<td>1.2599</td>
<td>0.2298</td>
</tr>
<tr>
<td>20/25</td>
<td>0.7861</td>
<td>0.7794</td>
<td>0.7815</td>
<td>1.2381</td>
<td>0.2271</td>
</tr>
</tbody>
</table>

Table C.2: Sensitivity to firm numbers for orange juice industry.
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