# THREE ESSAYS APPLYING MICROECONOMIC THEORY TO INTERNATIONAL TRADE ISSUES

By

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# ABSTRACT

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This dissertation is comprised of two microeconomic models, one in partial equilibrium and one in general equilibrium, applied to international trade topics. A unifying theme for the dissertation is that trade is not always advantageous, and trade restrictions are not always disadvantageous.

Chapter 1 applies results from the literature on mergers to topics in strategic trade theory. In a three-country generalization of the Kreps-Scheinkman duopoly model with price competition and capacity constraints, I analyze the effects of discriminatory VIEs and VERs on equilibrium capacity and pricing decisions. VERs are shown to be bad for the exporting country, contradicting recent results in the literature by Harris (1985) and Krishna (1989a). VIEs are shown to decrease competition. Cases are analyzed where VIEs may actually lead to import contraction or to increases in efficiency in the home country.

Chapter 2 adds efficiency wage unemployment and factor immobility to a simple Ricardian model. I demonstrate that a trade-induced price shock can result in reduced welfare and permanent structural unemployment. I also demonstrate that there is, in general, room for government intervention to improve on social welfare.

Chapter 3 makes welfare comparisons of different trade policies in the framework of the model presented in chapter 2. While a Pareto ranking of tariffs and retraining subsidies depends crucially on parameter starting values, optimal production subsidies are shown to achieve a first-best solution.

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## TABLE OF CONTENTS

LIST OF TABLES

## LIST OF FIGURES

# Chapter 1. Voluntary Import Expansions and Voluntary Export Restraints in an Oligopoly Model with Capacity Constraints

## 1. Introduction

Free trade has long encountered a large amount of opposition. It comes as no surprise that as successive GATT rounds reduce tariff barriers, new tools of protectionism evolve to circumvent GATT rules. This chapter looks more closely at two such tools.

Voluntary Export Restraints (VERs) are bilateral agreements between exporting and importing countries, whereby the exporter agrees to "voluntarily" cap the level of exports to a specific trading partner. VERs are said to be discriminatory, since they do not treat all trading partners equally. Voluntary Import Expansions (VIEs[1]) are closely related to VERs; also bilateral and therefore also discriminatory agreements, they refer to policies whereby a country "voluntarily" expands imports of a certain product from a specific trading partner, presumably also to ease protectionist pressures in export markets. While VIEs have not yet been widely analyzed, they seem to be rapidly growing in popularity, especially between the United States and Japan. Japanese imports of American semiconductors, beef and coal have been cited as examples of VIEs by Dinopoulos and Kreinin (1989). Other examples include recent Japanese commitments to expand imports of paper and paperboard products as well as of U.S. manufactured car parts. Almost certainly, more VIEs are currently being proposed or negotiated between the United States and Pacific Rim countries with a reputation for closed markets. In practice, VIEs amount to "affirmative action" quotas designed to open up markets that have proven difficult for foreigners to crack.

[1] VIEs have been identified and analyzed only very recently by Bhagwati (1987) and Dinopoulos and Kreinin (1990).

VERs have in recent years appropriately been analyzed using oligopolistic market structures[2], where interactions between countries play an important role. This chapter proceeds in section 2 by analyzing VIEs in oligopoly models as well. Both a simple Cournot model and the Kreps-Scheinkman (1983) model of price competition with endogenous capacity constraints are used. While Kreps and Scheinkman demonstrated that their model yielded identical firm behavior as a Cournot model in unconstrained equilibrium, I demonstrate that this is no longer true when considering VIEs. I show that in both models, efficiency improvements can be obtained in economies imposing VIEs. Further, paradoxically, VIEs may actually result in import contraction. Residual demand rationing rules are only of minor importance in price competition with VIEs, contrary to what might be expected based on results in the mergers literature by Davidson and Deneckere (1986). In section 3, the Kreps-Scheinkman price competition model is used to analyze the effects of VERs. I demonstrate that in the context of this model, Harris' (1985) and Krishna's (1989a) results suggesting that foreign firms benefit from VERs do not hold. This resurrects work by Mai and Hwang (1988), whose Cournot based reversal of the Krishna-Harris results has legitimately been criticized by Krishna (1989b)[3] as restricting the strategic variable. Finally, I demonstrate that my results are robust to adding third parties to the models besides those party to bilateral trade agreements. Section 4 contains a summary and conclusions.

[2] Some VERs (such as the MFA VERs) are in industries characterized by many firms. These are an exception to the rule; most VERs still seem to be in oligopoly industries.

[3] Krishna's criticism is grounded in the fact that VERs restrict the Cournot model's strategic variable itself, leaving firms unable to use the existence of a VER strategically.

## 2. Welfare effects of a VIE

The welfare effects of VIEs can be demonstrated using a simple, two-country Cournot framework.

Suppose that two countries face a common inverse demand curve given by

$$P=1-q_1-q_2 \tag{1}$$

where $q_1$, $q_2$ represent output by countries 1 and 2, respectively. Marginal cost is assumed to be 0 for each firm. The Cournot reaction functions for the firms are

$$q_1=\frac{1-q_2}{2} \qquad q_2=\frac{1-q_1}{2} \tag{2}$$

yielding the Nash equilibrium outputs of $q_1=q_2=P=1/3$, total output is 2/3 and profit for each firm is 1/9.

With VIEs I assume that countries do not purchase more of the imported commodity than they plan on utilizing. This assumption puts a cap on the price that can be charged for this commodity. I also assume that the VIE will never be set at a quantity higher than the exporter included in the VIE would be willing to export.

Suppose that a VIE on output from country 1 is imposed. Country 1 expands its output to the exogenous quantity $K_V$. Profit of country 1 is therefore

$$\pi_1=PK_V=(1-K_V-q_2)K_V \tag{3}$$

where $q_2$ is $(1-K_V)/2$. When the VIE output equals the monopoly output of 1/2, country 1 makes Stackelberg leader profits, the best possible outcome for country 1 given a VIE. However, its profits exceed Cournot levels for any VIE output greater than 1/3 up to the monopoly output. Country 2 suffers a decrease in profit as $K_V$ increases.

Notice that welfare increases as $K_V$ increases from 1/3. Welfare is given by consumer surplus plus producer surplus, and it necessarily increases as the total quantity produced increases from Cournot levels to Stackelberg levels. Giving country 1 a VIE of the monopoly quantity of 1/2 implies country 2 output of 1/4 and a total Stackelberg output of 3/4, which is greater than total output of 2/3 prior to the VIE.

This analysis easily generalizes to a greater number of firms. The country given the VIE becomes a leader[4], and remaining firms take the VIE capacity as given. Price is identical for all three firms[5].

Cournot competition has legitimately been criticised as unrealistic in many industries. An alternative, often more realistic model is price competition with endogenous output capacity constraints. One issue that becomes important when considering such models, however, is the form of residual demands for high-priced firms.

When we consider many large oligopolies, the assumption of capacity constraints in production seems easy to accept. Auto manufacturers, for example, typically decide a year in advance on quantity of output for a model year. Once the autos appear in showrooms, there is a great deal of price competition involved in clearing the showrooms. Following the intuition of Davidson and Deneckere (1986) and Tirole (1988), I think of many large oligopolies as being in long run quantity competition but in short run price competition.

[4] VIE analysis in this model still differs from Stackelberg analysis in the sense that the country given the VIE cannot directly choose the VIE quantity, whereas a Stackelberg leader is free to choose capacity.

[5] The same welfare results hold if country 1 uses its privileged status to raise prices above Cournot levels.

In order to capture the intuition above as well as look at discriminatory effects of bilateral trade measures, I have generalized a duopoly model by Kreps and Scheinkman (1983) to include three countries. This is a 2-stage model with linear demand, capacity choice in the first stage, price competition in the second stage and efficient rationing of residual demand to the high-priced country. Thus, both price and quantity are chosen, but price is more flexible than quantity. In this type of game, equilibrium is in mixed strategies for a wide range of capacities. However, as Kreps and Scheinkman (1983) showed in their model and as I show for three countries[6], the unique solution for the game given the assumptions above is that the players' behavior mimics that of countries (firms) in Cournot quantity competition.

Davidson and Deneckere (1986) showed this to be a knife-edge result, critically dependent on the assumption of efficient rationing. They considered a variety of rationing rules, the extreme cases of which were efficient rationing on one hand and Beckmann proportional rationing on the other.

Efficient rationing assumes that customers buy first from the cheapest supplier, and income effects are absent. Therefore, the residual demand for the high-priced country takes the form $z_h$=min(own capacity, max(0, demand at $p_h$ - capacities of all other countries)). Mathematically, efficient rationing is very tractable and is therefore popular in economic modelling, in spite of the shortcoming that it maximizes consumer surplus and thereby presents itself as the worst possible rationing rule for high pricing countries.

Proportional rationing assumes that consumers randomly walk into stores and purchase inexpensive goods on a first come, first served basis. This way, many customers with high reservation prices may receive low priced goods.

[6] See Appendix.

A binding VIE would allow one country to sell the VIE quantity (call this quantity $K_V$), regardless of what quantities other countries produce or what prices they charge, provided that there is demand for at least the VIE quantity. The VIE therefore has the theoretical effect of removing one firm from competition, allowing for price dispersion.

A VIE would serve the purpose of guaranteeing a certain level of demand for one country. This provides a strong defense for assuming efficient rationing in the case of VIEs; the first to come now pay the higher price. Therefore, all the first goods sold will necessarily go to persons with high reservation prices. The last to come (or those who can afford to wait) purchase their goods at lower prices. As a consequence, all of the rationing rules identified by Davidson and Deneckere collapse into the efficient rationing case when VIEs are used as policy tools[7]. After adjusting for appropriate units, the inverse residual demand for the country (countries) not included in the VIE takes the form

(4) $$P=1-K_V-\sum q_i$$

where $q_i$ represents the output of the ith country not included in the VIE.

Since the VIE guarantees a certain level of demand, a country included in a VIE would not incur the same expected loss in profits if its price were to be undercut. Graphically we can depict the demand facing the country that is included in the VIE (call it country i) as identical to the demand facing any country not included in the VIE (call it country j), except that it is shifted to the right by the quantity of the VIE. In figures 1 and 2 below, our two country example is illustrated. The two countries compete in one market, with demand (after adjusting for appropriate units) equalling $P=1-K_V$. Country 1 is included in a VIE, meaning that country 1 is guaranteed to sell at least the quantity $K_V$. Country 1 sells exactly this quantity at price $1-K_V$.

[7] This is true for a duopoly case. With more firms, rationing rules turn out to matter, for reasons detailed below.

Country 1 may sell more by lowering price, as long as country 2 does not undercut it. Let $K_{1E}$ (E for "Excess") represent the quantity of output over and above $K_V$ that country 1 is successful at selling. The size of $K_{1E}$ depends on whether country 1 prices higher or lower than country 2, and on the capacity choice of country 1.

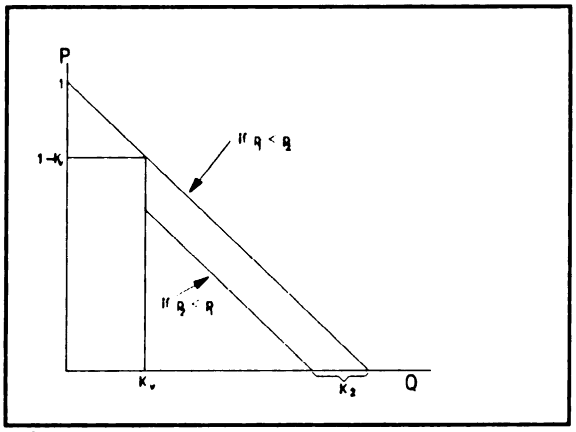

**Figure 1**

The demand facing country 1 is given in Figure 1.

Meanwhile, country 2 would face a demand that looks like the one illustrated in Figure 2.

This leads to the interesting observation that country 2 has nothing to lose by charging a price lower than $P=1-K_V$, whereas country 1 does have something to lose and unless the VIE is very small country 1 will not lower price.

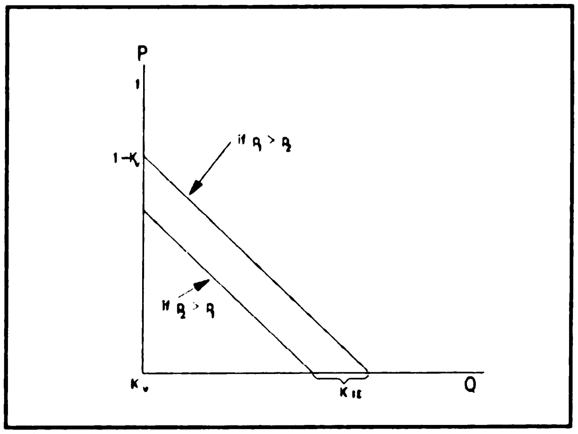

**Figure 2**

With three countries, where country i is included in a VIE and two countries j are not, rationing rules matter because they determine interactions of firms not included in a VIE. We have the following situation: when country i is offered a VIE quota, it can always get at least Cournot profits of 1/16 by ignoring the VIE. Therefore, country i's profit function becomes

$$\pi_i = \max\left[\frac{1}{16}, p_i K_V\right] \tag{5}$$

where $p_i K_V$ is a monotonically increasing function for any value less than 1/2, and it is equal to 1/16 for $K_V = (2-\sqrt{3})/4$.

We can now state that with a VIE, the equilibrium behavior of country i will be the following:

For $K_V < (2-\sqrt{3})/4$, country i takes Cournot profits of 1/16 by charging price $p_i = 1/4$ and selling capacity output of 1/4. In this case, the VIE is nonbinding. Note that this "VIE" is much smaller than the Cournot equilibrium output of country i, and if accepted would correspond to a contraction rather than an expansion.

For $(2-\sqrt{3})/4 \leq K_V \leq 1/2$, country i takes the greater-than-Cournot profits by charging $p_i = 1-K_V$ and selling capacity output of $K_V$. Over this range, the VIE is binding. (Recall that there is an upper limit on $K_V$: $K_V$ cannot be higher than the monopoly capacity of 1/2 since country i would not be willing to produce to such a high capacity.) The remaining two countries j will be in competition over the residual demand. Depending on the rationing rule assumed, this competition leads to outcomes identified in Davidson and Deneckere (1986).

With efficient rationing, there are three interesting cases to consider:

Case 1:

$$K_V < \frac{2-\sqrt{3}}{4}$$

Country j will take three-country Cournot profits of 1/16 by charging price $p_j = 1/4$ and selling capacity output of 1/4, just as country i will.

Case 2:

$$\frac{2-\sqrt{3}}{4} \leq K_V \leq \frac{1}{4}$$

Country j can now take two-country Cournot profits that exceed 1/16 by charging $p_j = 1 - K_V - 2K_j$ and selling capacity output of $K_j > 1/4$.

Note that over this entire range, as long as the VIE causes one country to cut back on capacity, the remaining two countries will both increase their capacities and their prices, and thus their profits. The total capacity of all three countries will be lower than was previously the case. However, the VIE will be politically supported by the home industry. This is a counterintuitive result; that home industry supports affirmative-action-type quotas in favor of foreign competition. The reasoning for this result is that effective price discrimination takes place. Foreign profits rise at the expense of domestic consumer surplus, even though country i imports decline. This leaves a larger residual demand for industry in the home country. When $K_V$ is exactly 1/4, both countries j make the same profit as was the case without the VIE but country i has substantially higher profits at the expense of the home country's consumer surplus.

This must still be considered a perverse case, since the import "expansion" is a de facto import contraction. Rather than follow this bizarre policy the home country might instead choose to guarantee a smaller-than-Cournot market share to domestic industry. Domestic industry would then capture the extra domestic consumer surplus, and foreign market share would increase across the board rather than decrease.

Case 3:

$$\frac{1}{4}<K_V\leq\frac{1}{2}$$

Over this range, country j makes two-country Cournot profits of less than 1/16 because it prices lower and produces less than in the unrestricted 3-country Cournot equilibrium. Although one firm is removed from competition, the market demand curve facing the remaining two firms is now shifted to the left by more than 1/4. However, although country j loses producer profit, the home economy becomes more efficient by eliminating some of the deadweight loss that follows from oligopoly markets, where output is lower than in competitive markets. The total output brought to market is now greater than 3/4, and as a consequence some consumers who would not otherwise have bought any of the output will now choose to do so. In summary, it is possible to state the following propositions on VIEs:

**Proposition 1:** The country taking full advantage of the binding VIE would maximize profits by raising its price to the level where demand exactly equals $K_V$, whereupon we would have a pure strategy equilibrium with one country charging a higher price (but not necessarily selling a higher quantity) than with free trade. This country would not be the exclusive supplier to the market, however. The remaining j countries would compete against each other for the residual demand $P=1-K_V-\sum q_j$. Using our now-familiar Kreps-Scheinkman result, this would result in a Cournot equilibrium between the remaining two countries, given efficient rationing. Given other rationing rules, equilibrium between the remaining two countries will be in mixed strategies, with both firms' average prices being lower and average quantities higher than with Cournot competition.

**Proposition 2:** With a sufficiently small VIE, country i will ignore it and choose not to set its price at the level where demand equals $K_V$.

**Proposition 3:** When the home country offers foreign country i a binding (i.e. sufficiently high) VIE, country i unambiguously benefits. A third-party country benefits as long as the VIE is lower than the Cournot output level. If the VIE is higher than the Cournot output level, the third party country is unambiguously worse off. As for the home country itself, its industry benefits from a VIE that is lower than the Cournot output level but its economy suffers greater deadweight loss; there is a tradeoff. The reverse is true when a binding VIE is greater than the Cournot output level: home industry is hurt but efficiency increases.

Above, the extreme case of efficient rationing was considered. Any other rationing rule yields mixed strategy equilibria with total output higher than that of Cournot equilibrium. It should be emphasized that the flavor of the results are unchanged.

## 3. VERs with Efficient Rationing

The Voluntary Export Restraint as a trade restriction is perhaps best formally defined in the literature by Carl Hamilton (1985) as

> "a measure by which the importing home country protects its own producers by imposing an upper limit on foreign supply (constraint 1), defined by source (constraint 2), defined by commodity group (constraint 3), often also defined in terms of volume rather than value (constraint 4), and typically defined over a limited time period. The VER is administered by the exporting country".

Many oligopoly models analyzing VERs ignore constraint 2 by assuming a duopoly with a VER on one country. This is unsettling, since VERs are inherently discriminatory trade practices; a VER on one country (country A) leaves not only the home country but all foreign countries other than A unrestricted and therefore free to "pick up the slack". As Dinopoulos and Kreinin (1988) point out, "A VER that limits Japanese auto exports to the US favors European suppliers who are excluded from the restriction: their terms of trade improve and/or their volume of export expands". It is therefore appropriate to include at least three countries in oligopoly models analyzing VERs in order to account for the positive third-party effects. VIEs, intended to reduce a specific trade deficit between 2 countries, naturally also affect third party suppliers not included in the VIE agreement[8].

In the model with price competition and endogenous capacity constraints, a VER would restrict capacity of one country to be less than some exogenously determined level. Since only binding VERs are of interest in the context of this model[9], this is the same as exogenizing one of the capacity constraints. Unlike the VIE case, the VER does not have the theoretical effect of removing one firm from competition.

**Proposition 4:** A binding VER on one country would imply that it have a capacity less than in the unconstrained equilibrium. Given the reaction functions of the remaining two countries, which coincide with Cournot reaction functions in the relevant region, we have a pure strategy equilibrium where both countries not subject to the VER would expand their capacities and earn higher profits. The country subject to the VER would unambiguously earn less profits than under free trade.

This contradicts the results of both Harris(1985) and Krishna (1989a) and circumvents the criticism in Krishna (1989b), that a quantity-competition model is inappropriate for the study of VERs (since VERs restrict the strategic variable).

[8] For example, Japan's decision to increase imports of American semiconductors, all other things constant, would cause both Japanese and third country manufacturers of semiconductors to face less Japanese demand for their products. This would hold true even if the Japanese and/or third country products were better and cheaper than American ones. The case of semiconductors in Japan is described in some detail in a first-page article in The Wall Street Journal, December 20, 1990 and again on March 31, 1992. Also in the WSJ on March 16, 1992, are reported Australian complaints with GATT about U.S. pressure on Japan to purchase U.S. manufactured car parts at the expense of other suppliers.

[9] In Krishna's and Harris' models, VERs can perform the function of credible threats, supporting a particular equilibrium outcome even though they are not binding in this equilibrium.

The reason for this result is that the countries' behavior in my three-country model mimics that of countries in Cournot competition. This is also true in the two-country case, where my results correspond exactly to those of Mai and Hwang (1988).

Non-binding VERs are "too big", whereas non-binding VIEs are "too small". Interestingly, VERs become "too big" as soon as they reach the Cournot level of 1/4, whereas binding VIEs include quotas substantially smaller than the Cournot level.

## 4. Summary and Conclusions

Harris (1985) and Krishna (1989a) have, using Bertrand models, established that VERs can be used strategically by oligopolists to enhance profits of both exporting and importcompeting firms. Krishna (1989b) calls this an "Interaction effect", resulting from the fact that the VER affects both parties.

Mai and Hwang (1988) showed that the Krishna-Harris result is reversed when quantity competition is assumed. However, this approach has been criticized (Krishna 1989b) on the basis that VERs in these models restrict the strategic variable, leaving firms unable to use the existence of VERs strategically.

The Mai and Hwang result is resurrected by introducing endogenous capacity constraints into a price competition model as in Kreps and Scheinkman (1983). Further, introduction of a third firm into the basic Kreps and Scheinkman model allows some conclusions on the question of supply diversion to be drawn. Such a model also causes some counterintuitive results to emerge on a related trade distortion, the VIE.

VERs and VIEs are discriminatory trade measures, but duopoly modelling can be justified if endogenous capacity constraints and efficient rationing are assumed in price competition models. What drives this result is the fact that the behavior of countries mimics that of countries in Cournot competition for capacities equal to or greater than Cournot equilibrium quantities[10].

The level of the VIE relative to the unconstrained solution is critical in determining the sign of its effect on producers not included in the VIE. A large VIE that expands a foreign firm's market presence hurts non-included (domestic and third-country) firms but increases efficiency. A sufficiently large VIE that still shrinks included firms' market presence helps non-included firms. To my knowledge, given the stated purpose of VIEs to expand domestic market presence of certain foreign countries' industries, there do not as yet exist VIEs that are smaller than the unconstrained market presence. If such existed, they would more appropriately be called "Voluntary Import Contractions". More plausible would be a perverse "buy domestic" program that, at the same time, limits domestic output to a level below the Cournot level. Such a "buy domestic" program would serve to expand imports, albeit in a nondiscriminatory way, while increasing profits for domestic firms by allowing them to charge a higher price than the foreign competition.

In the VIE case, in a model of price competition with endogenous capacity constraints, the assumption of efficient rationing of residual demand is shown to be compelling. Since the first buyers always encounter high prices with a binding VIE, any proportional rationing scheme necessarily collapses into efficient rationing. This is not the case with VERs.

It would be interesting to investigate what would happen if the assumption of efficient rationing of residual demand were dropped in the case of VERs. In this case, as Davidson and Deneckere (1986) show, the oligopolists may adopt mixed pricing strategies, generally pricing

[10] Although there seem to be no theoretical complications associated with ignoring the discriminatory effects of VERs and VIEs, it should by no means be inferred that third countries can be ignored in empirical studies of VERs. Dinopoulos and Kreinin (1988), in estimating the effects of a VER on Japanese automobiles to the United States, demonstrated that US welfare loss (in the form of lost consumer surplus) to Europe as a consequence of the VER was greater than the welfare loss to Japan. I would expect that empirical testing of VIE welfare effects may also demonstrate significant third party effects.

lower than countries in Cournot competition. Mai and Hwang (1988) would indicate that perhaps Harris' and Krishna's counterintuitive results can be salvaged after all, but that remains to be proven.

# Chapter 2. Trade and Structural Unemployment

## 1. Introduction

Policymakers in the United States and elsewhere have long linked unemployment issues with international trade. Indeed, casual observation indicates that a major argument in favor of trade restrictions such as tariffs, voluntary export restraints and quotas is to "save domestic jobs". Cheap foreign labor is seen as a threat to domestic labor interests.

In spite of the above, economic theory has until recently had difficulty in providing any microeconomic justification for connections between unemployment and trade. In large part, this is because the microeconomic models of pure trade had no mechanism for generating unemployment in equilibrium.

In recent years, theoretical microeconomic underpinnings of traditional macroeconomic problems such as unemployment have developed and become quite sophisticated. This gives trade theorists the tools to examine unemployment issues that previously weren't possible to analyze outside of international finance.

This chapter explores a way that structural unemployment can arise in equilibrium, and provides a theoretical basis for the tremendous short-run unemployment questions that have arisen in economies that are suddenly exposed to large price shocks[1]. Section 2 presents different ways in which unemployment can be dealt with in a microeconomic framework. Section 3 contains a cursory review of the literature on unemployment in pure trade models. In section 4, I review

[1] A list of such countries should include Poland, former East Germany, the Czech and Slovak Republics, Romania, former republics of the USSR, and on a smaller scale the EFTA countries, the EC countries, the United States, Canada, Australia, and many more. Other economies planning to open markets further, such as China, Vietnam, Korea and Japan can expect similar issues to arise in the future.

the concept of unemployment, defining frictional and structural unemployment. I present my model of structural unemployment in section 5. Essentially, a Ricardian trade model is modified by assuming costly mobility of labor across sectors as well as efficiency wage generated unemployment. Section 6 explores consequences of trade on welfare. Section 7 discusses alternative cost structures of worker retraining. In section 8, a specific example is generated where welfare decreases in the short run with trade, but increases over autarky levels in the long run. There is shown to be room for public policy in trade adjustment. Section 9 contains a summary and conclusions.

## 2. Microeconomic Approaches to Dealing with Unemployment

Microeconomics has recently developed a number of explanations for the phenomenon of unemployment.

When prices are artificially high, surpluses occur. Artificially high wages therefore result in surpluses of labor, otherwise known as unemployment. Artificially high wages can be caused by a number of phenomena, some of which are discussed below.

Explicit contracts (through unions) have often borne the blame for unemployment in the past. These are known as factor market distortions, and have been widely analyzed in general equilibrium models, where, however, full employment is assumed through the existence of a competitive sector. Likewise in trade models. For this reason, this brief survey will ignore the vast literature on factor market distortions. (It should be noted, however, that analysis of minimum wages distinguishes their effects from the effects of distortive wage differentials caused by unions. Brecher (1974) points out that with a wage floor, the supply of labor becomes perfectly elastic. Therefore, at the minimum wage, labor may be partially unemployed).

Keynesians traditionally suggest that when aggregate demand falls, wages are "sticky", remaining high and causing unemployment. Microeconomic justifications for "stickiness" in wages include implicit contracts between labor and management. Relatively more risk-averse laborers contract with relatively less risk-averse management for a joint product consisting of employment and insurance against income instability over the business cycle. This causes firms and in some models workers as well to act as if they were legally constrained. "Contracts" fix employees' wage rates and transfer risk to employers. This prohibits wages from moving to clear the labor market in response to changes in aggregate demand. In conjunction with business cycles or demand shocks, the sticky wages might lead to unemployment, providing that no competitive sector exists where wages can adjust to clear the labor market by accommodating those who lose their jobs in the sticky wage sector. Scarth (1988) points out that rigid real wages and layoffs only come about in this model if reservation wages are greater than 0, implying that workers get some utility from being laid off. This leads them to voluntarily accept some probability of being unemployed in return for a higher average wage while employed, a situation which still does not explain involuntary unemployment.

Another explanation for above-equilibrium wages is the efficiency wage theory. Firms who have trouble monitoring the effort of their employees may give their employees incentives not to shirk by paying them a higher wage than can be found elsewhere in the economy. The employees will then work harder, unwilling to risk losing their jobs because of the opportunity cost involved. However, the firm that is paying efficiency wages is unwilling to hire as many workers as a firm in which monitoring employees' efforts is inexpensive, since lower wages could increase rather than decrease its net labor costs. As a consequence, unemployment results. This unemployment also serves to help deter workers from shirking.

Search theory takes a different approach to explaining unemployment. Workers (who are either new to the economy or have somehow become deprived of jobs) hunt for employment opportunities. Upon receiving a wage offer, they compare this with their reservation (minimum acceptable) wage to decide whether to accept or to continue searching. Unemployment in these models is often voluntary; searchers just have not found acceptable offers yet. Involuntary unemployment in search models also exists; in these models, searchers cannot find any job openings for the time being and must wait until positions become available.

### 3. Review of the Literature

Models that use the above concepts to explain trade-affected unemployment can do so very easily. Suppose that there are two countries, each with two sectors. In autarky (no-trade equilibrium), one or both economies suffer from unemployment in one sector due to either implicit contracts, efficiency wages or search. When these two countries specialize and trade, relative price changes will increase or decrease unemployment as a consequence of the trade.

Matusz (1986) uses implicit contracts to show that unemployment can be affected through trade. In his model, trade may cause labor to redistribute itself across sectors. Since one sector is characterized by less employment security than the other, unemployment may rise or fall depending on the direction of the redistribution. Alternatively, trade may cause changes in contractual relationships such as across-theboard decreases in employment security. Whatever the case, Matusz still successfully shows that trade is beneficial (welfare increasing) to the representative agent in the model.

Davidson, Martin and Matusz (1988) enhance Jones' (1965) classic two-sector general equilibrium model by introducing trading frictions in the labor market in one sector. These frictions are of the type that Diamond (1982) pioneered; two types of workers in one sector must search each other out and make a match before production can take place. This type of search leads to some frictional unemployment, the size of which is dependent on the size of the sector in question. With specialization and trade between two such economies, the one specializing in the search sector (for want of a better term) will have higher unemployment as a direct consequence of the increased trade.

There are other models that analyze unemployment and could easily be extended to include trade effects:

Bulow and Summers (1986) develop a general equilibrium model with an efficiency wage primary sector and a secondary sector in which jobs are easily obtained. By making the key assumption that primary-sector employers hire only directly from the pool of unemployed workers, "wait" unemployment is generated as workers queue for primary-sector jobs. Growth in the primary sector due to trade would increase unemployment. Copeland (1989) adapts this model to allow for trade, but without making the key assumption above and therefore not having any unemployment in equilibrium.

Arvan and Schoumaker (1987) develop a two-sector small country trade model in which both sectors pay efficiency wages and use both labor and capital in the production process. Using a Heckscher-Ohlin framework, the authors demonstrate the existence of inefficiency in equilibrium and show how activist commercial policy can remedy this. The type of policy adopted depends on the relative capital intensity of the import competing sector, and the small country assumption is critical to the results that efficiency can be approved upon.

All of the models I encountered concern themselves with frictional rather than with structural unemployment, as defined in the next section.

## 4. Two Types of Unemployment

In this discussion, I avoid traditional Keynesian classifications of unemployment into the categories of "voluntary" versus "involuntary", involving the distinction of whether an unemployed worker's reservation wage is above or below the wage that firms offer identical workers. As Lucas (1978) points out,

> "the worker who loses a good job in prosperous times does not volunteer to be in this situation: he has suffered a capital loss...Nevertheless, the unemployed worker can always find some job at once...[That he typically doesn't do] so by choice is not difficult to understand given the quality of jobs ... that are easiest to find. Thus there is an involuntary element to all unemployment, in the sense that no one chooses bad luck over good; there is also a voluntary element in all unemployment, in the sense that however miserable one's current work options, one can always choose to accept them."

I perceive unemployment as voluntary responses by individuals to an unwelcome situation. The incidence of unemployment raises policy issues only to the extent that it has been distorted by domestic externalities or by trade.

For our purposes, however, unemployment can be usefully divided by cause into frictional and structural unemployment.

By frictional unemployment I refer to all persons in the work force who are in the process of moving to new jobs. These individuals are qualified to fill existing job vacancies, which they are actively searching for. Speculative and precautionary unemployment may also be considered elements of frictional unemployment; speculative unemployment refers to workers reducing their present supply of hours in favor of offering more hours in the future, when a higher wage rate is expected to prevail. Precautionary unemployment refers to workers declining job offers which, if accepted, would prevent them from later accepting other expected offers with higher wages. Including these elements into the definition of frictional unemployment would imply that anyone who chooses to remain unemployed in order to wait for better job opportunities in the future is also considered frictionally unemployed, even if there doesn't currently exist a job vacancy that could be filled by this individual. Frictional unemployment can also be thought of as search unemployment.

By structural unemployment I refer to all unemployed individuals who do not have the right skills or live in the right places to fill existing job vacancies. Their number includes people such as laid-off steel workers or auto workers, as well as seasonally unemployed individuals (who may work in such sectors as tourism or farming). Structural unemployment can be eliminated only by retraining workers or by changing the location of either industries or the unemployed[2]. Increasing aggregate demand is typically not an effective means of alleviating structural unemployment, which may have been brought about by technological change or simply by a change in seasons; rather, relative wages must adjust to reflect the underlying shifts in demand that caused the unemployment to begin with, and workers have to be able to respond to the incentives embodied in the relative wage changes.

Structural unemployment is of considerable concern to Keynesian economists and most policymakers. Neoclassical economists deny the possibility of its persisting in the long run, since they believe that relative wages eventually adjust to reflect the underlying shifts in demand which caused the imbalance to begin with. This is rarely of much consolation to structurally unemployed voters, their elected representatives and others with high time preferences.

## 5. A Model with Structural Unemployment

Structural unemployment is less pleasant to analyze. It necessarily involves different types of non-substitutable labor in input processes. For simplicity, I will assume that labor is completely immobile between sectors in the short run. The difference between the short run and

[2] Shapiro and Stiglitz (1985) illustrate the concept well in an example involving available grape picking jobs in California during the Great Depression, while 20 or 25 percent of the Chicago labor force was sitting idle at home, willing to work for the going wage in Chicago.

the long run is therefore defined as the time lag involved in workers retraining and switching sectors.

Workers are assumed to be identical and infinitely lived.

The following analysis owes much to Shapiro and Stiglitz (1984).

Suppose that there are two sectors in the economy; sector X and sector Y. Both sectors are perfectly competitive.

Technology: X is produced by labor trained in the production of X, and Y is produced by labor trained in the production of Y. The production functions for X and Y are

(1) $$X=\sum_{z=1}^{L_X} e_z$$

(2) $$Y=\sum_{z=1}^{L_Y} e_z$$

where

$e_z$ = 0 if the zth worker is unemployed or shirking, 1 if the zth worker is not shirking.

$L_X$ = labor trained in production of X

$L_Y$ = labor trained in production of Y

$L_X+L_Y=L$ = the size of the labor force.

Note that labor trained in the production of one good is useless in the production of the other good. This assumption is intended to reflect the specialization and immobility of inputs, the crucial feature of structural unemployment.

It is assumed that workers prefer shirking to working, and that effort cannot easily be monitored in either sector. A worker who is caught shirking is terminated. For simplicity, unemployment compensation is assumed to be zero.

The indirect utility function of each worker is separable, and is written as $U(w,e,P)=V(w,P)-e$ ,

where w represents the nominal wage received from working in either sector and $P=P_x/P_Y$, the relative price with good Y as numeraire. I assume that each individual consumes both goods X and Y.

$b_i$ = the rate of exogenous separation from a job. A positive $b_i$ gives unemployed workers opportunities to get jobs even if no-one is shirking, so that they needn't remain unemployed forever in equilibrium.

r = the time preference (discount rate) of the worker. It is assumed to be the same for both sectors.

$q_i$ = the rate of detection of shirking in sector i. This is 0 if the worker is not shirking, and some exogenous positive constant if the worker is shirking.

This is a continuous time model. Workers choose effort levels to maximize their discounted utility stream, which can be written as

(3) $$G=E\int_0^{\infty} U[w(t),e(t),P(t)]^{-rt}dt$$

The maximization problem involves comparing utility from shirking with utility from non-shirking. Define:

$V_i^S$ as the expected lifetime utility of an employed shirker in sector i

$V_i^N$ as the expected lifetime utility of an employed non-shirker in sector i, and

$V_i^U$ as the expected lifetime utility of an unemployed individual searching for work in sector i.

I can write the sector i shirker's discounted utility as

(4) $$rV_i^S = V(w_p P) + (b_i + q_i)(V_i^U - V_i^S)$$

The sector i non-shirker's discounted utility will be

(5) $$rV_i^N = V(w_p P) - e + b_i(V_i^U - V_i^N)$$

As in Shapiro and Stiglitz (1984), equations (4) and (5) are of the form "interest rate times asset value equals flow benefits (dividends) plus expected capital gains (or losses)".

Solving for the utilities themselves out of the expressions above, I get

(6) $$V_i^S = \frac{V(w_p P) + (b_i + q_i)V_i^U}{r + b_i + q_i}$$

(7) $$V_i^N = \frac{V(w_p P) - e + b_i V_i^U}{r + b_i}$$

Shirking won't occur as long as utility from shirking is no higher than utility from not shirking. This gives us a non-shirking condition (NSC):

(8) $$V(w_p P) \geq rV_i^U + \frac{(r + b_i + q_i)e}{q_i}$$

By cost minimization on the part of the firms, equality will hold in this relationship in equilibrium.

The asset equation for unemployed labor (analogous to (4) and (5)) is

$$rV_i^U = 0 + a_i(V_i^N - V_i^U) \tag{9}$$

where $a_i$ = the job acquisition rate in sector i. The discounted expected lifetime utility of an unemployed individual is her unemployment compensation plus the compensation she would receive from being employed in future time periods weighted by the probability of actually receiving such employment. Indirect utility above is normalized to equal zero when income is zero, and unemployment compensation is assumed to be 0. I can now use equations (7) and (9) to get

$$rV_i^N = \left(\frac{V(w_i,P)-e}{a_i+r+b_i}\right)(a_i+r) \tag{10}$$

$$rV_i^U = \left(\frac{V(w_i,P)-e}{a_i+r+b_i}\right)a_i \tag{11}$$

Substituting equation (11) into the non-shirking condition (8), I get

$$V(w_i,P) \geq e + \frac{(r+b_i+a_i)e}{q_i} \tag{12}$$

Since inflow into the pool of unemployed workers in each sector equals outflow in equilibrium, I can solve for $a_i$ (= the job acquisition rate in sector i).

Define $L_i^E$ = employment in sector i, and recalling that

$L_i$ = the total number of workers trained in production of i,

then $b_i L_i^E = a_i(L_i - L_i^E)$ and hence

(13) $$a_i = \frac{b_i L_i^E}{L_i - L_i^E}$$

Rewriting the NSC once again, I get

(14) $$V(w_i, P) \geq e + \frac{e}{q_i}\left[\frac{b_i L_i}{L_i - L_i^E} + r\right] = e + \frac{e}{q_i}\left[\frac{b_i}{u_i} + r\right]$$

where $u_i$ is defined as

(15) $$u_i \equiv \frac{L_i - L_i^E}{L_i}$$

and represents the unemployment rate of sector i, or the proportion of workers trained in the production of good i that are unemployed. By cost-minimization, equality holds in equation (14).

Short-Run Equilibrium:

In the short run, workers cannot switch sectors regardless of changes in price. Given their demands for labor, firms will offer some real wage which, by the nonshirking condition (NSC), leads to some particular level of equilibrium unemployment in each sector.

The short run equilibrium is characterized by the following equations:

(16) $$w_X = P$$

(17) $$w_Y = 1$$

(18) $$V(w_X, P) = e + \frac{e}{q_X}\left[\frac{b_X}{u_X} + r\right]$$

(19) $$V(w_Y, P) = e + \frac{e}{q_Y}\left[\frac{b_Y}{u_Y} + r\right]$$

(20) $$\frac{L_X^E}{1 - u_X} = \overline{L_X}$$

(21) $$\frac{L_Y^E}{1 - u_Y} = \overline{L_Y}$$

(16) and (17) are the zero profit conditions, since labor is the only input, marginal product is 1 in both industries, competitive markets are assumed and Y is the numeraire. (18) and (19) are the no shirking conditions for X and Y, respectively. (20) and (21) are the short run labor market constraints.

Equilibrium conditions (16) through (19) can be combined into equations (22) and (23):

(22) $$V(P, P) = e + \frac{e}{q_X}\left[\frac{b_X}{u_X} + r\right]$$

(23)
$$V(1,P)=e+\frac{e}{q_Y}\left[\frac{b_Y}{u_Y}+r\right]$$

Graphically, the relationships between price and unemployment in each sector are shown in Figures 1 and 2.

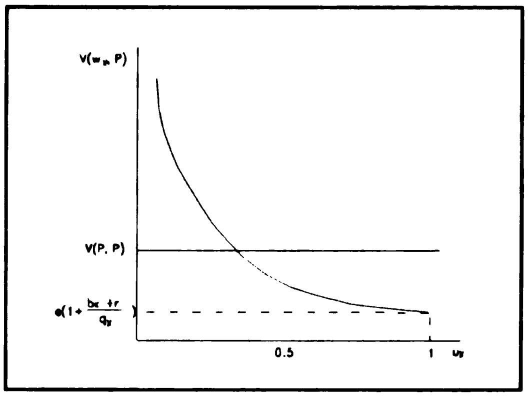

**Figure 1**

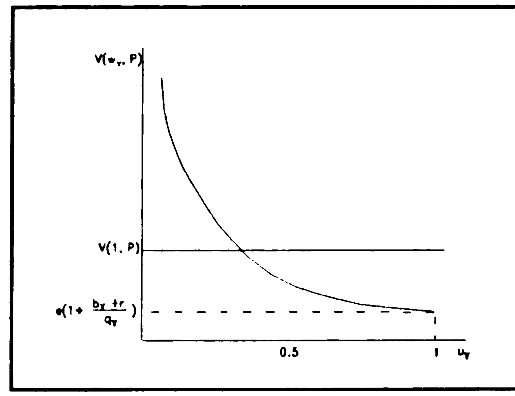

**Figure 2**

**Proposition 1:** All else equal, if consumers consume both goods, an increase in P causes output of Y to fall and output of X to rise in the short run.

Proof: Suppose price rises from $P_1$ to $P_2$.

In sector Y: since indirect utility is nonincreasing in price (see e.g. Varian, 1984), $V(1,P_1)$ is at least as great as $V(1,P_2)$. Equality holds only if workers in sector Y consume only Y. Since this case is assumed away, $V(1,P_1)>V(1,P_2)$. By equation (23), $u_Y$ must increase. By equation (21), $L_Y^E$ must decrease. Since the marginal product of each worker is 1, $L_Y^E=Y$.

In sector X: $V(P_2,P_2)$ is at least as great as $V(P_1,P_1)$ with equality holding if workers employed in X consume only good X, since indirect utility is homogeneous of degree 0 in prices and income. If income and $P_X$ are both multiplied by a number greater than 1 and the price of

Y remains unchanged, the budget set for workers employed in sector X increases. Since workers consume both X and Y,

$V(P_1,P_1) < V(P_2,P_2)$. By equation (22), $u_X$ must decrease. By equation (20), $L_X^E$ must increase. Since the marginal product of each worker is 1, $L_X^E = X$. QED.

Using these relationships, we can develop the upward sloping relative supply curve that is depicted in Figure 3. Also depicted in Figure 3 is a downward sloping relative demand curve.

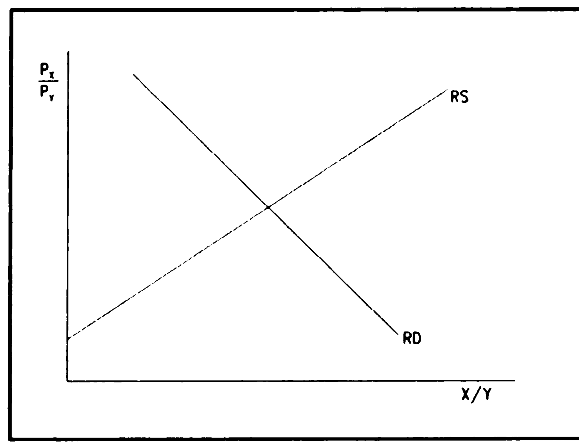

Figure 3

In the case of trade between two countries with identical, homothetic preferences, we can make some observations regarding trade flows and comparative advantage.

**Proposition 2:** All else equal, the home country has a comparative advantage in X if $q_X > q_X^*$ [$^*$ denotes foreign].

Proof: From equation (22), for any given P, if $q_X > q_X^*$ then $u_X < u_X^*$. Since $L_X = L_X^*$, more X is being produced in the home country and, consequently, the relative supply curve for the home country is below the relative supply curve for the foreign country.

Both countries face identical relative demand curves. Autarky price in the home country is below autarky price in the foreign country, implying that the home country has a comparative advantage in X. QED.

**Proposition 3:** All else equal, the foreign country has a comparative advantage in X if $b_X > b_X^*$.

Proof: Consider the relative supply curve of the home country. From equation (22), for any given P, a higher $b_X$ implies a higher $u_X$. Therefore, if $b_X > b_X^*$, then $u_X > u_X^*$ for every P. Since $L_X = L_X^*$, less X is being produced in the home country at any given P and, consequently, the relative supply curve for the home country is above the relative supply curve for the foreign country.

Both countries face identical relative demand curves. Autarky price in the home country is above autarky price in the foreign country, implying that the foreign country has a comparative advantage in X. QED.

The Market Frontier:

Given the technology assumed, the technological production possibilities frontier is rather uninteresting; in traditional cases with no efficiency wage distortion, autarky price could be anything and the production point would remain unchanged. However, due to the assumption of efficiency wages, I get a downward-sloping "market frontier", so named because of its dependence on market relationships as well as technological relationships[3] As the relative price of good X falls, the unemployment rate in sector X increases and reaches 100 percent when P is low enough so that $V(P,P)=e+e(b_X+r)/q_X$. Similarly, unemployment in sector Y reaches 100 percent when P is high enough so that $V(1,P)=e+e(b_Y+r)/q_Y$. As the relative price for good i approaches infinity, unemployment in sector i approaches 0.

To solve for the short-run tradeoff between X and Y as price changes, I can totally differentiate equation (14) for each sector to get equation (24).

[3] Brecher (1974) develops a similar concept with minimum wages, which he distinguishes from the PPF by calling it a Transformation Curve.

(24)
$$V_w(w_i,P)dw_i+V_P(w_i,P)dP=\frac{eb_iL_i}{q_i}\left[\frac{dL_i^E}{(L_i-L_i^E)^2}\right]=\frac{eb_i}{q_iL_iu_i^2}dL_i^E$$

For sector X, using the facts that $dw_X=dP$ and $dL_X^E=dX$, I can solve for dX/dP:

(25)
$$\frac{dX}{dP}=\frac{u_X^2L_Xq_X(V_{w_X}(w_X,P)+V_P(w_X,P))}{eb_X}$$

The expression dX/dP is positive; $V(w_X,P)$ rises with increases in $w_X$ by more than it falls in P, by the arguments in the proof of Proposition 1.

Following the same procedure with Y, but using the fact that $dw_Y=0$ (since $w_Y=1$) and $dL_Y^E=dY$, I can solve for dY/dP:

(26)
$$\frac{dY}{dP}=\frac{u_Y^2L_Yq_YV_P(w_Y,P)}{eb_Y}$$

dY/dP is negative; $V(w_Y,P)$ decreases with increases in P, since the real wage of workers in sector Y decreases.

The slope of the market frontier is the ratio of the expressions in (25) and (26):

(27)
$$\frac{dY/dP}{dX/dP}=\frac{b_X}{b_Y}\frac{q_Y}{q_X}\frac{L_Y}{L_X}\left(\frac{u_Y}{u_X}\right)^2\frac{V_P(w_Y,P)}{V_P(w_X,P)+V_{w_X}(w_X,P)}=\frac{dY}{dX}$$

Given the complete immobility of labor between sectors in the short run, a change in output of either commodity has no effect on the number of people trained in the production of either X or Y.

Using Roy's Identity, equation (27) can be rewritten as

(28) $$\frac{dY}{dX}=\frac{b_X}{b_Y}\frac{q_Y}{q_X}\frac{L_Y}{L_X}\left(\frac{u_Y}{u_X}\right)^2\frac{V_P(w_Y,P)}{V_{w_X}(w_X,P)}\frac{1}{1-d_X^X}$$

where $d_X^X$ represents the demand for X (subscript) by a worker employed in producing X (superscript). Assuming risk-neutral behavior on the part of the workers/consumers, $V(w_i,P)=w_iI(P)$ where $I(P)$ is an appropriately defined price index. Now $V_P(w_Y,P)=w_YI'(P)=(w_Y/w_X)w_XI'(P)=(w_Y/w_X)V_P(w_X,P)$.

Since $w_Y/w_X=1/P$, it follows that

(29) $$\frac{V_P(w_Y,P)}{V_w(w_X,P)}=\frac{1}{P}\frac{V_P(w_X,P)}{V_w(w_X,P)}=-\frac{1}{P}d_X^X$$

Equation (28) can therefore be further rewritten as

(30) $$\frac{dY}{dX}=-\frac{1}{P}\frac{d_X^X}{1-d_X^X}\frac{q_YL_Yb_Xu_Y^2}{q_XL_Xb_Yu_X^2}$$

In general, the market frontier may be either concave or convex. In order to provide a tractable framework for showing some possible implications of this model, I will temporarily narrow my scope by assuming that each individual in the economy has preferences represented by the utility function

(31) $$U=\min\left\{\frac{X}{\theta_X},\frac{Y}{\theta_Y}\right\}-e$$

Leontief preferences imply two properties which simplify the model considerably. First, consumer relative demand for goods X and Y is a vertical line, implying that the same relative quantities of goods will be consumed in autarky and at free trade prices. Second, as I will show below, the market frontier is always concave with respect to the origin when Leontief preferences are assumed. Neither of these two properties hold in general for other classes of utility functions. A discussion of relaxing the assumption of Leontief preferences follows in Section 6 below.

Utility maximization subject to the budget constraint implies $X/\theta_X = Y/\theta_Y$ in equilibrium. Therefore,

(32) $$\frac{X}{Y}=\frac{\theta_X}{\theta_Y}\equiv\theta$$

and the income consumption curve (ICC) is

(33) $$Y=\frac{X}{\theta}$$

The budget constraint is $w_i = PX + Y$. Using equations (16) and (17), the budget constraints for workers in sectors X and Y respectively are given by (34) and (35):

(34) $$P=PX+Y$$

(35) $$1=PX+Y$$

Substituting the income consumption curve (33) into (34), I have, in

sector X,

(36) $$X=\frac{\theta P}{1+\theta P}=d_X^X$$

(37) $$Y=\frac{P}{1+\theta P}=d_Y^X$$

Similarly, substituting the income consumption curve (33) into (35), I have, in sector Y,

(38) $$X=\frac{\theta}{1+\theta P}=d_X^Y$$

(39) $$Y=\frac{1}{1+\theta P}=d_Y^Y$$

The indirect utility function is written as $V(w_i,P)$-e, where, in equilibrium,

(40) $$V(w_X,P)=V(P,P)=\frac{P}{\theta_Y(1+\theta P)}$$

(41) $$V(w_Y,P)=V(1,P)=\frac{1}{\theta_Y(1+\theta P)}$$

**Proposition 4:** Given the assumed preferences, the market frontier is concave.

Proof: Equation (30) gives us the slope of the market frontier in general. Using equation (36) to plug in for $d_X^X$, I have

(42) $$\frac{dY}{dX}=-\frac{1}{P}\frac{\theta P}{1+\theta P}(1+\theta P)c\left(\frac{u_Y}{u_X}\right)^2=-\theta c\left(\frac{u_Y}{u_X}\right)^2 \quad where\ c=\frac{q_Y}{q_X}\frac{b_X}{b_Y}\frac{L_Y}{L_X}$$

o

Differentiating (42) with respect to P,

(43) $$\frac{d\left(\frac{dY}{dX}\right)}{dP}=-2\theta c\left(\frac{u_Y}{u_X}\right)\frac{d\left(\frac{u_Y}{u_X}\right)}{dP}<0$$

As P increases, unemployment in sector Y increases and unemployment in sector X decreases. Consequently, more X and less Y is produced. At the same time, the market frontier becomes steeper (the slope becomes more negative). Therefore, the market frontier is concave. QED.

In the short run, production takes place at some point on the market frontier. In autarky, production takes place where the ICC intersects the market frontier, point A in Figure 4.

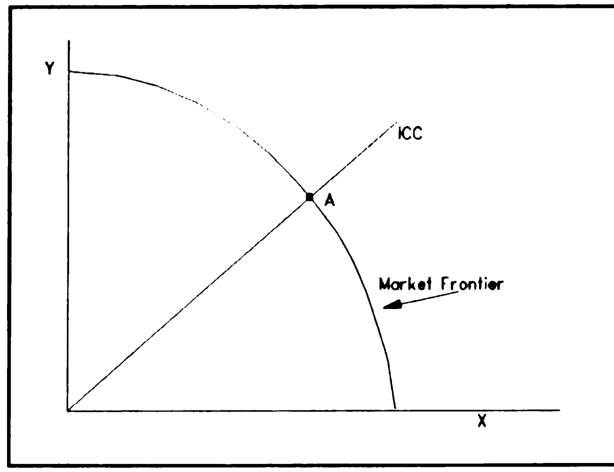

**Figure 4**

Long Run Equilibrium:

The long run equilibrium differs from the short run equilibrium only by the fact that labor is mobile across sectors, at a cost. This necessitates additional equations to specify the form of these costs.

The training costs are specified as follows: when workers train, they engage in non-paid self-study that gives them a disutility of t. The resource cost of training is assumed to be negligible.

Long run equilibrium is characterized by equations (22) and (23), as well as by equations (44) and (45) below:

(44) $$|V_X^U - V_Y^U| \leq t$$

(45) $$\frac{L_X^E}{1-u_X} + \frac{L_Y^E}{1-u_Y} = \bar{L}$$

Equation (44) ensures that no workers have incentive to retrain in equilibrium. The cost of switching sectors t is assumed to be the same across sectors, but it may differ across individuals. Training costs can be specified in a number of different ways, as will be discussed below. Equation (45) is the labor market constraint.

The utility of being trained but unemployed in sectors X and Y respectively is $V_X^U$ and $V_Y^U$. The utility of being untrained in either sector is assumed to be 0. The utility of engaging in training, as noted above, is -t. It is further assumed that $\max\{V_X^U, V_Y^U\}-t(L)>0$, so that each worker chooses to train initially and no workers are untrained in autarky equilibrium.

**Proposition 5:** In autarky equilibrium, if both goods are produced, $V_X^U=V_Y^U$.

Proof: By assumption, each untrained worker will train. The choice that the nth worker makes is which sector to train in. She is therefore comparing $V_X^U$-t to $V_Y^U$-t. Suppose that $V_X^U-t>V_Y^U-t$, meaning that $V_X^U>V_Y^U$. Untrained workers would train in X, then search for jobs in the X sector. More workers in sector X leads to greater X production relative to Y production. This causes P to fall, resulting in $V_X^U$ falling and $V_Y^U$ rising. Similarly, if $V_X^U<V_Y^U$, workers training in Y would result in P rising until $V_X^U=V_Y^U$. QED.

**Lemma 1:** Autarky price is given by $(K+1)/(1-\theta K)$ where K is a function of exogenous parameters.

Proof: Long run equilibrium requires equation (44). Using equation (8), this implies

(46) $$\left|V(w_X,P)-\frac{(r+b_X+q_X)e}{q_X}-V(w_Y,P)+\frac{(r+b_Y+q_Y)e}{q_Y}\right|\leq\frac{t}{r}$$

Imposing the no profit conditions (16) and (17), then using equations (40) and (41) to substitute in for V(P,P) and V(1,P) given the assumed preferences, I have

(47) $$\frac{t}{r}\geq\left|\frac{P}{\theta_Y(1+\theta P)}-\frac{1}{\theta_Y(1+\theta P)}-e\left(\frac{r+b_X}{q_X}-\frac{r+b_Y}{q_Y}\right)\right|$$

By Proposition 5, the right hand side of expression (47) equals 0. Therefore,

(48) $$(P-1)\left(\frac{1}{1+\theta P}\right)=K \quad where\ K=\theta_Y e\left(\frac{r+b_X}{q_X}-\frac{r+b_Y}{q_Y}\right)$$

(49) $$P=\frac{K+1}{1-\theta K}$$

QED.

Given the assumed Leontief preferences, the relative demand curve for this economy is vertical. As was shown following Proposition 1, this economy has a positively sloped relative supply curve. Graphically, this is represented in Figure 5. The positioning of this relative supply curve is determined by allocation of labor across sectors, which in turn is dictated through Proposition 5. The relative price derived through Lemma 1 is the price where relative supply intersects relative demand.

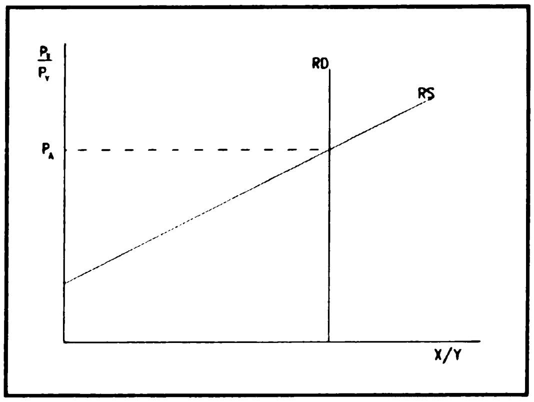

**Figure 5**

## 6. Short Run and Long Run Consequences of Trade on Welfare

At autarky price there exists some unemployment in both sectors. Since I am starting from long-run equilibrium, this unemployment is strictly frictional; offering workers retraining would not alleviate it because workers are uninterested in switching sectors even if it were possible. Only through a change in the relative price (e.g. through trade) or in some parameter governing sector-specific unemployment levels will the production point shift (thereby introducing structural unemployment[4]).

In the short run, an increase in price would move the economy's production point from the autarky equilibrium point A to a new point B on the market frontier. This gives rise to two possibilities concerning short run welfare. First, if the new price ($P_1$) is less than the slope of the chord connecting A and B, welfare decreases from $u_2$ to $u_1$. If not, price is something like $P_2$ and welfare increases from $u_2$ to $u_3$. This is shown in Figure 6.

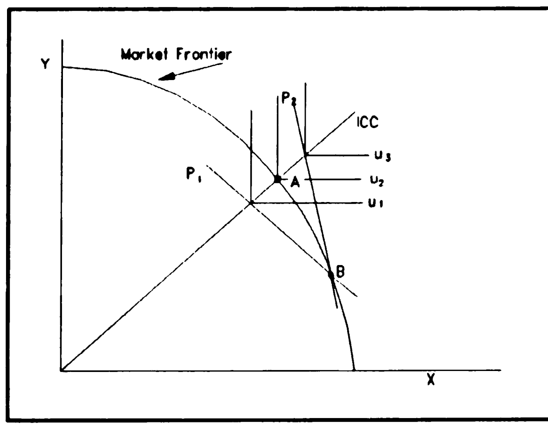


**Figure 6**

In the long run, workers retrain and move away from point B along a line of slope $-(1-u_Y)/(1-u_X)$ where $u_X$ and $u_Y$ represent unemployment rates associated with trade prices.

The slope of this line is derived by differentiating the function for relative supply with respect to $L_X$ and $L_Y$:

[4] Before such a change occurs, each worker is in the sector that they see as the best one to be in, under the circumstances, hence there is no structural unemployment. As we will see below, however, after such a change takes place, structural unemployment is created and some structural unemployment can even persist in the long run.

(50) $$\frac{S_Y}{S_X}=\frac{(1-u_Y)L_Y}{(1-u_X)L_X}=\frac{Y}{X} \quad \textit{so} \quad \frac{dY}{dX}=\frac{(1-u_Y)dL_Y}{(1-u_X)dL_X} \quad \textit{where} \quad dL_Y=-dL_X$$

In the long run, an increase in price will move the economy's production point from B to some point C in Figure 7. The distance between points B and C depend on the cost of retraining; in the absence of a corner solution, the greater retraining costs are, the fewer retrain and the closer C is to B.

Given the price increase, welfare increases from B to C if $P>(1-u_Y)/(1-u_X)$. If $P<(1-u_Y)/(1-u_X)$, welfare falls. This is true regardless of whether C is inside or outside the market frontier.

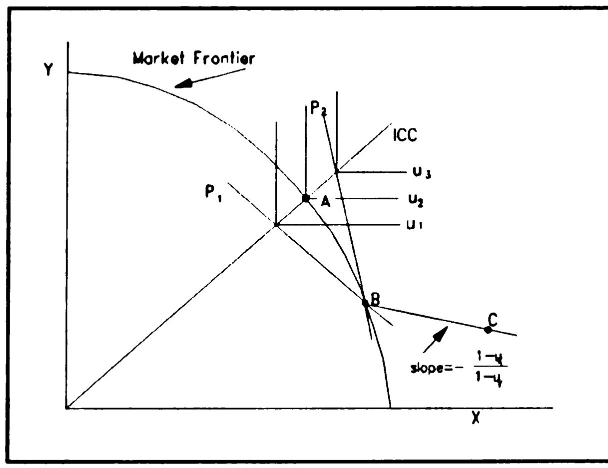

**Figure 7**

These results are robust to changing the preferences of the representative consumer. Although the Market Frontier no longer is necessarily concave and the income consumption curve shifts with a change in price, it is straightforward to see that utility may be higher or lower in the short run with trade, and that it can subsequently rise or fall in the long run after retraining takes place.

## 7. The Retraining Function

I consider three alternative ways in which the retraining cost t can be specified, each of which assumes that t is the same across sectors.

1) t is assumed to be the same across individuals. A sufficiently large change in price will result in every unemployed worker in the import competing industry to want to retrain simultaneously. By the no shirking condition, unemployment rates are constant so a departure of unemployed people from one sector results in employed people being laid off. These people will also retrain. In the long run, we have a corner solution; either the change in price is small enough so that no workers retrain, or the economy becomes completely specialized in the production of the export good.

2) t differs across individuals. Suppose that, across the entire population, training costs are initially distributed normally from a low value $t_L$ to a high value $t_H$. When the country is opened up to trade, unemployed persons in the import-competing industry with low retraining costs will choose to retrain. This, however, leads to a change in distributions of training costs in each sector and subsequent shocks will have effects on retraining that depend on what the previous shocks have been.

3) t is the same across individuals, but is an increasing function of the number of people who retrain. In this case, the retraining function t(n) embodies a negative externality in the sense that when one worker retrains, retraining costs rise for all workers who subsequently retrain. Under such circumstances, the distribution of training costs does not change with every shock, but corner solutions are avoided.

## 8. A Numerical Example

I will now use a specific numerical example to demonstrate how, in an economy characterized by this model,

a) Trade can hurt welfare in the short run;

b) Given long run adjustment, trade can be beneficial in the long run;

c) Trade adjustment assistance is justifiable.

Suppose that L=1000

$e=r=b_X=b_Y=q_X=q_Y=1/10$

$\theta_X=\theta_Y=\theta=1$

Using Lemma 1, autarky price $P_A=1$.

Solving for unemployment rates from the no shirking conditions (22) and (23),

(51)
$$u_X=\frac{eb_X}{V(P,P)q_X-e(q_X+r)}$$

(52)
$$u_Y=\frac{eb_Y}{V(1,P)q_Y-e(q_Y+r)}$$

in autarky,

(53)
$$u_X=u_Y=\frac{1/10*1/10}{1/2*1/10-1/10*2/10}=\frac{1}{3}$$

From equation (42), the slope of the market frontier at the autarky production point is -1.

The income consumption curve is Y=X. Since $D_X/D_Y=S_X/S_Y$ (relative supply always equals relative demand in autarky), it follows that $L_X(1-u_X)/L_Y(1-u_Y)=1$. Therefore, $L_X/L_Y=1$ and $L_X=L_Y=L/2=500$.

Welfare is defined as

(54) $$W=(V_X^U L_X^U)+(V_X^N L_X^E)+(V_Y^U L_Y^U)+(V_Y^N L_Y^E)$$

From equation (8), we know that

(55) $$V_i^U=\frac{V(w_i,P)}{r}-\frac{(r+b_i+q_i)e}{q_i r}$$

Similarly, from equation (7), we know that

(56) $$V_i^N=\frac{1}{r+b_i}\left[V(w_i,P)-e+b_i V_i^U\right]=\frac{V(w_i,P)-e}{r+b_i}+\frac{b_i}{r+b_i}\left[\frac{V(w_i,P)}{r}-\frac{(r+b_i+q_i)e}{q_i r}\right]$$

$$=\frac{V(w_i,P)-e}{r+b_i}+\frac{b_i V(w_i,P)}{r(r+b_i)}-\frac{b_i e(r+b_i+q_i)}{q_i r(r+b_i)}=\frac{V(w_i,P)}{r}-\frac{e}{r+b_i}-\frac{b_i e(r+b_i+q_i)}{q_i r(r+b_i)}$$

Consequently, in equilibrium, given the assumed preferences,

$$V_X^U=\frac{P}{r\theta_Y(1+\theta P)}-\frac{(r+b_X+q_X)e}{rq_X}$$

$$V_X^N=\frac{P}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_X}-\frac{b_X e(r+b_X+q_X)}{q_X r(r+b_X)}$$

$$V_Y^U=\frac{1}{r\theta_Y(1+\theta P)}-\frac{(r+b_Y+q_Y)e}{rq_Y}$$

$$V_Y^N=\frac{1}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_Y}-\frac{b_Y e(r+b_Y+q_Y)}{q_Y r(r+b_Y)}$$

In autarky, therefore,

$$V_X^U=\frac{1}{(1+1)*1/10}-\frac{(1/10+1/10+1/10)*1/10}{1/10*1/10}=5-3=2=V_Y^U$$

$$V_X^N=5-\frac{1}{2}-\frac{3}{2}=3=V_Y^N$$

Using equation (54), autarky welfare in my example is

$$W=2\left[\frac{500}{3}*2+\frac{1000}{3}*3\right]=2666\frac{2}{3}$$

Short run trade:

Suppose that with trade, price falls to 1/2. Now,

$$u_X=\frac{1/10*1/10}{1/3*1/10-1/10*(1/10+1/10)}=\frac{3}{4} \qquad u_Y=\frac{1/10*1/10}{2/3*1/10-1/10*(1/10+1/10)}=\frac{3}{14}$$

$$V_X^U=\frac{10}{3}-3=\frac{1}{3} \qquad V_Y^U=\frac{20}{3}-3=3\frac{2}{3}$$

$$V_X^N=\frac{10}{3}-2=1\frac{1}{3} \qquad V_Y^N=\frac{20}{3}-2=4\frac{2}{3}$$

Again using equation (54), short run trade welfare in my example equals

$$W=500\left[\frac{3}{4}*\frac{1}{3}+\frac{1}{4}*\frac{4}{3}+\frac{3}{14}*\frac{11}{3}+\frac{11}{14}*\frac{14}{3}\right]=2517\frac{6}{7}$$

With trade, welfare has fallen in the short run.

It might be noted that $V_Y^U > V_X^N$ above, with trade. It would be misleading to think, however, that workers employed in X would quit to retrain in Y once unemployed sector X workers had all retrained. As unemployed sector X workers retrain, some employed workers in sector X lose their jobs by the no-shirk condition. As a consequence, unemployment in X is never 0 and the marginal worker who retrains is always unemployed.

Long run trade:

Suppose that the retraining function t(n) is of the form[5]

$$t(n)=\frac{5\sqrt{L+n}}{54}$$

Parenthetically, the training function is $\sqrt{n}$ times 5/54. The 1000 workers initially train, so that before any retraining takes place, t(n) is up to $\sqrt{1000}$ times 5/54. The retraining function becomes the function above.

From the long run equilibrium condition given by equation (44), we know that in my example,

$$t(n^*)=V_Y^U-V_X^U=\frac{11}{3}-\frac{1}{3}=\frac{10}{3}$$

Using the retraining function above, we find that n*=296. Therefore, this particular retraining function implies that 296 workers retrain from sector X to sector Y in the long run when price falls to 1/2.

When price falls, long run trade welfare equals

$$W=u_X V_X^U(\overline{L_X}-n)+(1-u_X)V_X^N(\overline{L_X}-n)+u_Y V_Y^U(\overline{L_Y}+n)+(1-u_Y)V_Y^N(\overline{L_Y}+n)-nt(L+n) \tag{57}$$

[5] This is a very restrictive assumption; a discussion of this assumption and of generalizing the model in this respect appears in Section 7 above.

Plugging in the numbers from my example,

$$W=796\left[\frac{3}{14}*\frac{11}{3}+\frac{11}{14}*\frac{14}{3}\right]+204\left[\frac{3}{4}*\frac{1}{3}+\frac{1}{4}*\frac{4}{3}\right]-296*\frac{10}{3}=2676\frac{3}{7}$$

With trade, welfare has risen above autarky levels in the long run.

Note that even in long run equilibrium, due to positive retraining costs, unemployed workers in sector X would prefer to be in sector Y if retraining costs were lower. This implies persistent structural unemployment even in the long run; the autarky situation of exclusively frictional unemployment does not return.

Do enough workers retrain endogenously? To check if n* is the optimal n, we take the derivative of equation (57) with respect to n:

(58)
$$\frac{dW}{dn}=u_YV_Y^U+(1-u_Y)V_Y^N-u_XV_X^U-(1-u_X)V_X^N-t(L+n)-nt'(L+n)$$

Evaluating this for my example at n*=296,

$$\frac{dW}{dn}=\frac{3}{14}*\frac{11}{3}+\frac{11}{14}*\frac{14}{3}-\frac{3}{4}*\frac{1}{3}-\frac{1}{4}*\frac{4}{3}-\frac{10}{3}-296*\frac{5}{3888}=\frac{1055}{6804}>0$$

The endogenous number of retrainees n* is too low from a social welfare perspective. Welfare could be enhanced by subsidizing retraining.

Why and under what circumstances is n* too low? Equation (58) separates into four basic effects, as follows:

dW/dn = A-B-C-D where

$$A=u_Y V_Y^U+(1-u_Y)V_Y^N \quad B=u_X V_X^U+(1-u_X)V_X^N \quad C=t(L+n) \quad D=nt'(L+n)$$

A represents the social benefit of having one additional worker in sector Y. B represents the social benefit of having one additional worker in sector X. C is the explicit cost of retraining the nth worker. D is the increase in costs caused by retraining the nth worker to all of the other workers in the process of retraining.

A-B equals the marginal social gain of retraining any sector X worker to sector Y. C+D equals the marginal social cost of retraining any worker from one sector to the other.

These differ from the private marginal costs and benefits of retraining. The marginal individual who wishes to retrain is necessarily unemployed, and she becomes an unemployed worker in the new sector for which she retrains. Therefore, she is comparing $V_X^U$ to $V_Y^U$-t(n) in making her decision, as in equation (44).

By the no shirking conditions (22) and (23), any worker who leaves the Y sector does not affect the unemployment rate. When unemployed workers leave, some employed workers in Y lose their jobs. This affects social welfare but is not taken into consideration by the individual retrainee leaving the sector. Similarly, the social gain to having a worker retrain into sector X differs from that worker's private gain; that worker is unemployed in sector X, but by the no shirk condition, some (fraction of an) unemployed worker in sector X gets a job because of the increase in size of the sector.

Formally,

| | |
|---|---|
| The social gain of retraining is | $u_Y V_Y^U+(1-u_Y)V_Y^N-u_X V_X^U-(1-u_X)V_X^N$ |
| The private gain of retraining is | $u_Y V_Y^U+(1-u_Y)V_Y^U-u_X V_X^U-(1-u_X)V_X^U$ |
| The difference is | $(1-u_Y)(V_Y^N-V_Y^U)-(1-u_X)(V_X^N-V_X^U)$ |

Recognizing that $(V_Y^N-V_Y^U)$ and $(V_X^N-V_X^U)$ are constants, this difference changes as $u_Y$ falls and $u_X$ rises, which in turn happens as price changes.

Similarly, the difference between marginal social cost of retraining and private marginal cost of retraining is $nt'(L+n)$, term D.

Too few retrain endogenously if

(51) $(1-u_Y)(V_Y^N-V_Y^U)-(1-u_X)(V_X^N-V_X^U) > nt'(L+n)$.

In this case, retraining subsidies funded by a tax scheme that reallocates some of the benefits from trade could improve social welfare. From equation (51), increasing $nt'(L+n)$ by increasing the number of retrainees n moves the economy toward greater welfare. Differentiating $nt'(L+n)$ with respect to n, we get the expression

$$\frac{d}{dn}nt'(L+n)=t'(L+n)+nt''(L+n)>0 \qquad so \quad t''(L+n)>-\frac{t'(L+n)}{n}$$

If the inequality above does not hold, the economy should completely specialize in the production of Y; no matter how many retrain, the marginal social cost of retraining will always be below the marginal social benefit.

Too many retrain endogenously if $(1-u_Y)(V_Y^N-V_Y^U)-(1-u_X)(V_X^N-V_X^U) < nt'(L+n)$. This case is identical to the analysis above where too few retrain, except that the inequalities are reversed.

## 9. Summary and Conclusions

Expansion of trade has long been accompanied by considerable resistance. While traditional trade theory and most economists strongly favor free trade, populations of countries about to lower import barriers frequently have mixed feelings about opening markets. Public debates show concern over loss of jobs to overseas producers, sometimes suggesting that public welfare might be reduced with trade.

This chapter provides a theoretical basis for such concerns. Although recent developments in microeconomic theory enable trade theorists to study unemployment issues, most of what has been done has focused on frictional unemployment, ignoring the more pressing structural unemployment issues entirely. In this chapter, I have demonstrated that trade can decrease welfare and cause persistant structural unemployment in a Ricardian model with efficiency wages and costly reallocation of labor across sectors. However, depending on labor retraining costs, welfare may (but does not necessarily) rise above autarky levels in the long run even if it should fall in the short run. The strong arguments in favor of free trade that have been defended for centuries using the Ricardian model are therefore put into question when this model is adapted to allow for unemployment in equilibrium.

In my model, the retraining of one worker imposes a positive externality on society and a negative externality on other retraining workers. Due to this, marginal social costs/benefits of retraining differ from private marginal costs/benefits. In general, room for public policy exists to enhance welfare by encouraging or discouraging retraining.

## Chapter 3. Public Policy Alternatives Available to Economies Suffering Trade Generated Structural Unemployment

### 1. Introduction

In recent years, much has been made of loss of jobs to overseas competitors. Microeconomic trade theory has traditionally been unable to satisfactorily explain such a phenomenon, focusing instead on theoretical aggregate welfare gains from trade obtained in models where full employment is assumed. Only in international finance has trade generated unemployment been an issue, and even then, theory focuses on intraindustry trade problems where domestic goods become overpriced "lemons" due to trade liberalization at a wrong exchange rate (see e.g. Dornbusch, 1992).

This chapter presents the short run and long run unemployment and welfare consequences of opening a country up to (interindustry) trade, using the two sector general equilibrium model with efficiency wage generated frictional unemployment and inter-sectoral immobility of labor which was presented in Chapter 2. Given this model, I intend to analyze policy alternatives designed to alleviate structural unemployment and to increase welfare. Such policy measures include tariffs, government-subsidized worker retraining and production subsidies.

Section 2 reviews the model used in this chapter. Section 3 presents public policy options and a more formal analysis of policy issues in the context of the model, and makes welfare comparisons. Section 4 contains a summary, conclusions and policy recommendations.

## 2. The Model

There are two sectors in the economy, producing goods X and Y respectively. Both sectors are perfectly competitive, and use only labor as an input. Both sectors have constant returns to scale, with marginal product = 1. Jointly this implies that, in equilibrium, $w_X=P_X$ and $w_Y=P_Y$. Define Y as numeraire, so that in equilibrium $w_Y=P_Y=1$, $w_X=P_X=P$.

There are efficiency wages in both sectors, along the model of Shapiro and Stiglitz (1984). Labor is non-substitutable across sectors in the short run, reflecting the fact that different specialized training and/or location is involved across the sectors X and Y. Workers are identical and have the utility function

(1)
$$U=\min\left[\frac{X}{\theta_X},\frac{Y}{\theta_Y}\right]-e$$

This implies an indirect utility function for workers in each sector that can be written in the form $V(w_i,P) - e$, where, in equilibrium, since $w_X=P$ and $w_Y=1$,

(2)
$$V(w_X,P)=V(P,P)=\frac{P}{\theta_Y(1+\theta P)}$$

(3)
$$V(w_Y,P)=V(1,P)=\frac{1}{\theta_Y(1+\theta P)}$$

where $\theta$ is defined as $\theta_X/\theta_Y$.

As in chapter 2, the following notation is used:

e = disutility of work. It is defined as 0 if a worker is unemployed or shirking, and as some exogenous positive constant if a worker is not shirking.

$q_i$ = the probability of getting caught shirking in sector i. This is 0 if the worker is not shirking, and some exogenous positive constant if the worker is shirking.

$b_i$ = the probability of exogenous separation from a job in sector i.

$w_i$ = the nominal wage received from working in sector i.

r = the time preference (discount rate) of the representative worker.

$L_X$ = labor trained in the production of X.

$L_Y$ = labor trained in the production of Y.

$L_X + L_Y = L$ = the size of the labor force.

$P = P_X/P_Y$, the relative price with good Y as numeraire.

n = the number of workers who retrain.

Superscripts U and E denote "unemployed" and "employed", respectively. The following is a synopsis of the results obtained in Chapter 2.

Short-Run Equilibrium:

In the short run, workers cannot switch sectors regardless of changes in price. Given their demands for labor, firms will offer some real wage which, by the non-shirking condition (NSC), leads to some particular level of equilibrium unemployment in each sector.

The short run equilibrium is characterized by the following equations:

$$w_X = P \tag{4}$$

$$w_Y = 1 \tag{5}$$

$$V(w_X, P) = e + \frac{e}{q_X}\left[\frac{b_X}{u_X} + r\right] \tag{6}$$

(7)
$$V(w_Y,P)=e+\frac{e}{q_Y}\left[\frac{b_Y}{u_Y}+r\right]$$

(8)
$$\frac{L_X^E}{1-u_X}=\overline{L_X}$$

(9)
$$\frac{L_Y^E}{1-u_Y}=\overline{L_Y}$$

(4) and (5) are the zero profit conditions, since labor is the only input, marginal product is 1 in both industries, competitive markets are assumed and Y is the numeraire. (6) and (7) are the no shirking conditions for X and Y, respectively. (8) and (9) are the short run labor market constraints.

Equilibrium conditions (4) through (7) can be combined into equations (10) and (11):

(10)
$$V(P,P)=e+\frac{e}{q_X}\left[\frac{b_X}{u_X}+r\right]$$

(11)
$$V(1,P)=e+\frac{e}{q_Y}\left[\frac{b_Y}{u_Y}+r\right]$$

Long Run Equilibrium:

The long run equilibrium differs from the short run equilibrium only by the fact that labor is mobile across sectors, at a cost. This necessitates additional equations to specify the form of these costs.

The training costs are specified as follows: when workers train, they engage in non-paid self-study that gives them a disutility of t(n). This disutility is increasing in n, the number of people who have retrained.

Long run equilibrium is characterized by equations (10) and (11), as well as by equations (12) and (13) below:

(12)
$$\left|V_X^U - V_Y^U\right| \le t(n)$$

(13)
$$\frac{L_X^E}{1-u_X} + \frac{L_Y^E}{1-u_Y} = \bar{L}$$

Equation (12) specifies that the difference in utilities of being unemployed (searching for work) in each sector is equal to the cost of retraining. This ensures that no workers have incentive to retrain in equilibrium. The cost of switching sectors t(n) increases in n. Equation (13) is the adding-up constraint for the labor force.

The utility of being trained but unemployed in sectors X and Y respectively is $V_X^U$ and $V_Y^U$. The utility of being untrained in either sector is assumed to be 0. The utility of engaging in training, as noted above, is -t(n). It is further assumed that $\max\{V_X^U, V_Y^U\} - t(L) > 0$, so that each worker chooses to train initially and no workers are untrained in autarky equilibrium.

**Lemma 1:** Autarky price is given by $(K+1)/(1-\theta K)$, where

(14)
$$K = \theta_Y e \left( \frac{r+b_X}{q_X} - \frac{r+b_Y}{q_Y} \right)$$

Proof: See Chapter 2.

Short Run and Long Run Consequences of Trade on Welfare:

At autarky price there exists some unemployment in both sectors. Since we are starting from long-run equilibrium, this unemployment is strictly frictional; offering workers retraining would not alleviate it because workers are uninterested in switching sectors even if it were possible. Only through a change in the relative price (e.g. through trade) or in some parameter governing sector-specific unemployment levels will the production point shift (thereby introducing structural unemployment[1]).

In Chapter 2, we used the following numerical example to demonstrate that in an economy characterized by this model:

a) Trade can hurt welfare in the short run;

b) Given long run adjustment, trade can be beneficial in the long run;

c) Trade adjustment assistance is justifiable.

A specific example:

Suppose that $L=1000$

$e=r=b_X=b_Y=q_X=q_Y=1/10$

$\theta_X=\theta_Y=\theta=1$

Using Lemma 1, autarky price $P_A=1$.

[1] Before such a change occurs, each worker is in the sector that they see as the best one to be in, under the circumstances, hence there is no structural unemployment. As we will see below, however, after such a change takes place, structural unemployment is created and some structural unemployment can even persist in the long run.

Solving for unemployment rates from the no shirking conditions (10) and (11),

(15)
$$u_X=\frac{eb_X}{V(P,P)q_X-e(q_X+r)} \qquad u_Y=\frac{eb_Y}{V(1,P)q_Y-e(q_Y+r)}$$

$$u_X=u_Y=\frac{1/10*1/10}{1/2*1/10-1/10*2/10}=\frac{1}{3}$$

The income consumption curve is Y=X. Since $D_X/D_Y=S_X/S_Y$ (relative supply always equals relative demand in autarky), it follows that $L_X(1-u_X)/L_Y(1-u_Y)=1$. Therefore, $L_X/L_Y=1$ and $L_X=L_Y=L/2=500$.

Welfare is defined as

(16)
$$W=\left(V_X^U L_X^U\right)+\left(V_X^N L_X^E\right)+\left(V_Y^U L_Y^U\right)+\left(V_Y^N L_Y^E\right)$$

As determined in Chapter 2, we know that in equilibrium, given the assumed preferences,

(17)
$$V_X^U=\frac{P}{r\theta_Y(1+\theta P)}-\frac{(r+b_X+q_X)e}{rq_X}$$

(18)
$$V_X^N=\frac{P}{r\theta_Y(1+\theta P)}-\frac{e}{(r+b_X)}-\frac{b_X e(r+b_X+q_X)}{q_X r(r+b_X)}$$

(19)
$$V_Y^U=\frac{1}{r\theta_Y(1+\theta P)}-\frac{(r+b_Y+q_Y)e}{rq_Y}$$

(20)
$$V_Y^N=\frac{1}{r\theta_Y(1+\theta P)}-\frac{e}{(r+b_Y)}-\frac{b_Y e(r+b_Y+q_Y)}{q_Y r(r+b_Y)}$$

In autarky, therefore,

$$V_X^U=\frac{1}{(1+1)*1/10}-\frac{(1/10+1/10+1/10)*1/10}{1/10*1/10}=5-3=2=V_Y^U$$

$$V_X^N=5-\frac{1}{2}-\frac{3}{2}=3=V_Y^N$$

Using equation (16), autarky welfare in our example is

$$W=2\left[\frac{500}{3}*2+\frac{1000}{3}*3\right]=2666\frac{2}{3}$$

Short run trade:

Suppose that with trade, price falls to 1/2. Now,

$$u_X=\frac{1/10*1/10}{1/3*1/10-1/10*(1/10+1/10)}=\frac{3}{4} \qquad u_Y=\frac{1/10*1/10}{2/3*1/10-1/10*(1/10+1/10)}=\frac{3}{14}$$

$$V_X^U=\frac{10}{3}-3=\frac{1}{3} \qquad V_Y^U=\frac{20}{3}-3=3\frac{2}{3}$$

$$V_X^N=\frac{10}{3}-2=1\frac{1}{3} \qquad V_Y^N=\frac{20}{3}-2=4\frac{2}{3}$$

Again using equation (16), short run trade welfare in our example equals

$$W=500\left[\frac{3}{4}*\frac{1}{3}+\frac{1}{4}*\frac{4}{3}+\frac{3}{14}*\frac{11}{3}+\frac{11}{14}*\frac{14}{3}\right]=2517\frac{6}{7}$$

With trade, welfare has fallen in the short run.

Long run trade:

Suppose that the retraining function t(n) is of the form[2]

$$t(n)=\frac{5\sqrt{1000+n}}{54}$$

Parenthetically, the training function is $\sqrt{n}$ times 5/54. The 1000 workers initially train, so that before any retraining takes place, t(n) is up to $\sqrt{1000}$ times 5/54. The retraining function becomes the function above.

From the long run equilibrium condition given by equation (12), we know that in our example,

$$t(n^*)=V_Y^U-V_X^U=\frac{11}{3}-\frac{1}{3}=\frac{10}{3}$$

Using the retraining function above, we find that n*=296. Therefore, this particular retraining function implies that 296 workers retrain from sector X to sector Y in the long run when price falls to 1/2.

When price falls, long run trade welfare equals

(21) $$W=u_X V_X^U(\overline{L_X}-n)+(1-u_X)V_X^N(\overline{L_X}-n)+u_Y V_Y^U(\overline{L_Y}+n)+(1-u_Y)V_Y^N(\overline{L_Y}+n)-nt(L+n)$$

Plugging in the numbers from our example,

$$W=796\left[\frac{3}{14}*\frac{11}{3}+\frac{11}{14}*\frac{14}{3}\right]+204\left[\frac{3}{4}*\frac{1}{3}+\frac{1}{4}*\frac{4}{3}\right]-296*\frac{10}{3}=2676\frac{3}{7}$$

With trade, welfare has risen above autarky levels in the long run.

[2] A discussion of this assumption, as well of different forms for training costs, can be found in Chapter 2.

Note that even in long run equilibrium, due to positive retraining costs, unemployed workers in sector X would prefer to be in sector Y if retraining costs were lower. This implies persistent structural unemployment even in the long run; the autarky situation of exclusively frictional unemployment does not return.

Enough workers do not retrain endogenously. To demonstrate that n* is not the optimal n, we take the derivative of equation (21) with respect to n:

(22) $$\frac{dW}{dn}=u_Y V_Y^U+(1-u_Y)V_Y^N-u_X V_X^U-(1-u_X)V_X^N-t(L+n)-nt'(L+n)$$

Evaluating this for our example at n*=296,

$$\frac{dW}{dn}=\frac{3}{14}*\frac{11}{3}+\frac{11}{14}*\frac{14}{3}-\frac{3}{4}*\frac{1}{3}-\frac{1}{4}*\frac{4}{3}-\frac{10}{3}-296*\frac{5}{3888}=\frac{1055}{6804}>0$$

The endogenous number of retrainees n* is too low from a social welfare perspective. Welfare could be enhanced by subsidizing retraining.

Why and under what circumstances is n* too low? Equation (22) separates into four basic effects, as follows:

dW/dn = A - B - C - D where

$$A=u_Y V_Y^U+(1-u_Y)V_Y^N \quad B=u_X V_X^U+(1-u_X)V_X^N \quad C=t(L+n) \quad D=nt'(L+n)$$

A represents the social benefit of having one additional worker in sector Y. B represents the social benefit of having one additional worker in sector X. C is the explicit cost of retraining the nth worker. D is the increase in costs caused by retraining the nth worker to all of the other workers in the process of retraining.

A-B equals the marginal social gain of retraining any sector X worker to sector Y. C+D equals the marginal social cost of retraining any worker from one sector to the other. These differ from the private marginal costs and benefits of retraining. The marginal individual who wishes to retrain is necessarily unemployed, and she becomes an unemployed worker in the new sector for which she retrains. Therefore, she is comparing $V_X^U$ to $V_Y^U$-t(n) in making her decision, as in equation (12).

By the no shirking conditions (10) and (11), any worker who leaves the Y sector does not affect the unemployment rate. When unemployed workers leave, some employed workers in Y lose their jobs. This affects social welfare but is not taken into consideration by the individual retrainee leaving the sector. Similarly, the social gain to having a worker retrain into sector X differs from that worker's private gain; that worker is unemployed in sector X, but by the no shirk condition, some (fraction of an) unemployed worker in sector X gets a job because of the increase in size of the sector.

Formally,

| | |
|---|---|
| The social gain of retraining is | $u_Y V_Y^U+(1-u_Y)V_Y^N-u_X V_X^U-(1-u_X)V_X^N$ |
| The private gain of retraining is | $u_Y V_Y^U+(1-u_Y)V_Y^U-u_X V_X^U-(1-u_X)V_X^U$ |
| The difference is | $(1-u_Y)(V_Y^N-V_Y^U)-(1-u_X)(V_X^N-V_X^U)$ |

Recognizing that $(V_Y^N-V_Y^U)$ and $(V_X^N-V_X^U)$ are constants, this difference changes as $u_Y$ falls and $u_X$ rises, which in turn happens as price changes.

Similarly, the difference between marginal social cost of retraining and private marginal cost of retraining is $nt'(L+n)$, term D. Too few retrain endogenously if

(23) $$(1-u_Y)(V_Y^N-V_Y^U)-(1-u_X)(V_X^N-V_X^U)>nt'(L+n)$$

### 3. A Formal Comparison of Policy Options

Suppose that a small, closed economy as described above is utilizing public policy tools to maximize welfare in autarky equilibrium. When the country opens up to trade, thus becoming a small, open economy, the following will occur:

(i) Price changes. Assume that it falls.

(ii) The economy moves away from the autarky production point along the market frontier.

(iii) The economy trades to a point on the income consumption curve that intersects with the price line through the new production point on the market frontier.

(iv) The economy moves along the market frontier appropriate to the new, free trade price, until no more workers wish to retrain.

(v) The economy trades to a point on the income consumption curve that intersects with the price line through the new production point.

**Policy Option 1:** a retraining subsidy. Policymakers can subsidize retraining by offering each unemployed sector X worker a retraining subsidy S. Lump sum subsidies are financed by lump sum taxes T that are imposed on each worker equally. In this case, the tax burden is non-distortionary, meaning that the no-shirking conditions of both sectors are unaffected. Recall that the no-shirk condition says that shirking will not occur so long as utility from shirking is no higher than utility from not shirking. Given the Leontief preferences assumed, an equal tax on unemployed and employed alike will lower utilities for each by the same amount, so that unemployment remains unchanged.

To determine labor division between sectors X and Y in autarky ($L_X$ and $L_Y$), recall that autarky production is given by the point where the income consumption curve crosses the market frontier. Given the preferences assumed in equation (1), the income consumption curve is

(24) $$Y=\frac{X}{\theta} \quad so \quad (1-\tilde{u}_Y)L_Y=\frac{(1-\tilde{u}_X)L_X}{\theta}$$

where the tildes denote autarky levels of the unemployment rates.

From (24), it follows that

(25) $$L_X=\frac{\theta(1-\tilde{u}_Y)L_Y}{1-\tilde{u}_X}$$

Using the fact that $L_X+L_Y=L$,

(26) $$L-\frac{\theta(1-\tilde{u}_Y)L_Y}{1-\tilde{u}_X}=L_Y$$

The labor division between the two sectors in autarky can now be obtained by solving (25) for $L_Y$, and again using the fact that $L_X=L-L_Y$. Doing this,

(27) $$L_Y=\frac{(1-\tilde{u}_X)L}{1-\tilde{u}_X+\theta(1-\tilde{u}_Y)}$$

(28) $$L_X=\frac{\theta(1-\tilde{u}_Y)L}{1-\tilde{u}_X+\theta(1-\tilde{u}_Y)}$$

We have assumed a decrease in P with trade. Retraining will take place to satisfy equation (12). With a money retraining subsidy S, equation (12) needs to be modified; training costs are no longer borne by the retrainee alone. In utility terms, the subsidy to a worker is valued the way any other one-time addition to income in the current time period would be. As can be seen from equations (17) through (20), this would be

(29) $$\frac{S}{\theta_Y(1+\theta P)}$$

Using the relationship in equation (12) and the retraining function t(n) in the specific example above,

(30)
$$n=\left[\frac{54}{5}\left(V_Y^U-V_X^U+\frac{S}{\theta_Y(1+\theta P)}\right)\right]^2-1000$$

Utilities of being employed or unemployed in each sector remain unchanged from what they were in equations (17) through (20), save for the last term, as can be seen from equations (31) through (34). With one-time lump sum taxes, each individual suffers an equal utility loss due to the forgone income taxed away. This decreases utility for each individual.

(31)
$$V_X^U=\frac{P}{r\theta_Y(1+\theta P)}-\frac{(r+b_X+q_X)e}{rq_X}-\frac{T}{\theta_Y(1+\theta P)}$$

(32)
$$V_X^N=\frac{P}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_X}-\frac{b_Xe(r+b_X+q_X)}{rq_X(r+b_X)}-\frac{T}{\theta_Y(1+\theta P)}$$

(33)
$$V_Y^U=\frac{1}{r\theta_Y(1+\theta P)}-\frac{(r+b_Y+q_Y)e}{rq_Y}-\frac{T}{\theta_Y(1+\theta P)}$$

(34)
$$V_Y^N=\frac{1}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_Y}-\frac{b_Ye(r+b_Y+q_Y)}{rq_Y(r+b_Y)}-\frac{T}{\theta_Y(1+\theta P)}$$

Unemployment rates in each sector are solved for using (15) and the fact that, given assumed preferences[3],

$$V(P,P)=\frac{P}{\theta_Y(1+\theta P)} \qquad V(1,P)=\frac{1}{\theta_Y(1+\theta P)}$$

[3] See Chapter 2.

Therefore,

$$(35) \qquad u_X = \frac{eb_X\theta_Y(1+\theta P)}{Pq_X - e(q_X+r)\theta_Y(1+\theta P)} \qquad u_Y = \frac{eb_Y\theta_Y(1+\theta P)}{q_Y - e(q_Y+r)\theta_Y(1+\theta P)}$$

Long run welfare is calculated as

$$(36) \qquad W = \left[u_X V_X^U + (1-u_X)V_X^N\right](L_X - n) + \left[u_Y V_Y^U + (1-u_Y)V_Y^N\right](L_Y + n) - n*t(n) + \frac{nS}{\theta_Y(1+\theta P)}$$

where the V terms denote utilities for employed and unemployed individuals in both sectors, given by equations (31) through (34).

Since lump sum taxes enter into the utility functions identically for each individual, the total effect on social utility of imposing the lump sum taxes can be obtained by multiplying the representative individual effect by the population L. Equation (36) can therefore be rewritten as

$$(37) \qquad W = \left[u_X V_X^U + (1-u_X)V_X^N\right](L_X - n) + \left[u_Y V_Y^U + (1-u_Y)V_Y^N\right](L_Y + n) - n*t(n) + \frac{nS - LT}{\theta_Y(1+\theta P)}$$

where the V terms, as before, denote utilities for employed and unemployed individuals in both sectors before taxes are considered, as given by equations (17) through (20). Since the money amount of lump sum taxes (LT) is exactly equal to the money amount of lump sum subsidies (nS), the last term in equation (37) disappears. This means that increases and decreases in incomes enter into utility functions identically for each individual, and the sum of one-period utility gains for recipients of retraining subsidies exactly offsets the sum of one-period utility losses that each individual incurs through paying lump-sum taxes. The lump sum subsidies and lump sum taxes cancel each other out in the welfare calculation.

Short run welfare is the same as long run welfare, with n=S=T=0.

**Policy Option 2:** import tariffs. Policymakers can ameliorate the effects of opening up to trade by imposing tariffs (T) on imports. This not only decreases trade-related disruptions to the economy, but also brings in tariff revenue which can be distributed to the public in the form of lump sum distributions (S).

Labor division between sectors X and Y in autarky is as determined above by equations (27) and (28). Assuming a decrease in P with trade, and using the relationship in equation (12) and the specific retraining function in the example above,

(38)
$$n=\left[\frac{54}{5}\left(V_Y^U-V_X^U\right)\right]^2-L$$

Utilities of being employed or unemployed in each sector are altered by the tariff and lump sum subsidies. In equations (17) through (20), the numerators of the first terms on the right-hand side represent income and the denominators represent a price index. Lump sum distributions affect income, so they appear in the numerators. Tariffs change relative prices and income, so they appear in both the numerators and the denominators as follows:

(39)
$$V_X^U=\frac{P+T+S}{r\theta_Y(1+\theta P+\theta T)}-\frac{(r+b_X+q_X)e}{rq_X}$$

(40)
$$V_X^N=\frac{P+T+S}{r\theta_Y(1+\theta P+\theta T)}-\frac{e}{r+b_X}-\frac{b_Xe(r+b_X+q_X)}{rq_X(r+b_X)}$$

(41)
$$V_Y^U=\frac{1+S}{r\theta_Y(1+\theta P+\theta T)}-\frac{(r+b_Y+q_Y)e}{rq_Y}$$

(42) $$V_Y^N = \frac{1+S}{r\theta_Y(1+\theta P+\theta T)} - \frac{e}{r+b_Y} - \frac{b_Y e(r+b_Y+q_Y)}{rq_Y(r+b_Y)}$$

Using the same procedure as for (35), but recognizing the effect of tariffs on both income and relative prices, unemployment rates in each sector are given by

(43) $$u_X = \frac{eb_X\theta_Y(1+\theta P+\theta T)}{(P+T)q_X - e(q_X+r)\theta_Y(1+\theta P+\theta T)} \qquad u_Y = \frac{eb_Y\theta_Y(1+\theta P+\theta T)}{q_Y - e(q_Y+r)\theta_Y(1+\theta P+\theta T)}$$

To calculate imports M, we look at consumption minus production of the import good. The budget line for the economy is Y=C-(P+T)X. C is a constant equal to

(44) $$C=(1-u_Y)(\overline{L_Y}+n)+(P+T)(1-u_X)(\overline{L_X}-n)$$

Using equations (27) and (28) to substitute in for labor in sectors X and Y,

(45) $$C = \frac{L[(1-u_Y)(1-\bar{u}_X)+(1-u_X)(1-\bar{u}_Y)(P+T)\theta]}{1-\bar{u}_X+\theta(1-\bar{u}_Y)} + n[1-u_Y-(P+T)(1-u_X)]$$

The income consumption curve is Y=X/$\theta$, as in equation (24). The intersection of the budget line and the ICC gives us the demand for X:

(46) $$\frac{X}{\theta} = C-(P+T)X \quad so \quad X = \frac{\theta C}{1+\theta P+\theta T}$$

Since P is assumed to fall, the economy imports X (and exports Y). Imports must be equal to quantity of X demanded minus quantity of X supplied domestically, as in equation (47).

(47) $$M=\frac{\theta C}{1+\theta P+\theta T}-(1-u_X)(\overline{L_X}-n)$$

Substituting in for C,

(48) $$M=\frac{\theta L[(1-u_Y)(1-\bar{u}_X)-(1-\bar{u}_Y)(1-u_X)]}{(1+\theta P+\theta T)(1-\bar{u}_X+\theta(1-\bar{u}_Y))}+\frac{n[1-u_X+\theta(1-u_Y)]}{1+\theta P+\theta T}$$

Long run welfare can be written as

(49) $$W=\left[u_X V_X^U+(1-u_X)V_X^N\right](L_X-n)+\left[u_Y V_Y^U+(1-u_Y)V_Y^N\right](L_Y+n)-n*t(n)$$

Performing the same transformation as previously to eliminate the lump-sum transfer term, welfare is calculated as

(50) $$W=\left[u_X V_X^U+(1-u_X)V_X^N\right](L_X-n)+\left[u_Y V_Y^U+(1-u_Y)V_Y^N\right](L_Y+n)-n*t(n)-\frac{LS-TM}{r\theta_Y(1+\theta P+\theta T)}$$

Short run welfare is the same as long run welfare, with n=0.

**Policy Option 3:** a production subsidy on the export industry. Policymakers can make retraining more attractive to unemployed workers in the import-competing sector by imposing a production subsidy S on the export industry, financed by (non-distortionary) lump sum taxes. This lowers the unemployment rate in the export sector further, while the unemployment rate in the import-competing sector remains unchanged. The mathematics for this are as follows:

Labor division between sectors X and Y in autarky is as determined by equations (27) and (28).

Assuming a decrease in P with trade, Y becomes the export sector and X becomes the import-competing sector. Using the relationship in equation (12) and the same retraining function t(n) as earlier,

(51)
$$n=\left[\frac{54}{5}\left(V_Y^U-V_X^U\right)\right]^2-L$$

Utilities of being employed or unemployed in the exporting sector (Y) are altered by the subsidy. Production subsidies change income, but do not affect relative prices. Consequently, they only show up in the numerators of (54) and (55). Utilities of each individual are lowered by the lump sum tax, similarly to the situation with a retraining subsidy but different in the sense that this tax is permanent, as opposed to a one-time-only tax. Algebraically, this can be seen by comparing the way that T enters into equations (52) through (55) with equations (31) through (34). In the case of a permanent tax, its effect on utilities is discounted into the future.

(52)
$$V_X^U=\frac{P-T}{r\theta_Y(1+\theta P)}-\frac{(r+b_X+q_X)e}{rq_X}$$

(53)
$$V_X^N=\frac{P-T}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_X}-\frac{b_Xe(r+b_X+q_X)}{rq_X(r+b_X)}$$

(54)
$$V_Y^U=\frac{1-T+S}{r\theta_Y(1+\theta P)}-\frac{(r+b_Y+q_Y)e}{rq_Y}$$

(55)
$$V_Y^N=\frac{1-T+S}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_Y}-\frac{b_Ye(r+b_Y+q_Y)}{rq_Y(r+b_Y)}$$

Using the same procedure as earlier, unemployment rates in each sector are given by

(56)
$$u_X=\frac{eb_X\theta_Y(1+\theta P)}{Pq_X-e(q_X+r)\theta_Y(1+\theta P)} \qquad u_Y=\frac{eb_Y\theta_Y(1+\theta P)}{(1+S)q_Y-e(q_Y+r)\theta_Y(1+\theta P)}$$

Long run welfare is

(57)
$$W=\left[u_X V_X^U+(1-u_X)V_X^N\right](L_X-n)+\left[u_Y V_Y^U+(1-u_Y)V_Y^N\right](L_Y+n)-n*t(n)$$

To eliminate T from this expression (it appears in the V's, as seen from equations (52) through (55)), we can use the fact that tax revenue is completely used for the production subsidy and perform the following transformation on equation (57):

(58)
$$W=\left[u_X V_X^U+(1-u_X)V_X^N\right](L_X-n)+\left[u_Y V_Y^U+(1-u_Y)V_Y^N\right](L_Y+n)-n*t(n)$$
$$+\frac{LT}{r\theta_Y(1+\theta P)}-\frac{S(1-u_Y)(L_Y+n)}{r\theta_Y(1+\theta P)}$$

Short run welfare is the same as long run welfare in (58), with n=0.

**Policy Option 4:** a general production subsidy. A general production subsidy can be imposed, where lump sum taxes are used to subsidize production in both industries. This would lower unemployment in both sectors. The mathematics for this are as follows:

Labor division between sectors X and Y in autarky is determined by equations (26) and (27).

Assuming a decrease in P with trade, and using the relationship in equation (12), as well as the assumed particular retraining function,

(59) $$n=\left[\frac{54}{5}\left(V_Y^U-V_X^U\right)\right]^2-L$$

Utilities of being employed or unemployed in both sectors are altered by the subsidy, which affects income (but not relative prices) in both industries.. As before, lump sum taxes that finance the subsidies will lower the utility of each individual by an equal amount.

(60) $$V_X^U=\frac{P+S-T}{r\theta_Y(1+\theta P)}-\frac{(r+b_X+q_X)e}{rq_X}$$

(61) $$V_X^N=\frac{P+S-T}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_X}-\frac{b_Xe(r+b_X+q_X)}{rq_X(r+b_X)}$$

(62) $$V_Y^U=\frac{1+S-T}{r\theta_Y(1+\theta P)}-\frac{(r+b_Y+q_Y)e}{rq_Y}$$

(63) $$V_Y^N=\frac{1+S-T}{r\theta_Y(1+\theta P)}-\frac{e}{r+b_Y}-\frac{b_Ye(r+b_Y+q_Y)}{rq_Y(r+b_Y)}$$

Unemployment rates in each sector are given by

(64) $$u_X=\frac{eb_X\theta_Y(1+\theta P)}{(P+S)q_X-e(q_X+r)\theta_Y(1+\theta P)} \qquad u_Y=\frac{eb_Y\theta_Y(1+\theta P)}{(1+S)q_Y-e(q_Y+r)\theta_Y(1+\theta P)}$$

Long run welfare is calculated as

(65) $$W=\left[u_XV_X^U+(1-u_X)V_X^N\right](L_X-n)+\left[u_YV_Y^U+(1-u_Y)V_Y^N\right](L_Y+n)-n*t(n)$$

Performing the same transformation as in (58) and (50) in order to eliminate T from the welfare calculation, where it appears through the V's,

$$W = \left[u_X V_X^U + (1-u_X) V_X^N\right](L_X - n) + \left[u_Y V_Y^U + (1-u_Y) V_Y^N\right](L_Y + n) \tag{66}$$
$$- n * t(n) + \frac{TL - S\left[(1-u_Y)(L_Y + n) + (1-u_X)(L_X - n)\right]}{r\theta_Y(1+\theta P)}$$

Short run welfare is the same as long run welfare, with n=0.

Welfare ranking of policies:

At first glance, it would appear that welfare equations (37), (50), (58) and (66) can each be maximized with respect to the policy variable. If this were possible, a ranking could be achieved of the different policies in cases 1 through 4 above. In fact, however, the welfare equations involve many nonlinearities, and analytical solutions to the problem of determining the optimal policy do not exist. Particular values for the parameters make a very large difference.

The summary table below documents the results of simulations where different values for the parameters are used. $W_{SR}$ refers to short run welfare, $W_{LR}$ refers to long run welfare. Case 1 uses the parameter values assumed in the example above; in order to determine how sensitive the welfare ranking of policies was to slight changes in parameter values, I systematically changed one of the exogenous parameters at a time in the X sector. Since the X and Y sectors are symmetric, nothing is gained from changing Y-sector parameters as well.

The Cases in the table below are therefore as follows:

| | | | | |
|---|---|---|---|---|
| Case 1: | | L=1000, | $e=r=b_X=b_Y=q_X=q_Y=1/10$, | $\theta_X=\theta_Y(=\theta)=1$ |
| Case 2: | $q_X=0.2$ | L=1000, | $e=r=b_X=b_Y=q_Y=1/10$, | $\theta_X=\theta_Y(=\theta)=1$ |
| Case 3: | $b_X=0.11$ | L=1000, | $e=r=b_Y=q_X=q_Y=1/10$, | $\theta_X=\theta_Y(=\theta)=1$ |
| Case 4: | $\theta_X=0.9$ | L=1000, | $e=r=b_X=b_Y=q_X=q_Y=1/10$, | $\theta_Y=1$, $\theta=0.9$ |

For each case, short run and long run welfare are entered for optimal values of the policy variable. Asterisks denote corner solutions.

| | Optimal Retraining Subsidies | | Optimal Tariff | | Optimal Production Subsidy on Y | | Optimal Production Subsidy on X,Y | |
|---|---|---|---|---|---|---|---|---|
| | $W_{SR}$ | $W_{LR}$ | $W_{SR}$ | $W_{LR}$ | $W_{SR}$ | $W_{LR}$ | $W_{SR}$ | $W_{LR}$ |
| Case 1 | 2518 | 2786* | 2716 | 2716 | 3125* | 3874* | 4000* | 4000* |
| Case 2 | 3181 | 3375* | 3182 | 3275* | 3834* | 4490* | 4128* | 4353* |
| Case 3 | 2399 | 2531 | 2643 | 2643 | 2997* | 3695* | 3974* | 3956* |
| Case 4 | 2829 | 2929 | 3004 | 3004 | 3462* | 4078* | 4263* | 4263* |

**Table 1**

From table 1, it is immediately apparent that production subsidies dominate tariffs and retraining subsidies as policy options. Furthermore, the optimal production subsidy is invariably a corner solution. The intuition behind this is that unemployment only exists in this model because workers need to be deterred from shirking. The greater the spread between utilities of employed workers and utilities of unemployed workers in a sector, the greater the opportunity cost of being unemployed and therefore the smaller unemployment needs to be. As higher and higher taxes are levied on everyone and employed workers receive the entire tax revenue in the form of higher wages (by the zero profit conditions), the spread in utilities between unemployed and employed workers increases and unemployment necessarily approaches 0.

The simulations also show that retraining subsidies are difficult to welfare rank against tariffs; slight changes in parameters reverse ranking orders. Likewise, general production subsidies are difficult to welfare rank against production subsidies in the export industry since neither subsidy scheme in any way guarantees that the socially optimal number of workers retrains. However, the following propositions can be shown:

**Proposition 1:** If short run welfare declines with trade, an optimum tariff is superior to a retraining subsidy in the short run.

Proof: Since retraining is by definition a long run phenomenon, short-run welfare is unchanged with retraining subsidies. A tariff can restore short run welfare to at least autarky levels, and in many cases higher, as can be seen from the summary table above.

**Proposition 2:** Long run welfare may increase or decrease with a tariff, even if short run welfare is higher with a tariff.

Proof: In Case 2 above, the optimal tariff in the long run is 0. As the tariff is increased, long run welfare declines. In the other three cases this does not hold true.

**Proposition 3:** Long run welfare with an optimal retraining subsidy may be higher or lower than long run welfare with an optimal tariff.

Proof: Cases 1 and 2 are examples where optimal retraining subsidies yield higher long run welfare than optimal tariffs. Cases 3 and 4 are examples where optimal tariffs yield higher long run welfare than optimal retraining subsidies.

**Proposition 4:** Short run and long run welfare with an optimum tariff can be greater than short run and long run welfare with an optimum retraining subsidy.

Proof: See Cases 3 and 4 for examples of this.

**Proposition 5:** A general production subsidy and a production subsidy on the export industry alone cannot be unambiguously ranked.

Proof: See Case 2 for an example where long run welfare is higher with an optimal production subsidy in the export industry than with a general production subsidy. The reverse is true in Cases 1, 3 and 4.

**Proposition 6:** An optimal combination of production subsidies, both general and specific to the export industry, will always provide for greater long run welfare than either an optimal tariff or an optimal retraining subsidy.

Proof: A sufficiently large production subsidy in the export industry results in complete specialization in the export industry. A general production subsidy has no effect on retraining. An appropriate combination of both types of production subsidies will result in the same level of retraining as either the optimal tariff or optimal retraining subsidy. Production subsidies are welfare increasing in this model, since they lower unemployment. Therefore, with the same mix of labor between sectors but much lower unemployment, welfare must be higher than with any tariff or retraining subsidy.

## 4. Summary and Conclusions

This model demonstrates how trade-induced price shocks in an economy can cause decreases in short-run welfare, although long run welfare may increase. It also demonstrates that there exists room for public policy in trying to improve welfare.

Policy alternatives considered include tariffs, worker retraining subsidies and production subsidies. In the context of this model, an analytical solution ranking these policies does not exist. Sensitivity of the results to minor changes in parameter values is documented through a series of simulations, yielding some insight; all policies cannot be unambiguously ranked, but an appropriate use of production subsidies will always provide for greater long run welfare than any tariff or subsidy. In addition, in the short run, tariffs can be useful in decreasing the size of disruptive price shocks.

Policy recommendations would therefore be twofold:

1) If taxes cannot be quickly collected to subsidize production, use tariffs to decrease the size of disruptive price shocks in the short run.

2) In the long run, an appropriate mix of production subsidies is preferred to any other adjustment policy.

# APPENDIX

## APPENDIX

### Putting a third country into the Kreps-Scheinkman (1983) model

Assume a home country demand given by $Q=1-P$.

There are three countries with capacity constraints, competing in price. Assume zero marginal costs of production; this implies expected profit functions of price charged times expected quantity sold[1]. Assume $K_1 \leq K_2 \leq K_3$; country 1 has the smallest capacity of output and country 3 the largest, where $K_i$ represents capacity of country i. Finally, assume efficient rationing as a rationing rule.

Using Davidson-Deneckere's notation and liberally borrowing from their procedure, I begin by assuming exogenously determined capacities and deriving the pricing behavior of countries. After this is done, I shall allow for endogenous capacities in a 2-stage model.

$\Phi_i(p)$ = the price distribution announced by country i. $\phi_i(p)$ is the cumulative density function.

$$\underline{p_i}=\mathit{infinum}[p\,|\,\phi_i(p)>0]$$

$$\overline{p_i}=\mathit{supremum}[p\,|\,\phi_i(p)<1]$$

$\pi_i(p)$ = expected profit for country i when charging price p.

$\psi_i(p)$ = the probability that country i charges price p.

[1] In a dynamic model multiperiod effects can greatly change the form of the profit functions. This model sidesteps such issues by not looking at behavior over time or timing of information reception.

The following seven useful facts hold:

(F.1) In any pure strategy equilibrium all three countries charge the same price.

Proof: Suppose not. One country charges more than the others. If it still sells any output, it must be because the lower priced countries are capacity constrained and cannot satisfy demand at the price(s) they charge. Therefore, lower priced countries could increase profit by raising price by a small amount. If a high-priced country does not sell any output, it can increase profits by lowering price to the level of or a small amount below what a lower-priced country is charging.

(F.2) Pure strategy equilibrium prices are 0 and $1-K_1-K_2-K_3$.

Proof: From (F.1), we know that in any pure strategy equilibrium all three countries charge the same price. Let $p^*$ denote the equilibrium price. If $0 < p^* < 1-K_1-K_2-K_3$ an $\epsilon$ increase in price will raise any country's profit since it can still sell up to capacity. If $p^* > 1-K_1-K_2-K_3$ an $\epsilon$ decrease in price will raise any country's profit, since it has the capacity to sell more and it will undercut the other countries. The price of 0 can also be a pure strategy equilibrium price for the simple reasons originally expressed by Bertrand: if the combined capacities of all three countries equal or exceed quantity demanded at a price of 0, undercutting in price will ultimately drive prices charged by all three countries to the level of marginal cost, i.e. 0.

(F.3) $$\underline{p}_1=\underline{p}_2=\underline{p}_3$$

Proof: Suppose not. Assume $\underline{p}_1 > \underline{p}_2 > \underline{p}_3$ . For all $p \in [\underline{p}_3, \underline{p}_2)$ the biggest country is lowest priced, and therefore sells (in this range of prices) $\min(K_3, 1-p)$. It would not pay for the country to charge a price so that $K_3 < 1-p$ since the country could raise price by some small amount without losing customers. So $K_3 \geq 1-\underline{p}_3$ or $\underline{p}_3 \geq 1-K_3$ . Since the biggest country is always the lowest priced at $\underline{p}_3$ and since $\underline{p}_2 > \underline{p}_3$ this country must not have an incentive to raise price by a small amount. Hence,

$$\frac{\delta\pi}{\delta p}\Big|_{p=\underline{p}_3}=0$$

But this implies that profits are at a global maximum at $\underline{p}_3$, so the country doesn't want to charge any other price. So it announces a pure strategy of charging this price. By (F1), this causes a contradiction; the countries are pursuing pure strategies and yet they are charging different prices. [If country 2 were the low priced country, by similar reasoning we could argue that $\underline{p}_2 \geq 1-K_2$ , which of course is not as low as $1-K_3$ since country 3 is the largest country. Therefore, the minimum mixed strategy equilibrium price is given by $\underline{p}_3$ and it isn't necessary to test price configurations where $\underline{p}_1$ or $\underline{p}_2$ are assumed to be lower than the prices of the other countries].

(F.4) $$\psi_i(p)\psi_j(p)=0 \quad \forall p\in[\underline{p},\bar{p}], \ \ \forall i,j$$

Proof: Suppose that $\psi_i(p)=C_i>0$ for two or more i, for some p. By definition $\Phi_i(p)$ for one country must maximize expected profits given $\Phi_j(0)$ for all other countries, and $\pi_i(p)$ must be the same for all p in the support of $\Phi_i(p)$. Since $\psi_i(p)=C_i>0$ for at least two countries (call them A and B), no country j (which can be A, B or C) can play in a small neighborhood below p since either A's or B's profit would not be constant over the neighborhood (since the countries divide up market demand at p but country A or country B do not have to share the market if either one charges p-$\epsilon$). However, the strategy $\psi_i(p)=0$, $\psi_i(p-\epsilon)=C_i$ for some arbitrarily small $\epsilon>0$ clearly dominates the strategy $\psi_i(p)=C_i$, $\psi_i(p-\epsilon)=0$ given that $\psi_j(p)=C_j$ for at least one country j. Hence, if $\psi_i(p)\psi_j(p)>0$ for some p then at least two countries are not profit maximizing. This fact rules out two or more mass points at the same price. Kreps and Scheinkman (1983) did not include this result in their analysis.

(F.5) $$\overline{p_1}=\overline{p_2}=\overline{p_3}$$

Proof: By contradiction: Suppose that $p_i > p_j$ for some i and j. In this case, a gap exists in country i's support (since country i will only play one price above country j). From the arguments in the proof of (F.4) above, country j has an incentive to play in the interval $(p_j,p_i)$, so country i must not be profit maximizing when it chooses to play $p_i$. When country j plays in the interval $(p_j,p_i)$ by charging $\epsilon$ below $p_i$, it expects a higher profit than it could get by charging $p_j$ and certainly higher than if it were to charge $p_i$. But if this is the case, country i has no incentive to actually charge $p_i$! Hence, it follows that $p_i=p_j$. This lemma is very useful in generalizing the Kreps-Scheinkman result to more than two countries; without it I am not convinced that their result can be generalized.

(F.6) No mass points exist in any support.

Proof: A similar argument to the one used in proving (F.5) can be used to prove that no gaps exist in the interior of any country's support. If such a gap did exist, the other countries would have an incentive to play in this interval and hence at least one country would not be profit maximizing.

(F.7) $$1-K_1-K_2-K_3 \leq p \leq 1-K_3$$

Proof: If all three countries were charging $p=1-K_1-K_2-K_3$, they would all sell at capacity. There is therefore no incentive for any country to charge a price lower than $1-K_1-K_2-K_3$. This part of the lemma essentially states that in a mixed strategy equilibrium at least one country must be selling below capacity.

Next, suppose that $p>1-K_3$. Since country 3 never charges higher than $p=1-K_3$ and satisfies demand completely at this price, neither of the smaller two countries would charge higher than this with any positive probability.

Now that the useful facts above have been established, we shall begin by finding all possible pure strategy equilibria.

Recall: Country 1 was defined to be the smallest country, country 2 the middle and country 3 the largest country (with the highest capacity).

**Lemma 1:** If $K_1+K_2 \geq 1$ a pure strategy equilibrium exists with $p_1=p_2=p_3=0$. If $K_1+K_2+2K_3 \leq 1$ a pure strategy equilibrium exists with $p_1=p_2=p_3=1-K_1-K_2-K_3$. No pure strategy equilibrium exists for other values of $K_1$, $K_2$ and $K_3$.

Proof: From (F.1) we know that in any pure strategy equilibrium all countries charge the same price and from (F.2) we know that the only prices sustainable as equilibrium prices are 0 and $1-K_1-K_2-K_3$.

If all three countries charge $p^*=0$ it must be the case that any country that raises its price sells nothing (otherwise they would have nonzero profits and would do better than by charging $p^*=0$). For the smallest country contingent demand would be:

$D(p)=1-p-K_2-K_3$ for all $p>0$.

For a pure strategy equilibrium we must have

$1-\epsilon-K_2-K_3\leq 0$ for all $\epsilon>0$, or $K_2+K_3\geq 1$.

For the largest country contingent demand would be:

$D(p)=1-p-K_1-K_2$ for all $p>0$.

For a pure strategy equilibrium we must have

$1-\epsilon-K_1-K_2\leq 0$ for all $\epsilon>0$, or $K_1+K_2\geq 1$.

This is a stronger condition than $K_2+K_3\geq 1$. Hence, $p_1=p_2=p_3=0$ is an equilibrium iff $K_1+K_2\geq 1$.

If all countries charge $p^*=1-K_1-K_2-K_3$, all three countries sell at capacity and therefore no country has an incentive to lower price. For this to be a pure strategy equilibrium profits must be lower if any country charges $p>p^*$. But, for the smallest country this requires $(p^*+\epsilon)(1-p^*-\epsilon-K_2-K_3)\leq p^*K_1$ for all $\epsilon>0$ or, $2K_1+K_2+K_3\leq 1$; and, for the largest country this requires $(p^*+\epsilon)(1-p^*-\epsilon-K_1-K_2)\leq p^*K_3$ or, $K_1+K_2+2K_3\leq 1$.

The second condition is stronger than the first and therefore $p_1=p_2=p_3=1-K_1-K_2-K_3$ is an equilibrium iff $K_1+K_2+2K_3\leq 1$. QED.

For $1-K_2-2K_3\leq K_1+K_2\leq 1$ equilibrium can only be in mixed strategies. In any mixed strategy expected profit for country 3 when charging price p is given by:

$$(1.1)\quad \pi_3(p\,|\,\Phi_1(p),\Phi_2(p))=p\{\Phi_1\Phi_2\min(K_3,1-p)+\Phi_1(1-\Phi_2)\min(K_3,1-p-K_2)$$
$$+\Phi_2(1-\Phi_1)\min(K_3,1-p-K_1)+(1-\Phi_1)(1-\Phi_2)\min(K_3,1-p-K_1-K_2)\}.$$

We begin construction of the mixed strategy equilibrium by finding the high price p. If the large country charges p it is the highest priced country with probability one (by F.5) and its profits are

(1.2) $$\pi_3(\bar{p})=\bar{p}(1-\bar{p}-K_1-K_2)$$

The derivative of the profit function at this point cannot be greater than 0, since this would signify that the country has an incentive to raise price even further. Therefore, it follows that

(1.3) $$\bar{p}\geq\frac{(1-K_1-K_2)}{2}$$

Since $\Phi_j$ is a distribution function, it must be the case that $\Phi_j'(p)\geq 0$ for all

$$p\in[\underline{p},\bar{p}]$$

From (1.1) we have:

$$\phi_1=\frac{\frac{\pi_3}{p}-\phi_2\min(K_3,1-p-K_1)-(1-\phi_2)\min(K_3,1-p-K_1-K_2)}{\phi_2\min(K_3,1-p)-\phi_2\min(K_3,1-p-K_1)+(1-\phi_2)\min(K_3,1-p-K_2)-(1-\phi_2)\min(K_3,1-p-K_1-K_2)}$$

$$\phi_2=\frac{\frac{\pi_3}{p}-\phi_1\min(K_3,1-p-K_1)-(1-\phi_1)\min(K_3,1-p-K_1-K_2)}{\phi_1\min(K_3,1-p)-\phi_1\min(K_3,1-p-K_1)+(1-\phi_1)\min(K_3,1-p-K_2)-(1-\phi_1)\min(K_3,1-p-K_1-K_2)}$$

For j = 1,2, in order for us to have

$$\lim\phi_j'(p)\geq 0$$

it must be true that

(1.4) $$\bar{p} \leq \frac{(1-K_1-K_2)}{2}$$

Comparing (1.3) and (1.4) yields

(1.5) $$\bar{p} = \frac{(1-K_1-K_2)}{2}$$

and from (1.2):

(1.6) $$\pi_3 = \frac{(1-K_1-K_2)^2}{4}$$

$\pi_3$, the expected profit, must be constant throughout the interval $[\underline{p},p]$ and thus we now have enough information to solve for $\underline{p}$. From (1.1) and (1.6) we now have:

$$\pi_3(\underline{p}) = \underline{p}\min(K_3, 1-\underline{p}) = \frac{1}{4}(1-K_1-K_2)^2$$

which implies:

(1.7) $$\underline{p} = \begin{cases} \frac{1}{2}\left[1+\sqrt{1-(1-K_1-K_2)^2}\right] & \text{if } K_3 \geq \frac{(1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}} \\ \frac{(1-K_1-K_2)^2}{4K_3} & \text{if } K_3 \leq \frac{(1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}} \end{cases}$$

Since $\pi_1(\underline{p}) = \underline{p}K_1$ (from F.7), we can solve for $\pi_1$ for different values of $K_2$ and $K_3$. Likewise for $\pi_2$. So from (1.7),

(1.8) $$\pi_1 = \begin{cases} \frac{K_1}{2}\left[1+\sqrt{1-(1-K_1-K_2)^2}\right] & \text{if } K_3 \geq \frac{1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}} \\ \frac{K_1(1-K_1-K_2)^2}{4K_3} & \text{if } K_3 \leq \frac{(1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}} \end{cases}$$

$$\text{(1.9)} \qquad \pi_2=\begin{cases} \dfrac{K_2}{2}\left[1+\sqrt{1-(1-K_1-K_2)^2}\right] & \text{if } K_3 \geq \dfrac{1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}} \\ \dfrac{K_2(1-K_1-K_2)^2}{4K_3} & \text{if } K_3 \leq \dfrac{(1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}} \end{cases}$$

Finally, $\Phi_1(p)$, $\Phi_2(p)$ and $\Phi_3(p)$ may be derived from (1.1), (1.7), (1.8) and (1.9) and $\psi_j(p)$ may be derived by evaluating $\Phi_j(p)$ at p for $j=2,3$ and subtracting from 1. The results of this section are summarized in Theorem 1:

**Theorem 1:** If (a) three countries compete in prices with fixed capacities, $K_1 \leq K_2 \leq K_3$; (b) countries face a linear demand curve $Q=1-p$; (c) marginal cost of production is zero; and (d) efficient rationing is assumed for the high priced country's contingent demand curve, then the equilibrium prices and profits are given by:

Case 1: If $K_1+K_2 \geq 1$ then $p_1=p_2=p_3=0=\pi_1=\pi_2=\pi_3$ with all three countries playing a pure strategy.

Case 2: If $K_1+K_2+2K_3 \leq 1$ then $p_1=p_2=p_3=1-K_1-K_2-K_3$ and $\pi_1=K_1(1-K_1-K_2-K_3)$; $\pi_2=K_2(1-K_1-K_2-K_3)$; $\pi_3=K_3(1-K_1-K_2-K_3)$ with all three countries playing a pure strategy.

Case 3: If $K_1+K_2+2K_3 \geq 1$ and

$$K_3 \geq \frac{(1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}}$$

then all three countries play a mixed strategy with:

$p=(1-K_1-K_2)/2$ $\quad \underline{p}=0.5+[1-(1-K_1-K_2)^2]^{1/2}$ $\quad \pi_3=(1-K_1-K_2)^2/4$ .

$\pi_1=K_1[1+(1-K_1-K_2)^2]^{1/2}/2$ $\quad \pi_2=K_2[1+(1-K_1-K_2)^2]^{1/2}/2$

Case 4: If $K_1+K_2+2K_3 \geq 1$ and

$$K_3 \leq \frac{(1-K_1-K_2)^2}{2+2\sqrt{1-(1-K_1-K_2)^2}}$$

then all three countries play a mixed strategy with

$p=(1-K_1-K_2)/2 \quad \underline{p}=(1-K_1-K_2)^2/4K_3 \quad \pi_3=(1-K_1-K_2)^2/4$

$\pi_1=K_1(1-K_1-K_2)^2/4K_3 \quad \pi_2=K_2(1-K_1-K_2)^2/4K_3$

Proof: See discussion above.

Note that one of the pure strategy equilibria is identical to the Bertrand solution and the other one is identical to the Cournot solution (provided that the capacities are symmetric and we are at the boundary of the pure strategy region).

The Two Stage Game:

Suppose countries simultaneously choose their capacity levels and then, once capacity is fixed, they compete in prices; what sort of equilibrium is achieved? To answer this question we must compute the Nash equilibrium which is achieved when countries compete in capacity while realizing that the profit rates for any combination $(K_1,K_2,K_3)$ are given in Theorem 1.

In order to determine country 1's reaction function we must calculate the optimal value of $K_1$ for any given values of $K_2,K_3$.

The following two observations greatly simplify the task:

a) Profits are increasing throughout the pure strategy region in which countries are capacity constrained.

b) Profits are independent of the largest country's capacity in the mixed strategy region. Thus, assuming capacity is not free, it never pays to be the biggest competitor if you are in the mixed strategy region.

There are two cases to consider:

Case 1: $K_3 \leq 1/4$ . Observation (a) tells us that country 1 and country 2 never choose $K_1 < 1/4$ or $K_2 < 1/4$ and observation (b) guarantees that the optimal choice of $K_1$ and $K_2$ is $(1-K_3)/3$. Thus, countries one and two always choose to be on the boundary of the pure strategy region. Note that if capacity is costly it may pay to choose $K_1^* < (1-K_3)/3$. If $\lambda$ denotes the per unit cost of capacity then $K_1^*$ will maximize $K_1(1-K_1-K_2-K_3)-\lambda K_1$. In either case the reaction functions in K space in this region are identical to the reaction functions in quantity space in a Cournot game. This is the key to the Kreps-Scheinkman result, which evidently generalizes into analysis with more than two countries.

Case 2: $K_3 > 1/4$ . In this case it may pay countries 1 and 2 to increase their capacity levels enough so that we end up in the mixed strategy region. However, by observation (b) it never pays to choose capacities greater than $K_3$. Does it ever pay to choose capacities equal to $K_3$? The answer to this question turns out to be no. Note that if $K_3 > 1/4$, $\pi_i'(K_i | K_j, K_3)$ for $i,j = 1,2$ when $K_1 = K_2 = K_3$ is strictly negative (in both mixed strategy regions). Thus, if $K_3 > 1/4$ the optimal value of $K_1$ (and $K_2$) is strictly less than $K_3$ (if capacity is costly this result is strengthened).

We now have enough information to calculate the equilibrium in the two-stage game. For $K_i \geq 1/4$ the reaction curves are given by $K_i^* = (1-K_j)/3$. They intersect at $K_1 = K_2 = K_3 = 1/4$, the Cournot solution.

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