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Resistance to New Technology and Trade Between Areas*

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The theme of this article is that competition, here modeled as the movement of goods between two areas, reduces resistance to new technology and, hence, leads to increased technology adoption and wealth. The article develops a model in which the extension of markets leads to reductions in activities that block new technologies.

Why build a model that has a new role for competition in creating wealth? As an empirical matter, the introduction of markets brings tremendous increases in wealth. (See, for example, Rosenberg and Birdzell 1986.) This has been observed over and over and is again being witnessed, for example, in Southeast China. However, there is still plenty of uncertainty among economists as to why competition, or the extension of markets, has been so successful in creating wealth. Two mechanisms are clearly at work: the extension of markets leads to increases in specialization and facilitates comparative advantage. But it is not clear that these mechanisms alone account for the tremendous success of markets. Other mechanisms may be as, or even more, important.

Why introduce the particular mechanism we explore—that an extension of markets leads to reductions in resistance to new technology? Our motivation here is also primarily empirical, that is, based on observation. We noticed a large number of industries in which the extent of the market for the industry's good explained, in large part, the degree to which new ways of producing the good were resisted. Below, we present a few brief industry case studies—for the construction, automobile, and dairy industries—that make this point. The U.S. construction industry is one in which, because of the nontransportable nature of the good, the extent of the market is narrow. Given this, we are not surprised by the significant resistance to new production techniques that is found in this industry. Though the auto industry is one in which the good can be moved across areas, the industry in the United States has been relatively more open to competition than has the European car industry. In our view (and in the view of industry observers), the more rapid adoption of Japanese *lean production* methods in the United States is due to greater resistance to these methods in Europe that resulted from the European car market being relatively more closed to competition—that is, to Japanese cars. The final example we discuss below is one in which resistance to a new technology in the U.S. dairy industry—namely, the use of a growth hormone genetically engineered to increase the milk production of cows—failed because the extent of the market was too great.

The model we develop is a simple general equilibrium model that determines the extent of resistance to new technology at each of a number of (usually two) locations or areas. We ask how the extent of resistance depends on the extent of markets. By *extent of markets,* we simply mean whether or not goods can move between the two areas.

In the model, the sources of resistance to new technology are groups of individuals who stand to lose rents if a new technology is introduced. In the real world, these rents take a number of forms: for example, returns to skills in a technology that is less efficient than the new one or returns to a privileged position granted, say, by the government. In the model, we take the rents to be returns to skills in a less efficient technology. Hence, we use the term *skilled groups* to refer to the people who stand to lose rents if the new technology is adopted. We assume that the skilled groups can use a regulatory/political process to attempt to block the new technology. To keep matters as simple as possible, that process is largely kept in the background in this article. We assume the process is such that the skilled groups have the means, at certain resource costs, of constructing barriers to the efficient technology.

We first study a single area, area *A,* showing that under some conditions skilled groups erect barriers to new technology. We then study a two-area world. To make our argument as simply as possible, we study a world in which the two areas, areas *A* and *B,* are identical in all respects except that in area *B* the costs to blocking technology are prohibitively expensive. Hence, blocking does not happen in area *B.* If markets are limited—that is, if goods do not move between *A* and *B*—then under some conditions (the same conditions as above) the new technology is blocked in *A.* If the technology is blocked in *A,* then we show that if there is an extension of markets—that is, if goods do move between *A* and *B*—the resistance to new technology in area *A* is broken (under some conditions).

The argument for why resistance is broken is simple. To be concrete, it might be helpful to think of area *A* as Europe and *B* as Japan. Suppose the new technology is the lean production methods used in the auto industry. Suppose initially that *A,* or Europe, is closed to Japanese auto imports and that it bans the use of lean production in its factories (through rigid work-rule laws, for example). Now suppose that trade with *B,* or Japan—which by assumption has no barriers to lean production—is introduced. With the extension of markets, cars produced with the more efficient technology in Japan will be exported to Europe. The exported cars will displace the cars produced in Europe with the inefficient technology. Hence, those with a vested interest in the inferior technology in Europe will gain nothing from the rigid work-rule laws. Therefore, the extension of markets diminishes the incentive to keep the work-rule laws. The model, then, makes clear that competition can reduce resistance to technology.

The idea that competition may reduce resistance to new technology is not, of course, new. For example, Olson (1982, especially chap. 5) has discussed how trade and factor mobility may limit the effectiveness of special interest groups. And it has long been recognized that special interest groups may attempt to block new technology; since the 19th century, for example, the word *Luddite* has been used to refer to such a group. (For an extensive discussion of resistance to new technology, see Mokyr 1990.) What is new in this article is an exploration, in a formal model, of the link between how easily goods move between areas and whether or not special interest groups resist new technology. Before we can provide answers to such quantitative questions as why markets have been so successful in creating wealth, we must develop formal models.

A property of competition, then, is that it reduces resistance to new technology. But why, then, would skilled groups ever agree to an extension of markets, as they sometimes do? (Witness the recent increase in the number of regional free-trade zones.) It turns out that this question too can be understood in the context of the model. To see the answer suggested by the model sketched above, consider the interest of a particular skilled group in promoting competition. Competition will break its barrier to new technology, clearly a bad prospect for the group, everything else equal. But competition will have the same effect on the barriers of other skilled groups. They, too, will reduce their resistance to new technology. For the original group, that is a good prospect, everything else equal. The second effect may be so good that it offsets the losses from the first effect of competition, that is, from its influence on the skilled group's own barrier. If the second effect dominates, then all groups can agree to extend markets and competition. This analysis leads to the conclusion that competition, or extension of markets, may be an efficient way to commit to removing barriers to new technology.

We study this second question—Why does competition spread?—in a slightly different model than the first. In this second model, areas A and B are identical in all respects, including their resistance technologies. In this setup, we ask, When will skilled groups in the two areas vote to allow goods to move between areas?

The remainder of the article is structured as follows. We begin by discussing the model environment. We then discuss the equilibrium and the resistance to new technology in a one-area world. After this, we show that an extension of markets reduces resistance to new technology. After this, we show that under some conditions all skilled groups can agree to an extension of markets. This material completes the formal presentation of the model. We then turn to discuss the examples mentioned above. The final section presents some discussion of related literature and future research.

The Model Environment

In this section, we describe the one-area world. We begin with a very brief overview of the model. We then describe preferences, endowments, and technologies. Finally, we give a formal statement of the timing of events.

An Overview

In the model economy, there are two periods. At the start of the first period, there is a technology—the old technology—for producing each good. Some individuals are skilled in the old technology. During the first period, another technology for producing each good becomes available—the new technology. This technology can be adopted at zero cost. Skilled groups decide whether or not to resist the new technology. After this decision, the model economy enters the second period, during which goods are produced. The goods are produced with the old technology and, if it has not been blocked, the new technology.

Preferences

Individuals in the model consume $k + 2$ goods. There are three types of goods. One is food. We denote the quantity of food by the variable x. Next, there are k manufactured goods. We denote the quantity of manufactured good i by the variable y_i, $i = 1,...,k$. The last good is leisure. We denote quantities of leisure by the variable ℓ.

All individuals in the economy have the same utility function over commodity bundles, given by

$$(1) \qquad U(x,y_1,y_2,...,y_k,\ell) = [u(x,y)][h(\ell)] = (x^{\alpha}y_1^{\beta}y_2^{\beta}...y_k^{\beta})[h(\ell)]$$

where $\alpha > 0$, $\beta > 0$, $\alpha + k\beta = 1$, and $h(\ell)$ is strictly increasing. The utility function is the product of a term that depends on the consumption of food and manufactured goods and a term that depends on leisure. The utility of goods consumption is Cobb-Douglas. The k manufactured goods enter symmetrically in the utility function.

Endowments

There is a unit measure of individuals in the economy. Each individual is endowed with one unit of labor in each period. In period 1, the endowment is used for either leisure or resistance activities. The nature of resistance activities is described later. In period 2, the endowment is used to produce either food or manufactured goods.

Individuals are also endowed with skills for producing goods. Everyone is assumed to have the same skill in producing food, but to differ in their skill for producing manufactured goods. It will be simpler to describe these skills after the production functions are introduced.

Technology

□ Production

Let l denote the input of labor into the production of goods. We assume that the production of food takes place under constant returns to scale. We also normalize units so that one unit of labor produces one unit of food; that is, $x = l$.

Next, consider the production functions for manufactured goods. As suggested above, there is initially an old technology for producing each manufactured good i. Some people are skilled in the old technology for producing good i; others are unskilled. The output of an unskilled laborer using the old technology is $y_i = l$. The output of a *skilled* laborer using the old technology is $y_i = \theta l$, where $\theta > 1$.

As also mentioned above, a *new* technology for producing good i becomes available during the first period. Since the technology is new, all individuals are unskilled in this method. The output of an unskilled laborer using the new technology is $y_i = \gamma l$, where $\gamma > 1$. We assume that $\gamma > \theta$. This condition says that a unit of unskilled labor applied to the new technology is more productive than a unit of skilled labor applied to the old technology. Finally, we assume that all manufactured goods have the same production possibilities. (That is, neither θ nor γ is indexed by i.)

We now describe the endowments of skills in the old technologies. Some individuals are unskilled in the old technology for each good i. We call this group of individuals the *unskilled group.* Those not in this group are in the *skilled group.* A member of the skilled group is skilled in producing only one of the manufactured goods. The group of individuals skilled in producing good i we call *skilled group i*. We assume that the fraction of the population in skilled group i is the same for all i and denote this fraction as η. Hence, $k\eta$ is the fraction of the population that belongs to some skilled group. Let $\lambda \equiv k\eta$. Then the fraction of the population in the unskilled group is $1 - \lambda$.

□ Resistance

Skilled group i has the ability to construct a barrier to the new technology for producing good i, meaning that no individual can use the new technology (including the members of skilled group i). We now describe the process by which barriers to new technology are erected. The members of skilled group i decide, as a group, whether or not to engage in resistance activity to block the new technology. We denote the action taken by group i as a_i, $a_i \in \{b,n\}$, where $a_i = b$ means that the skilled group erects a barrier (b for *barrier*) to the new technology and $a_i = n$ means that the skilled group does not erect a barrier (n for *no barrier*).

The members of skilled group i must spend resources to block the new technology. We assume that the group must spend a total of ρ units of labor endowment in order to block the technology. Let $r = \rho/\eta$. Then if each member of skilled group i contributes r units of labor endowment, the new technology is blocked. We assume that the group can act collectively in getting its members to contribute to the common cause. Since each individual is endowed with one unit of labor in period 1, an individual's leisure is $\ell = 1$ if no barrier is erected and $\ell = 1 - r$ otherwise. (We assume that $r \leq 1$.)

Timing of Events

We now describe the sequence of events in the model. There are two periods. In the first period, a new technology becomes available. Each skilled group i chooses to erect a barrier or not; that is, it chooses $a_i \in \{b,n\}$. Each skilled group i makes its choice to maximize the utility of the individuals in skilled group i. The choices a_i are made simultaneously. In the second period, all agents in the economy act competitively. The nature of the competitive equilibrium in the second period depends on the extent of resistance in the first period. This completes the description of the one-area world. We analyze this world in the next section.

The One-Area World

To keep matters simple, we begin with the case of a single manufacturing good ($k = 1$). To show that competition reduces resistance to new technology, it will suffice to have $k = 1$. Later, to show that skilled groups may agree to an extension of markets, it will be necessary to have many manufactured goods ($k > 1$).

Recall the timing of events from above. In the first period, the skilled group chooses whether or not to erect a barrier to the new technology; that is, it chooses $a \in \{b,n\}$. In the second period, there is a competitive equilibrium. In order to study this situation, we work backward in time. First, we define and calculate the competitive equilibrium in the second period. We calculate the second-period equilibrium for the case in which the barrier is constructed as well as for the case in which the barrier is not constructed. Let v^b denote the utility of the representative skilled individual in the barrier case and v^n the utility in the no-barrier case. Second, given the values of v^b and v^n, we turn to the analysis of the first-period problem of the skilled group. The decision is simple: the skilled group chooses to erect a barrier if and only if $v^b > v^n$.

Equilibrium With a Barrier . . .

Suppose the new technology has been blocked during the first period; that is, $a = b$. The first step is to define a competitive equilibrium of the economy. Without loss of generality, we assume that all individuals of the same skill level behave the same way.[1] Individuals allocate their unit second-period labor endowment between the production of food and the production of the single manufactured good. Let m_s denote the units of labor allocated to the manufactured good by an individual with skill level s, where $s = L$ denotes an unskilled, or *low*-skill, individual and $s = H$ a skilled, or *high*-skill, individual. The units of labor allocated to food production is the residual $1 - m_s$ of the unit labor endowment. Regarding consumption, let (x_s,y_s) denote food and manufactured good consumption of an individual with skill level s.

Let food be the numeraire, and let p denote the price of the manufactured good in terms of food. A *competitive equilibrium under the barrier* is a set $\{p^b,m_L^b,x_L^b,y_L^b,m_H^b,x_H^b,y_H^b\}$ satisfying three conditions:

- The choice (m_H^b,x_H^b,y_H^b) maximizes type H's utility; that is, it solves this problem:

(2) $\max_{(m,x,y)}[u(x,y)][h_H]$

subject to

(3) $x + p^b y \leq (1-m) + p^b\theta m$

(4) $0 \leq m \leq 1$

where $h_H = h(1-r)$. (Recall that each high-skill individual has to allocate r units of his or her leisure endowment to erect the barrier.)

- The choice (m_L^b,x_L^b,y_L^b) maximizes type L's utility. [The utility-maximizing problem of type L is the same as that for H except that θ is replaced with 1 and h_H with $h_L = h(1)$.]
- Demand must equal supply for both goods:

(5) $(1-\lambda)x_L^b + \lambda x_H^b = (1-\lambda)(1-m_L^b) + \lambda(1-m_H^b)$

(6) $(1-\lambda)y_L^b + \lambda y_H^b = (1-\lambda)m_L^b + \lambda\theta m_H^b.$

It is easy to show that there is a unique equilibrium. The following proposition characterizes some properties of the equilibrium. In order to state the proposition, we define two critical values of λ, λ' and λ'', where $\lambda' \equiv (1-\alpha)/(1-\alpha+\alpha\theta)$ and $\lambda'' \equiv 1 - \alpha$ (so that $0 < \lambda' < \lambda'' < 1$).

PROPOSITION 1. *There is a unique equilibrium. If $\lambda < \lambda'$, then $m_H^b = 1$ and $m_L^b \in (0,1)$. The price of the manufactured good is $p^b = 1$. If $\lambda' < \lambda < \lambda''$, then $m_H^b = 1$ and $m_L^b = 0$. The price of the manufactured good is $p^b \in (1/\theta,1)$. Finally, if $\lambda > \lambda''$, then $m_H^b \in (0,1)$ and $m_L^b = 0$. The price of the manufactured good is $p^b = 1/\theta$.*

Before we discuss this proposition, there are two things to recognize. First, skilled individuals have the same productivity in food production as do unskilled individuals, but the skilled have a higher productivity in manufactured good production. Hence, skilled individuals have a comparative advantage in the production of manufactures; unskilled individuals, in the production of food. This means skilled individuals work relatively more in the production of the manufactured good. Second, the degree of specialization depends on λ, the fraction of skilled workers in the population.

Suppose, then, that λ is very small. Then unskilled workers cannot completely specialize in the production of food because there is an insufficient number of skilled workers to accommodate the demand of unskilled workers for the manufactured good. Hence, in the equilibrium allocation, unskilled individuals produce both food and the manufactured good while the skilled individuals completely specialize in manufacturing. That is, $m_H^b = 1$ and $m_L^b \in (0,1)$. Since unskilled individuals produce both goods, they must receive the same income per unit of labor in both production activities. The income per unit of labor in food is 1. The income per unit of labor in manufactures is p^b. Equilibrium requires that these two returns be equal; hence, $p^b = 1$.

By analogous reasoning, if λ is close to 1, then skilled individuals produce both food and the manufactured good, while the unskilled individuals completely specialize in food production. That is, $m_H^b \in (0,1)$ and $m_L^b = 0$. Here, the price of the manufactured good equals the marginal rate of transformation between the two goods for the skilled individuals; that is, $p^b = 1/\theta$.

Finally, if $\lambda' < \lambda < \lambda''$, then skilled individuals completely specialize in manufacturing while the unskilled individuals completely specialize in food production. That is, $m_H^b = 1$ and $m_L^b = 0$. The equilibrium price declines monotonically from $p^b = 1$ at $\lambda = \lambda'$ to $p^b = 1/\theta$ at $\lambda = \lambda''$. That is, the price lies between the marginal rates of transformation of the two skill levels. The equilibrium price equates the demand for the manufactured good by the unskilled individuals with the supply from the skilled individuals.

The equilibrium utility v^b of the representative skilled individual depends upon the equilibrium price of the manufactured good, and this, in turn, depends upon the fraction λ of skilled individuals in the population. Chart 1 plots equilibrium utility v^b as a function of λ. In the case where λ is less than λ', price is constant at 1, so utility does not change with λ. In the range between λ' and λ'', the price declines and the utility of the skilled individuals falls along with it. For λ above λ'', the price is constant at its minimum point of $p^b = 1/\theta$. The utility of the representative skilled individual is constant at its minimum point.

. . . And Without a Barrier

Now suppose the new technology was not blocked in the first period; that is, $a = n$. Recall that the new technology with unskilled labor input is more productive than the old technology with skilled input; that is, $\gamma > \theta$. The old technology will not be used, so possession of high skill for the old technology is irrelevant. All individuals in the economy are equal in that they are all unskilled in the new technology.

Given that all individuals are alike, it is easy to define equilibrium. We will not do that here, but will rather state some of the properties of equilibrium. The equilibrium price of the manufactured good is the marginal rate of transformation between the two goods; that is, $p^n = 1/\gamma$. All individuals in the economy have an income of one unit of food. This follows because each individual is indifferent, in equilibrium, to allocating his or her entire unit labor endowment to the production of a unit of food. Finally, the utility v^n does not depend on λ, as shown in Chart 1.

Conditions for Resistance

We have completed the analyses of second-period equilibrium when there is a barrier—that is, when $a = b$—and when there is no barrier—that is, when $a = n$. We are now in a position to state conditions under which the representative skilled individual is better off with a barrier than without one (the conditions which permit us to draw Chart 1 as we did, that is, with v^b above v^n for small λ).

PROPOSITION 2. *Suppose that* $\theta > \gamma^{1-\alpha}$. *For small enough r, there exists a point* $\hat{\lambda} \in (\lambda', \lambda'')$, *such that if* $\lambda < \hat{\lambda}$, *then* $v^b > v^n$, *while if* $\lambda > \hat{\lambda}$, *then* $v^b < v^n$.

This is illustrated in Chart 1. The proof of this proposition is in the Appendix. Here, let us describe the intuition behind this result. Erecting a barrier increases the price of the manufactured good, and it also means that a skilled individual has a lower productivity in producing manufactured goods. This has two effects on the utility of a skilled individual: one in the individual's role as consumer, the other in his or her role as producer. As a consumer, an individual is, of course, hurt by higher prices. For example, if $\lambda \le \lambda'$, then erecting a barrier increases the price from $p^n = 1/\gamma$ to $p^b = 1$. The increase in price is smaller the larger is λ. If $\lambda \ge \lambda''$, then the price increases from $p^n = 1/\gamma$ to $p^b = 1/\theta$. As a producer, the individual is typically helped by higher prices but hurt by lower productivity. On balance, erecting a barrier increases income (or leaves it unchanged). This has a positive effect on utility. If $\lambda \le \lambda'$, then erecting a barrier increases the income of a skilled individual from $p^n\gamma = 1$ to $p^b\theta = \theta$, where $\theta > 1$. The increase in income is smaller the larger is λ. If $\lambda \ge \lambda''$, then there is no increase in income.

Given these effects, it is clear that if $\lambda \ge \lambda''$, then the skilled group chooses not to erect a barrier. If a barrier is erected, then the price of the manufactured good increases, yet there is no increase in income. But if $\lambda \le \lambda'$, then erecting a barrier results in both higher prices and income. Which effect, the price or income effect, dominates depends on other parameters of the model. If the share of food in the budget is large (that is, if α is large), then the increase in the price of the manufactured good is of small consequence. The income effect dominates. This is the logic behind the condition $\theta > \gamma^{1-\alpha}$ stated in the proposition.

How Competition Reduces Resistance

We now show how the extension of markets reduces resistance to new technology. We consider an environment in which there are two areas. The first area, area *A*, is identical to the area in the analysis above. The second area, area *B*, is identical to that above except that resistance costs in *B* are extremely high—so high that there are never barriers to new technology in area *B.* In this section we ask, What happens in area *A* if there is an extension of markets, that is, if the markets in *A* and *B* are *integrated,* or the two areas form a free-trade union? In particular, we ask whether or not the skilled group in *A* will choose to erect a barrier given the extension of markets. We compare this choice to that made when markets are limited, that is, the outcome in the preceding section.

We assume that the shipment of goods between the two areas involves no resource costs, but that labor is immobile.

It will be of interest to consider two types of barriers to new technology in this section. One, a *production barrier* in an area, makes it impossible for any worker to use the new technology in the area. The other, a *consumption barrier* in an area, makes it illegal to sell goods in the area that are produced with the new technology. In a one-area world, a consumption barrier has the same effect as a production barrier. (There is no point to producing a good if its sale is illegal.) In a two-area world, a consumption barrier is not the same as a production barrier.

Production Barriers

We have the following proposition concerning production barriers:

PROPOSITION 3. *If* $\alpha > 1/2$, *then the skilled group in area A does not erect a production barrier when there is an extension of markets.*

Before we describe the intuition for this result, notice that this outcome in area *A* is different from that in the one-area world. From Proposition 2, we know that if α is big, then the new technology is blocked in the one-area world if λ is small. In a world with integrated markets, in which the areas have formed a free-trade union, and with

α big, the new technology is not blocked (regardless of the size of λ).

The proof for this is as follows. We derive a contradiction. Suppose a barrier is constructed in area *A*. By assumption, there is no barrier in area *B*. Hence, producers in area *B* have a comparative advantage in the production of the manufactured good because they have access to the new technology whereas producers in *A* do not. Whether or not area *B* produces all the manufactured goods for both areas depends on the share of manufactured goods in the consumer budget. The assumption $\alpha > 1/2$ insures that the share of manufactured goods in the consumer budget is sufficiently small so that production in area *B* is sufficient to accommodate the demand of the two areas.[2] All individuals in area *A*, therefore, produce food. Hence, the representative skilled individual in area *A* gains nothing from blocking the new technology in *A*. Since the act of blocking the new technology wastes leisure time and delivers no benefit, the representative skilled individual is better off when the barrier is not erected.

Consumption Barriers

The basic result of this section is that trade between areas also eliminates consumption barriers, though this kind of barrier is more difficult to break than a production barrier. The reason an extension of markets places pressure on a consumption barrier in area *A* is that this barrier does not preclude those individuals in area *B* who are skilled in the old technology from exporting to *A* and thus diminishing the returns to skills in area *A*.

In order to state our result, let v^b_{union} denote the return to the representative skilled individual in area *A* if there is a consumption barrier in *A* when *A* is integrated, or in a free-trade union, with area *B*. The return to the representative skilled individual in *A* if there is no barrier in *A* when *A* is in a free-trade union with area *B* is equal to the return to the representative skilled individual in area *A* when there is no barrier in *A* in the one-area world. Recall that this return was denoted v^n above.

PROPOSITION 4. *Suppose that* $\theta > \gamma^{1-\alpha}$. *For small enough r, there exists a point* $\tilde{\lambda} \in (0,\hat{\lambda})$, *where* $\hat{\lambda}$ *is defined as in Proposition 2, such that if* $\lambda < \tilde{\lambda}$, *then* $v^b_{union} > v^n$. *If* $\lambda > \tilde{\lambda}$, *then* $v^b_{union} < v^n$.

This result is illustrated in Chart 2. The proposition states that for certain parameters the representative skilled individual is better off with a barrier than without one. This proposition, together with Proposition 2, implies that integrating the markets in *A* with those in *B* will also eliminate consumption barriers under certain conditions. To show this, we have included in Chart 2 not only the curves v^b_{union} and v^n, but also the curve v^b from Chart 1. Recall that v^b is the utility of the representative skilled individual in area *A* under a barrier in the one-area world. As seen in Chart 2, if $\lambda < \tilde{\lambda}$, the skilled group in *A* erects a consumption barrier in both the one-area world and the union with *B*. However, if $\lambda \in (\tilde{\lambda},\hat{\lambda})$, then the skilled group in area *A* erects a consumption barrier in the one-area world but not in the union with area *B*. Hence, joining the free-trade union eliminates barriers to new technology in area *A* in this case.

It is worthwhile discussing why $v^b_{union} \leq v^b$ for $\lambda < \lambda''$ (and a strict inequality for a range of λ below λ''). We will show that if there is a consumption barrier in *A* when a union is formed, and if $\lambda < \lambda''$, then skilled individuals in area *B* will produce the manufactured good with the old technology for export to area *A*. This will depress the utility to skilled individuals in *A*.

That skilled individuals in area *B* will produce the manufactured good with the old technology for export to area *A* can be seen as follows. Suppose to the contrary that they do not export the manufactured good when there is a free-trade union and a consumption barrier in *A*. Then there is no trade between area *A* and area *B*. The equilibrium allocation in area *A* is the same as that in the one-area case with a barrier. The equilibrium allocation in area *B* is the same as that in the one-area case with *no* barrier. Each individual in area *B* earns an income of one food unit. (Such individuals can use their unit labor endowment to produce one food unit or γ units of the manufactured good at a price of $1/\gamma$.) Suppose instead that a skilled individual in *B* produces the manufactured good with the old technology for export to area *A*. Since, by assumption, $\lambda < \lambda''$, the manufactured good price in *A* exceeds $1/\theta$. (See Proposition 1.) Since output equals θ units and price exceeds $1/\theta$, the income of a representative skilled individual exceeds one food unit. Hence, a skilled individual in *B* can earn higher income by exporting. This contradicts the earlier assertion that there is an equilibrium with no exports. Because of exports from *B* to *A* and the resulting decrease in the manufactured good price, $v^b_{union} \leq v^b$ for $\lambda < \lambda''$ (and a strict inequality for a range of λ below λ''), as illustrated in Chart 2.

Recall that in the one-area case, at the point $\hat{\lambda}$, skilled individuals in *A* are indifferent between erecting and not erecting the barrier. Since joining a free-trade union reduces the return to erecting a barrier, but has no effect on the return to not erecting a barrier, skilled individuals are better off without a barrier at this point. This is also true for λ just below $\hat{\lambda}$. Therefore, for λ in this range, consumption barriers are not erected when there is a union, but they are erected without a union. Extension of markets reduces barriers.

We conclude this section by discussing the claim that it is more difficult for trade to eliminate a consumption barrier than a production barrier. To see this, we show that there are conditions under which forming a free-trade union with *B* eliminates production barriers but not consumption barriers. Assume, then, that $\alpha > 1/2$. Then from Proposition 3 we know that forming a union eliminates production barriers. It may not eliminate consumption barriers. From Proposition 4 (and Chart 2) we know that if λ is small, then $v^b_{union} > v^n$. In this case, consumption barriers are erected.

Why Competition Spreads

If competition reduces resistance to new technology, why would skilled groups ever agree to an extension of markets, as they sometimes do? Because, sometimes, letting goods move between areas is in the best interests of all skilled groups. Here we demonstrate that by studying the question in a slightly modified version of our model.

Thus far the model has had two periods: period 1 and period 2. This section adds an additional period, period 0, that precedes the two periods covered in the previous analysis. In period 0, decisions are made regarding whether or not the two areas form a free-trade union. (More on this institution-building stage below.)

This section also adds many manufactured goods. As mentioned above, to show that skilled groups may agree to an extension of markets requires introducing many manufactured goods. Here is the reason why. Recall the analysis of the one-area world. Under the conditions of Proposition 2, if λ is small, then skilled individuals resist the new technology. Consider the impact on utilities in area A of forming a free-trade union with area B. If the union results in a dismantling of barriers, then skilled individuals in A lose rents. But unskilled individuals in A are better off. Hence, some groups gain from extending markets; some lose. However, this need not always be the case. In particular, if there are many manufactured goods, then it is possible for all groups to be better off with a free-trade union than without one. The trade union case Pareto-dominates the alternative of no trade union. In this case, since every individual in the economy is better off with a free-trade union, we can be confident, without specifying the details of the political process, that a union is set up in period 0. Hence, we keep the institution-building stage in the background.

One Area With Many Manufactured Goods

Before proceeding to discuss the formation of a free-trade union, we need to briefly study the one-area world with many manufactured goods, that is, with $k > 1$. We sometimes refer to the different manufacturing goods as different *industries.* Recall that in the first period, each skilled group i chooses whether or not to erect a barrier; $a_i = \{b,n\}$. Let $\tilde{a} = (a_1,a_2,...,a_k)$ be the vector of choices made in the first period. We call this the *barrier set.* In the second period, there is a competitive equilibrium given the barrier set $\tilde{a}$ selected in the first period.

□ Equilibrium in the Second Period

We begin by determining the competitive equilibrium for a given barrier set $\tilde{a}$. In order to state the following proposition about equilibrium, we need to define a critical level of λ. We denote this level by λ', where $\lambda' \equiv k(1-\alpha) \div [(\alpha+k-1)\theta+(1-\alpha)]$. Recall that λ is the fraction of the population that is in some skilled group and that $\eta = \lambda/k$ is the fraction that is in some particular industry i.[3] We can now state

PROPOSITION 5. *Take as given some barrier set $\tilde{a}$ in which some of the technologies have a barrier and others do not. If $\lambda \leq \lambda'$, the unique equilibrium is as follows. If technology i has a barrier—that is, $a_i = b$—then $p_i = 1$; individuals in skilled group i completely specialize in the production of good i; and individuals who are not skilled in any of the goods with a barrier also produce good i. If technology i does not have a barrier—that is, $a_i = n$—then $p_i = 1/\gamma$ and the individuals in skilled group i have the same consumption and utility as unskilled individuals.*

This result is a generalization of Proposition 1 to the case of $k > 1$. To simplify matters, for the rest of this section we assume that $\lambda \leq \lambda'$ (the case with the greatest incentive to erect barriers).

□ Resistance

We now discuss how the barrier set is determined. Each group i makes its barrier choice to maximize group utility taking as given the barrier choices of the other groups. An equilibrium barrier set $(a_1^*,a_2^*,...,a_k^*)$ is a set such that $a_i^* \in \{b,n\}$ is optimal for i given the choices of the other groups. This is the standard Nash equilibrium concept. Determining the Nash equilibrium is easy when $\lambda \leq \lambda'$ because the optimal strategy of each group is independent of what the other groups do. In other words, each skilled group has a *dominant strategy.*

PROPOSITION 6. *Assume that $\lambda \leq \lambda'$, $\theta > \gamma^{(1-\alpha)/k}$, and r is small. Each skilled group has a dominant strategy to erect a barrier. The unique equilibrium is for a barrier to be erected in each industry.*

A proof of this result is in the Appendix. This result is the extension of Proposition 2 to the case of multiple manufactured goods. The condition $\theta > \gamma^{(1-\alpha)/k}$ is a generalization of the condition $\theta > \gamma^{1-\alpha}$ in Proposition 2.

The next proposition is the key welfare result in this section.

PROPOSITION 7. *Maintain the assumptions of the preceding proposition. If $\theta \in (\gamma^{(1-\alpha)/k},\gamma^{1-\alpha})$, then all skilled groups are strictly better off with no barriers in any industry than with barriers in every industry.*

The Appendix contains the proof. This proposition highlights the key difference between the cases of $k = 1$ and $k > 1$. With $k = 1$, the interval $(\gamma^{(1-\alpha)/k},\gamma^{1-\alpha})$ specified in the proposition disappears. With $k > 1$, there exists a parameter region in which all individuals are better off with no barriers in any industry than with barriers in every industry.

Taken together, Propositions 6 and 7 show that if $\theta \in (\gamma^{(1-\alpha)k},\gamma^{1-\alpha})$, then the unique equilibrium involves barriers in every industry, though a situation with no barriers is strictly preferred by all. This situation is analogous to the well-known prisoner's dilemma. In the next section, we show that trade can be used as a device to achieve the cooperative outcome in which no barriers are constructed.

Two Areas With Trade

We now assume that areas A and B are integrated and ask what equilibria are possible. We assume that the two areas are identical, including their resistance technologies.

The skilled groups in the two areas all move simultaneously in period 1 when choosing to erect a barrier or not. Each skilled group takes as given the choices of all the other skilled groups in the two areas when making its choice. For example, when choosing its action $a_1^A \in \{b,n\}$, skilled group 1 in area A takes as given the actions a_2^A, a_3^A, ..., a_k^A of the other skilled groups in area A and the actions a_1^B, a_2^B, ..., a_k^B, of the skilled groups in area B. Our result is

PROPOSITION 8. *Suppose that $k > 1$ and that the barriers are production barriers. If the two areas are integrated, then there exists an equilibrium in which no skilled group erects a barrier.*

The proof is straightforward. Consider the problem of a particular skilled group in a particular area. By symmetry, we can examine skilled group 1 in area A. Suppose that all other skilled groups in both areas choose not to erect a barrier. Suppose skilled group 1 in area A erects a barrier. It is easy to see that this barrier has no bite. In the resulting competitive equilibrium, all production of good 1 will occur in area B where there is no restriction to producing good 1 with the new technology. Area B can produce enough for both areas since the good makes up less than one-half of the share of the consumer budget. (This follows from $k > 1$.) Hence, the barrier does not raise the incomes of skilled individuals in area A. But imposing this barrier requires that group 1 give up some leisure time. This barrier thus entails costs but delivers no benefits.

Hence, skilled group 1 in area *A* will strictly prefer not to erect a barrier. Analogously, all other groups strictly prefer not to erect barriers. Hence, it is a Nash equilibrium for there to be no barriers.

We can now state the main result of this section:

PROPOSITION 9. *Maintain the parameter assumptions of Proposition 6. If there is no free-trade union, then the unique equilibrium is for a barrier to be erected in every industry. With a union, there exists an equilibrium with no barriers. All individuals are strictly better off with the union than without it.*

We should point out that there can exist multiple equilibria in the free-trade union case. For example, under the assumptions of Proposition 9, there also exists an equilibrium of the union case in which all skilled groups erect barriers. Note, however, that everyone is better off in the no-barrier equilibrium than in the barrier equilibrium. It is reasonable to expect that the Pareto-superior no-barrier equilibrium will be selected instead of the Pareto-inferior barrier equilibrium.

Examples of How Competition Reduces Resistance

In this section, we present a few brief industry case studies in which the extent of the market for a good explains, in large part, we think, the extent to which new ways of producing the good are resisted. We use the theory developed so far to examine episodes of technological change in three industries: the advent of lean production in the world automobile industry, the introduction of a growth hormone in the U.S. dairy industry, and a discovery about the spacing of wall studs in the U.S. construction industry. These three episodes present an interesting mix in the sense that in the construction industry, because of the nature of the good, the extent of the market is narrow; in the auto industry, the extent of the market has been narrowed by policy; and in the dairy industry, the extent of the market is great.[4]

Lean Production of Cars

Let's start with the world automobile industry.

A rough outline of some of the major technological changes in this industry over the past 20 years or so is as follows. Beginning over 30 years ago, a new approach to producing cars was taking shape in Japan. These new methods revolutionized the production of automobiles. Womack, Jones, and Roos (1991) describe the features of this production technology and call it *lean production.* They, and others, document that large gains in productivity follow from adopting the new technology. The response to these new methods by automobile makers has differed widely around the world. For example, the new methods are now widely employed in the United States. In contrast, European car makers have lagged behind their U.S. competitors in adopting these Japanese methods.

Why has the experience in the United States been different from that in Europe? We give an interpretation in terms of the model. Then we spend the rest of the section defending the interpretation.

In terms of the model, we think of Japan as area *B.* More precisely, we think of Japan as area *B* when the new technology (lean production) is freely available in *B.* We imagine the United States as area *A*—in the case where *A* is integrated with *B.* We take Europe to be area *A* in the case where there is no integration. With this interpretation, the new methods were adopted in the United States because resistance was less in the United States than in Europe—because the United States was more open to trade competition with Japan than was Europe.[5] In order to defend this interpretation, we need to document two things: first, that the United States was more open to competition and, second, that this led to less resistance to the new methods.

The claim that the U.S. automobile market is more open than Europe's is fairly easy to substantiate. Japanese-produced cars have penetrated the U.S. market to a substantial degree as compared to the European market. The accompanying table presents evidence on this point. In 1992, about 1.58 million automobiles were produced in Japan and then exported to the United States.[6] Exports of Japanese-produced cars to the United States accounted for nearly 20 percent of car sales in the United States in 1992.[7]

This can be contrasted with the shares of Japanese-produced cars exported to the markets of European countries. The table groups the European countries into those countries that have automobile industries producing over 1 million cars and those countries that have small or nonexistent industries. The Japanese share of the market in auto-producing European countries is quite small relative to the Japanese share of the U.S. market. For example, in Italy, the share is only 0.1 percent; in France, it is still quite small at 2.9 percent. However, in the countries of Europe without a large industry to protect, the Japanese market share is huge. In Norway, it is actually 50 percent. This table suggests that Japanese cars are superior to European-produced cars since when consumers have a choice between the two (because there is no domestic industry to protect), they buy Japanese cars.[8] We can infer that there must be substantial barriers to the inflow of Japanese cars in Spain, France, and Italy—and, for that matter, even the United Kingdom and Germany.[9]

The second thing to document in defense of our model interpretation of this industry is that there was less resistance to the new lean production methods in the United States than in Europe. We discuss two issues related to this. First, we show that the new methods have been more rapidly adopted in the United States than in Europe. Then we present some discussion that the reason has something to do with less resistance in the United States.

It is now conventional wisdom that the U.S. automobile industry has undergone a major transformation. The word *renaissance* is often used to describe the changes in the U.S. automobile industry. A substantial portion of the cars produced in the United States (25 percent in 1992) are made in Japanese transplant factories using the latest technology. In addition, Ford and Chrysler, and to a lesser extent General Motors, have made great strides in adopting the new methods in their factories. This is the conclusion of the MIT International Motor Vehicle Program, a five-year, $5 million research project on the automobile industry that culminated with the publication of the influential book, *The machine that changed the world: The story of lean production,* by Womack, Jones, and Roos (1991). For example, they write (pp. 86–87) that

> Average American performance—under unrelenting pressure from the Japanese transplants in North America—has improved dramatically, partly by closing the worst plants, such as Framingham, and partly by adopting lean production techniques at others.

They note that the productivity level and output quality of Ford plants in the United States are now equal to those of the Japanese transplants in the United States.

But there is no talk of a renaissance of the European auto industry. At this point, only a small fraction of production (1.3 percent in 1992) is by Japanese transplant firms.[10] And the production by the six volume producers in Europe is anything but lean. Womack, Jones, and Roos (1991, p. 87) also write that "Europe, by contrast, has not yet begun to close the competitive gap." A recent report prepared by the McKinsey Global Institute (1993a) makes the same point. It estimates that labor productivity in German auto plants is only 66 percent of that in U.S. auto plants.

Resistance to lean production in Europe has often come from autoworker unions. These unions have resisted the flexible work practices and reduced job classifications that are hallmarks of the Japanese production organization, and they have tried to maintain the rigid work rules that have been a part of past union contracts. (See Kenney and Florida 1993, p. 315.) Unions have resisted the closure of outdated factories and layoffs. In the face of the resistance to layoffs, Volkswagen is attempting to be more productive by moving to a four-day workweek. But according to Daniel Jones (one of the authors of the MIT study cited above), in reference to Volkswagen's German operations, "You cannot manage 50,000 people at one site in a lean way" (Europe's car makers, 1994, p. 22).

But has autoworker resistance been less severe in the United States than in Europe? One piece of evidence is the response in the United States and Europe to the threat of Japanese transplants. Both unions and management of domestic automobile firms have tried to block the establishment of Japanese transplant factories within their own countries. They have done this by arguing that production by transplant factories should be counted as imports and subject to the import quotas imposed on the Japanese. Proponents of such a policy have never made any headway in the United States, but this policy was actually adopted by the European Union.[11]

A Growth Hormone for Cows

We next use the model to interpret the events surrounding a recent major change in the U.S. dairy industry.

A rough outline of the facts is as follows. Some years ago, the Monsanto Company genetically engineered bovine somatotropin, a naturally occurring hormone in cows. When this hormone is injected into cows, milk production increases in the range of from 10 to 15 percent (Marion and Wills 1990). Many groups have opposed the use of the hormone. For example, some opponents of the new technology have raised the issue of a health risk to justify a ban of the new technology.

In the United States, attempts to block the growth hormone have occurred at both the federal and state levels. At the federal level, the Food and Drug Administration (FDA) has jurisdiction over the approval process. Efforts to block this hormone at the federal level have therefore involved lobbying the FDA. At the level of individual states, the efforts to block the new technology have taken many forms. One form—used in Vermont and Wisconsin, for example—is to try to enact state laws that simply ban production with the new technology.

After a long battle, the hormone was finally approved by the FDA. Commercial use began in the United States in early 1994. The efforts in individual states to enact laws prohibiting the use of the hormone have also failed. We use the model to offer an interpretation of why states have failed to enact such laws.

In terms of the model, we think of areas *A* and *B* as corresponding to states in the United States. We imagine the model situation in which there are no restrictions on trade between areas *A* and *B.* This is because the Constitution of the United States has been interpreted in such a way as to prohibit the states from interfering with interstate trade.

Individual states ultimately did not enact laws prohibiting the use of this new technology in the state because interstate trade reduced the incentive for interest groups within a state to lobby the state legislature to pass such laws. For example, suppose that the Wisconsin legislature passed a law which blocked Wisconsin dairy farmers from using the new technology. If other states did not block the new technology, then imports of low-priced milk produced with the new technology would flow into Wisconsin. In addition, Wisconsin would no longer be competitive in exporting milk to other states. Hence, this law would not benefit Wisconsin dairy farmers. Suppose instead that the Wisconsin law banned consumption of milk produced with the new technology, but did not ban production, and suppose that Wisconsin is the only state with such a law. Wisconsin dairy farmers would be free to use the new technology for export to other markets. As discussed earlier, in such a situation, there would be an incentive for old-technology producers in other areas to export milk made without the growth hormone to the area with the ban, and this would limit the benefit of the policy to the old-technology firms in Wisconsin.

In sum, the bovine growth hormone case is an excellent example of how the ability to trade between areas can reduce barriers to new technology.

More Room for Wall Studs

Finally, let's look at an advance in the U.S. construction industry.

Because of advances in science, construction engineers have realized that safety does not require wall studs to be as close together as had been thought. Placing wall studs (in non–load-bearing partitions) every 24 inches is just as safe as the old standard distance, every 16 inches. The homes with 24-inch placement are clearly not identical to those with 16-inch placement, but regarding the ability of the home to bear stress and weight, a national commission reported, "Experts agree that . . . [spacing] every 24 inches would be just as safe. There seems to be no . . . scientific data to refute these facts" (National Commission on Urban Problems 1968, p. 258).

Using 24-inch placement saves on labor costs and reduces materials costs by 33 percent. Moreover, the cost of adopting the method is zero. It simply entails reducing redundancies in the previous method. Yet in many U.S. towns, 16-inch placement continues. Why? We give an interpretation in terms of the model.

We think of areas *A* and *B* as corresponding to different towns in the United States. Since housing services are a good that cannot be traded, we imagine the model situation in which the markets of *A* and *B* are not integrated. Given this situation, we expect that resistance to the new methods may be high in a given area. Moreover, if one area fails to block the new methods, we do not expect that this will put pressure on other areas to change their building codes.

That it is resistance to new technology that blocks 24-inch placement in some towns is supported by the work of Oster and Quigley (1977). They find that 24-inch placement is not used in some towns because local building codes prohibit its use. Moreover, they find evidence that such restrictions are the work of building trade unions who believe, presumably, that 24-inch placement will mean fewer jobs.

Concluding Comments

We conclude with three comments, the first about related literature, the next about the model, and the last about future research.

When we showed that competition reduces resistance, we studied resistance to new *technology* and how the extension of markets, or the freer movement of goods between areas, influences this activity. To show this, we exogenously joined area *A* to area *B* and examined the consequences on technology adoption in area *A*. This thought experiment is similar to that performed by Adam Smith when he argued that extending markets would result in greater division of labor.

This analysis is not to be confused with research that examines resistance to *trade,* for example, models in which groups lobby for tariffs and the like. (See, for example, Magee, Brock, and Young 1989 and Grossman and Helpman 1994.) Our analysis where we showed that skilled groups might agree to join a free-trade union is related to that research.

It is worth mentioning that it is really the threat of goods moving between areas that leads to reductions in resistance activities. Goods themselves do not have to move. For example, suppose that in the model above, area *A* is integrated with area *B*, but there is no movement of goods between the areas. It does not follow that because the volume of trade is zero, closing the areas off from each other will have no impact on the economies. In fact, this action will typically lead to increased resistance in area *A*. The point, then, is that the volume of trade may not be a good indicator of the role trade is playing in producing wealth. So, for example, the increase in tariffs during the 1930s may have played an important role in the Great Depression even though trade volume before the tariff increases accounted for only about 5 percent of output.

Finally, a word about future research. The very large differences in income per capita across countries are well known and well documented. (See, for example, Parente and Prescott 1993.) We think that these large differences are due in large part to differences in the technologies that are employed in the countries. One hypothesis for the difference in technology use is that the extent of markets differs across these countries (because of, for example, differences in tariff policy and differences in transportation infrastructure) and, hence, resistance to new technology as well. (For a different theory of resistance to new technology, see Krusell and Ríos-Rull 1992. For another interesting model explaining differences in technology use, see Romer 1994.) Ultimately, then, we hope that this line of inquiry contributes to the literature on the "problem of economic development" (Lucas 1988; Mankiw, Romer, and Weil 1992; Schmitz 1993; and Parente and Prescott 1994). We hope this article has taken some small steps toward understanding and solving that problem.

Appendix

Proofs of Propositions 2, 6, and 7

Here we develop the proofs for several propositions discussed in the preceding paper.

Proof of Proposition 2

PROPOSITION 2. *Suppose that* $\theta > \gamma^{1-\alpha}$. *For small enough r, there exists a point* $\hat{\lambda} \in (\lambda', \lambda'')$, *such that if* $\lambda < \hat{\lambda}$, *then* $v^b > v^n$, *while if* $\lambda > \hat{\lambda}$, *then* $v^b < v^n$.

Proof. The first step in the proof is to compare the skilled-individual utility with and without a technology barrier for the case in which $\lambda \le \lambda'$.

Under the barrier, the price of the manufactured good is $p^b = 1$ for such λ, and this implies that the income of skilled individuals is θ units of food. (Recall that a skilled individual produces θ units of the manufactured good.) Given the Cobb-Douglas form for $u(x,y)$, the share of income spent on food is α and the share spent on the manufactured good is $\beta = 1 - \alpha$. Hence, the consumption levels for a skilled individual are $x_H^b = \alpha\theta$ and $y_H^b = (1-\alpha)\theta^{1/p^b} = (1-\alpha)\theta$. The equilibrium utility level is, therefore,

$$\text{(A1)} \qquad v^b = \{(\alpha\theta)^\alpha[(1-\alpha)\theta]^{1-\alpha}\}[h(1-r)].$$

Note that the utility from leisure is $h(1-r)$ because the individual must allocate r units of leisure time to resistance activities in this case.

In the no-barrier case, the price is $p^n = 1/\gamma$ and income is one unit of food. This implies consumption levels of $x^n = \alpha$ and $y^n = (1-\alpha)\gamma$. Equilibrium utility is

$$\text{(A2)} \qquad v^n = \{\alpha^\alpha[(1-\alpha)\gamma]^{1-\alpha}\}[h(1)].$$

Note that the utility in the no-barrier case is independent of λ. Note also that the utility of a skilled individual is the same as the utility of an unskilled individual. This follows because the old technology is not used.

For the case of $\lambda < \lambda'$, the ratio of utilities in the two cases is

$$\text{(A3)} \qquad v^b/v^n = [\theta/\gamma^{1-\alpha}][h(1-r)]/h(1).$$

The first term on the right side of equation (A3) is greater than 1 by assumption. The second term is less than 1. However, it is arbitrarily close to 1 for small enough *r*. Hence, $v^b > v^n$ for small enough *r,* as claimed.

Next, suppose that $\lambda \ge \lambda''$. In this case, with the barrier, the equilibrium price is $p^b = 1/\theta$ and the equilibrium income is one unit of food. Without a barrier, the income is the same, at one unit of food, but the price of manufactured goods is lower, at $p^n = 1/\gamma$. Hence, the utility from goods consumption is strictly higher without a barrier. Since the utility of leisure is also higher without a barrier $[(h(1) > h(1-r)]$, overall utility is also higher; $v^n > v^b$, as claimed. Q.E.D.

Proof of Proposition 6

PROPOSITION 6. *Assume that* $\lambda \le \lambda'$, $\theta > \gamma^{(1-\alpha)/k}$, *and r is small. Each skilled group has a dominant strategy to erect a barrier. The unique equilibrium is for a barrier to be erected in each industry.*

Proof. We need to show it is a dominant strategy for each skilled group to erect a new technology barrier. By symmetry, it is sufficient to consider the choice of skilled group 1.

Suppose this skilled group takes as given that in *m* of industries 2 through *k* there are barriers and in $k - m - 1$ of industries 2 through k there are no barriers. (By symmetry, it doesn't matter which of the industries are in the two groups.)

Let $v_1^b(m)$ denote the utility of a person in skilled group 1 when there is a barrier to new technology in industry 1 given m. Under the assumption $\lambda \leq \lambda'$, Proposition 5 says that the price of good 1 is $p_1 = 1$, as is the price of the other m manufactured goods with a barrier. The price of the remaining $k - m - 1$ manufactured goods with no barrier is $1/\gamma$. The income of an individual in skilled group 1 is θ units of food. The food consumption of such an individual is $x = \alpha\theta$. (The price of food is 1, and α is the share of income spent on food.) Consumption of manufactured goods with a barrier is $\beta\theta$, where $\beta \equiv (1-\alpha)/k$. (The price of such a good is 1, and the share of income spent on a particular manufactured good is β.) Consumption of manufactured goods without a barrier is $\beta\gamma\theta$. (The price of such a good is $1/\gamma$.) The utility of an individual in skilled group 1 is, therefore,

$$\text{(A4)} \quad v_1^b(m) = [(\alpha\theta)^\alpha(\beta\theta)^{(m+1)\beta}(\beta\gamma\theta)^{(k-m-1)\beta}][h(1-r)].$$

Let $v_1^n(m)$ denote the utility of a person in skilled group 1 when there is no barrier to new technology in industry 1 and when m other industries have erected barriers and $k - m - 1$ have not. Without a barrier, the price of good 1 is $p_1 = 1/\gamma$ while the prices of the other goods are the same as described above. The income of an individual in skilled group 1 falls to 1. That person's consumption of food in this case is $x = \alpha$. His or her consumption of the m manufactured goods with a barrier is β, and his or her consumption of the $k - m$ goods without a barrier (including good 1) is $\beta\gamma$. The utility of an individual in skilled group 1 in this case is

$$\text{(A5)} \quad v_1^n(m) = [\alpha^\alpha(\beta)^{m\beta}(\beta\gamma)^{(k-m)\beta}][h(1)].$$

The ratio of the utilities of an individual in skilled group 1 when there is a barrier and when there is no barrier is

$$\text{(A6)} \quad v_1^b(m)/v_1^n(m) = (\theta/\gamma^\beta)[h(1-r)]/h(1).$$

Note that in this ratio there are no terms involving m, the number of other skilled groups that erect barriers. Hence, whether or not $v_1^b(m) > v_1^n(m)$ (that is, whether or not the ratio (A6) is greater than 1) does not depend on the actions of the other skilled groups. Recall that $\beta \equiv (1-\alpha)/k$; if $\theta > \gamma^{(1-\alpha)/k}$ and if r is small, then skilled group 1 chooses to erect a barrier, as claimed.

Q.E.D.

Proof of Proposition 7

PROPOSITION 7. *Maintain the assumptions of the preceding proposition. If* $\theta \in (\gamma^{(1-\alpha)/k}, \gamma^{1-\alpha})$, *then all skilled groups are strictly better off with no barriers in any industry than with barriers in every industry.*

Proof. Suppose that skilled group 1 erects a new technology barrier and all the remaining $k - 1$ skilled groups do so as well. Then the utility of skilled group 1 is given by $v_1^b(k-1)$, where $v_1^b(m)$ is defined by (A4) above. If skilled group 1 does not erect a barrier and no other skilled group erects a barrier, then utility is $v_1^n(0)$. The ratio of these utilities is

$$\text{(A7)} \quad v_1^b(k-1)/v_1^n(0) = (\theta/\gamma^{1-\alpha})[h(1-r)]/h(1).$$

The second term on the right side of (A7) is less than 1 since $r \geq 0$. The first term is less than 1 if

$$\text{(A8)} \quad \theta < \gamma^{1-\alpha}.$$

If (A8) holds, then skilled group 1 is strictly better off when no barriers are erected than when every barrier is erected. Q.E.D.

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[1]Because of the linearity of the production function, there may exist multiple equilibria regarding the allocation of production tasks. We can assume that the representative individual of a given skill level produces the average of the set of individuals of that skill level. Because of the strict concavity of the utility function, the consumption bundle for an individual is the same across any multiple equilibria that exist.

[2]We have not worked out the case of $\alpha < 1/2$. Calculating equilibrium in the integrated world given a barrier in area *A* and no barrier in area *B* is somewhat complex in this case. If α is small, then area *B* consumes most of the manufacturing goods it produces. This limits the pressure on the skilled group in *A* from exports from *B*. But when α is small, there is little incentive to erect barriers in the one-area world. (See Proposition 2.) Hence, when α is small, trade is less powerful in eliminating barriers, but these barriers are less likely to be there in the first place.

[3]Note that for $k = 1$, the formula for λ' in this section reduces to that defined earlier. Because we like to think of k as being large, it is worth noting that λ' is bounded above zero and monotonically declines to $(1-\alpha)/\theta > 0$ as k goes to infinity.

[4]We should note that a number of recent studies have shown a close relationship between the degree of international competition faced by an industry in a country and that industry's productivity growth in that country. Notable examples are the studies by McKinsey Global Institute (1993a,b).

[5]Part of this interpretation is not new. Many observers of this industry attribute the more rapid diffusion of lean production in the United States to the U.S. market being more open to imports from Japan than is the European market. The McKinsey (1993a,b) studies, the Womack, Jones, and Roos (1991) project, and many other people argue that the fact that the U.S. market was open to imports forced the domestic industry to restructure and adopt the new techniques. What these observers have not done is discuss how the trade regime may affect the resistance activities of groups.

[6]This figure does not include the approximately 1.4 million cars produced in the United States by Japanese transplant factories such as the Toyota plant in Kentucky and the Honda plants in Ohio. The figure does include the 143 thousand cars produced in Japan in 1992 and sold under Chrysler and General Motors nameplates.

[7]We use new-car registrations in 1992 as our measure of car sales in the table because this number is available for all of the countries listed in the table and the number of actual car sales in 1992 is not available for all of the countries. The two numbers are close. For example, the number of actual car sales in the United States in 1992 was about 8.21 million compared to new-car registrations of about 8.06 million.

[8]On this point, it is worth noting that in the U.S. market where the Japanese and European firms are on an equal footing, the Japanese have huge sales while the Europeans have virtually no sales, except in the small, high-end luxury-car market.

[9]The U.S. market is by no means completely open to competition. The so-called voluntary export restraint agreements with Japan are a notable example of a U.S. trade barrier.

[10]The number of cars built by Japanese firms in Europe will increase since a number of transplant factories are being built there.

[11]The European Union later abandoned this policy. There are now no limits on the production of Japanese cars in Europe, and transplant production is expanding there.

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Charts 1 and 2

When Will New Technology Be Resisted?

Equilibrium Utility of Skilled Workers as a Function of the Fraction of the Population Skilled

Chart 1 In a World With One Area . . .

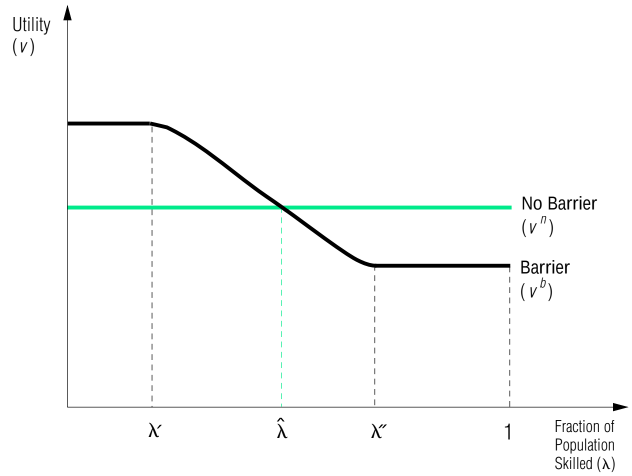
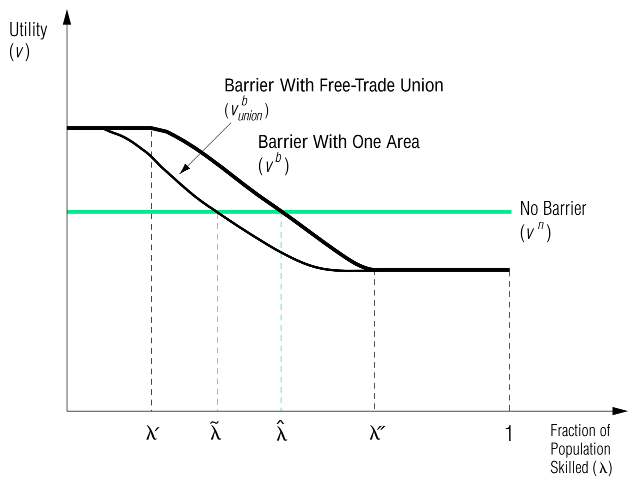


Chart 2 . . . And With Two Areas

(Under a Consumption Barrier)



Which Areas Are More Open to Competition?

The U.S. and European Automobile Markets in 1992

Country	Thousands of New Cars			Japanese Imports as a % of Registrations
	Produced	Registered	Imported From Japan	
United States	5,665	8,057	1,584	19.7
European Countries				
With a Large Auto Industry				
Germany	4,864	3,930	452	11.5
France	3,320	2,106	61	2.9
Spain	1,799	985	36	3.7
Italy	1,477	2,257	3	.1
United Kingdom	1,292	1,594	153	9.6
Without a Large Auto Industry				
Sweden	294	154	36	23.4
Belgium	268	466	126	27.0
Netherlands	94	494	117	23.7
Austria	15	320	101	31.6
Denmark	0	85	36	42.4
Ireland	0	68	28	41.2
Norway	0	60	30	50.0
Switzerland	0	286	87	30.4
Finland	0	68	25	36.8

Source: *Ward's Automotive Yearbook, 1993*