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Resistance to Technology and Trade Between Areas*

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ABSTRACT

Why are methods of production used in an area when more "efficient" methods are available? This paper explores a "resistance to technology" explanation. In particular, the paper attempts to understand why some industries, like the construction industry, have had continued success in blocking new methods, while others have met failure, like the dairy industry's recent attempt to block bST. We develop a model which shows that how easily goods move between areas determines in part the extent of resistance to new methods in an area.

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1 Introduction

Why are methods of production used in an area when more "efficient" methods are available? For example, why are residential homes constructed in some areas with wall studs placed 16 inches apart (in non-load-bearing partitions) when in other areas the studs are placed 24 inches apart? Using 24-inch placement saves on labor costs and reduces materials costs by 33 percent. The resulting homes are clearly not identical, but regarding the ability of the home to bear stress and weight, a national commission reported,[1] "Experts agree that . . . [spacing] every 24 inches would be just as safe. There seems to be no expert or scientific data to refute these facts."

This question has, of course, been asked before. One answer to the above question is that some investment, in either human or physical capital, is required to use the efficient method. Given that investment is costly, only those who receive the greatest benefit will make the investment (see, e.g., Jovanovic and Lach, 1989). While this explanation is often convincing, it seems that another type of explanation is needed in other instances. For example, adopting 24-inch placement of wall studs simply entails reducing redundancies in the previous method. The cost of adopting the method is *zero*. Yet in 1970, a survey of a large number of municipalities found that 16-inch placement of wall studs was the practice in nearly half the towns.[2]

The other type of explanation we have in mind for why efficient methods are not used is that these methods are blocked by groups that stand to lose by their introduction. In the construction example, houses continue to be built with 16-inch placement of wall studs because some local building codes *prohibit* 24-inch placement. And there is evidence that this restriction in building codes is the work of building trade unions that believe, presumably, that 24-inch placement will mean fewer jobs (Oster and Quigley, 1977).

This paper explores this "resistance to technology" explanation for why methods of production are used in an area when more efficient methods are available. In particular, our analysis is motivated by the following observation (and similar ones discussed below): While the building trade unions have had significant success in blocking 24-inch placements, as well as other innovations, such as preassembled parts, farm groups have failed in their recent

[1] National Commission on Urban Problems, 1968, p. 258.
[2] Field and Ventre, 1971, p. 149.

attempts to block a new genetically engineered cow-hormone, bST. When this hormone is injected into cows, milk production increases in the range of from 10 to 15 percent (see Marion and Wills, 1990). We are interested in understanding what accounts for this very different success in resisting technology.

The key difference between these cases, we believe, is the nature of the product: Milk is a traded good; housing services is not. To see the importance of this distinction, imagine that farmers in an area—say, Wisconsin—wish to ban milk production with bST in Wisconsin. When the group is deciding whether to erect a barrier to bST, the group recognizes that its effort may be for naught if farm groups in another area—say, Minnesota—do not erect barriers to bST. Why? Because those producing with bST in Minnesota may ship milk to Wisconsin. In contrast, carpenters in a town who succeed in banning 24-inch placements need not worry about houses being shipped from other towns.

There are broader lessons to be learned from this example. The nature of goods is, of course, only one determinant of how easily goods move between areas. How easily goods move depends, as well, on the transportation and communication possibilities between areas. Hence, improvements in transportation will lead to less resistance. How easily goods move also depends, of course, on institutional and political factors. That milk in Minnesota faces no bureaucratic obstacles from moving to Wisconsin is due to the clause in the U.S. Constitution that prohibits states from interfering with interstate trade. Hence, introduction of such clauses in other constitutions will lead to less resistance. Similarly, the formation of "free-trade" areas, such as with the NAFTA, will lead to less resistance activity. This, then, is the theme of the paper, that how easily goods move between areas determines, in part, the extent of resistance to technology. In brief, trade between areas reduces resistance to technology.

This theme is not new. For example, in *The Rise and Decline of Nations* (especially, chapter 5), Mancur Olson (1982) has discussed how trade and factor mobility may affect the actions of special interest groups. And it has long been recognized that special interest groups may attempt to block new technology—the word "Luddite" is often used to refer to such a group. One of our contributions is to explore the link between how easily goods move between areas and resistance to technology in a formal model.

Our model is a simple general equilibrium model that determines the extent of resistance to technology at each of a number of (usually two) locations or areas. In the model the sources of resistance to technology are groups of individuals that have specialized skills in existing technology. These groups stand to lose "rents" if a more efficient technology that is available is introduced. We assume the skilled groups have the means, at certain resource costs, of constructing barriers to the efficient technology. The goal is to explore the incentives of skilled groups to create barriers.

We consider the incentives to construct two types of barriers—production barriers and consumption barriers. A production barrier in an area precludes the *use* of a technology in the area. A consumption barrier in an area precludes the *consumption* of a good produced with a technology (regardless of its location of production). To see the difference between these barriers, consider again the case of the genetically engineered cow-hormone bST. A production barrier to bST in, say, Wisconsin would declare that cows in Wisconsin cannot be injected with bST. A consumption barrier to bST in Wisconsin would declare that milk produced with bST cannot be sold in Wisconsin.

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, with areas A and B identical in all respects except that there are no barriers to technology in area B. We ask, What happens to resistance activity in area A if it joins a free-trade union with area B? We show that under some conditions joining the free-trade union with B results in the dismantling of *both* production barriers and consumption barriers in area A. The argument for the case of production barriers was alluded to above. If Wisconsin bans the use of bST in dairy farms within the state, but trade with Minnesota, where by assumption there are no barriers, is possible, then milk produced with the more efficient technology in Minnesota will be exported to Wisconsin. The exported milk will displace the milk produced in Wisconsin without bST. The vested interests in the inferior technology in Wisconsin will gain nothing from the production barrier. Hence, trade diminishes the incentive to erect the barrier.

The argument for the case of consumption barriers is subtler. Under a consumption barrier, bST milk produced in Minnesota cannot be exported to Wisconsin. However, milk produced the old-fashioned way can be exported. Dairy farms in Minnesota that do not use bST will no longer be competitive in the Minnesota market. However, these farms will be competitive in the Wisconsin market since bST milk is not allowed there. Minnesota farms will export milk produced without bST to Wisconsin. This "pressure" from Minnesota farmers diminishes the incentive for those in Wisconsin with vested interests in the old technology to erect a consumption barrier.

These results are in the spirit of the literature that asks, What is the impact of trade? Or what does trade do? Most economists believe that trade increases incomes and productivity. And recent factual studies indeed find a link between trade and productivity. Notable here are the two recent reports by McKinsey Global Institute (1993a,b), *Manufacturing Productivity* and *Service Sector Productivity.* Though there is a wide consensus that making it easier for goods to move between areas can increase the technological possibilities of an area, and though there is mounting evidence for this, the mechanisms by which trade increases incomes is far from clear. For example, Rodrik (1993, p.9), in his review of the trade and development literature, states that "the analytical foundations of such arguments regarding the dynamic benefits of liberalization have never been too clear." The model presented below presents a clear link from trade to increased technology adoption through trade's impact on resistance activities.

We also present concrete examples that show that the extent to which goods can move between areas has a large impact on technology adoption through its influence on resistance activities. For example, we review the recent history of the international automobile market, in particular, the extent to which Japanese "lean" production methods have been adopted in Europe and the U.S. We use the model to interpret why U.S. producers have more readily adopted the new Japanese methods.

In order to further clarify what the analysis thus far is about, it is helpful to discuss what it is *not* about. There is a large literature that examines resistance to *trade*, for example, models where groups lobby for tariffs and the like (see, e.g., Magee, Brock, and Young, 1989, and Grossman and Helpman, 1994). The analysis thus far is *not* in this spirit. Rather, the focus is resistance to *technology* and how trade, or the freer movement of goods between areas, influences this activity.

The second part of the paper is related to this resistance to *trade* literature. In particular, we ask in the model economy, When do we expect areas to form free-trade unions? That is, we analyze the incentives of skilled groups to form a free-trade union. Suppose in the one-area world that skilled individuals in A resist the new technology. Suppose also that if a free-trade union with B is formed, then skilled individuals in A decide not to erect a barrier. In some versions of the model, this means that skilled individuals in A are worse off while unskilled individuals in A are better off. Hence, whether or not a free-trade union forms depends upon the relative political clout of these two groups. However, there are also versions of the model in which both groups, skilled and unskilled, benefit from forming a free-trade union. Under these conditions we expect that unions would form.

Briefly, the idea is as follows. Consider the decisions of skilled groups in area A in a one-area world. Imposing a barrier in one's own industry in area A benefits the members of the skill group in that industry. But skilled individuals in a particular industry are consumers of the manufactured goods of other industries, and they are harmed by the barriers in these other industries. There are, therefore, two offsetting effects. Because we assume the groups act noncooperatively, the Nash equilibrium involves each group erecting a barrier, regardless of the "size" of the two effects.

Suppose the loss discussed above from the barriers in other industries outweighs the gain discussed above from the barrier in one's own industry. The equilibrium in the one-area world, therefore, has "bad" properties. The equilibrium is reminiscent of the prisoner's dilemma: All groups would prefer no barriers, but erecting barriers is individually rational for each skill group. Under these conditions, trade is a mechanism by which the "cooperative" solution can be achieved. Trade will eliminate barriers, and all parties favor removing barriers.

A final word on related literature. We believe this line of research will ultimately contribute to the literature on the "problem of economic development" (see Lucas, 1988, and Parente and Prescott, 1994). We think that the differences in productivity across countries are due in large part to differences in the technologies that are employed. Further, we believe that these differences in technology adoption are related to varying degrees of resistance to technology across areas.

2 Description of the 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 the technologies. Finally, we give a formal statement of the timing of events.

Brief Overview. 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 period, another technology for producing each good becomes available—the new technology. This technology can be adopted at zero cost. Skilled individuals decide to resist the technology or not. After this decision, the 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 consume $k+2$ commodities. The first commodity 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

$$U(x, y_1, y_2, ..., y_k, \ell) = u(x, y) \cdot h(\ell) = x^\alpha y_1^\beta y_2^\beta \cdots y_k^\beta \cdot h(\ell)$$

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 goods consumption 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 has two labor endowments: one endowment is used for production activities; the other, for nonproduction activities. The production activities are producing food and manufactured goods. The nonproduction activities are leisure and resistance activities. The nature of resistance activities is described later. Each of these two endowments are normalized to one unit of labor. A more natural approach, of course, would be to assume that each individual has a single time endowment that is allocated between goods production, leisure, and resistance activity. We can easily extend our results to this case. The purpose of two endowments is to simplify calculations below.

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.

Production Technologies. Let l denote the input of labor into the production of goods.

We assume 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 $y_i = \theta \cdot l$, 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 $y_i = \gamma \cdot l$, 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 (note that neither θ or γ were 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 good i we call *skill group i.* We assume that the fraction of the population in skill 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 skill group. Let $\lambda \equiv k\eta$. Then the fraction of the population in the unskilled group is $1 - \lambda$.

Resistance Technology. We now describe the process by which barriers to new technology are erected. The members of skill 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 the skill group erects a barrier ("b" for barrier) to the new technology and $a_i = n$ means the skill group does not erect a barrier ("n" for no barrier). A *production barrier* means that no individual (including the members of skill group i) can use the new technology. A *consumption barrier* prohibits the sale of goods produced with the new technology. (The policies have the same effect in the one-area world but are different in the two-area world; more on this below.)

The members of skill group i must spend resources to block the new technology. We assume that the group must spend ρ units of labor endowment in total in order to block the technology. Let $r = \rho/\eta$. Then if all members of skill group i contribute 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 nonproduction labor, an individual's leisure is $\ell = 1$ if no barrier is erected and $\ell = 1 - r$ otherwise (we assume $r \leq 1$).

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 skill group i chooses to erect a barrier or not, that is, it chooses $a_i \in \{b, n\}$. Each skill group i makes its choice to maximize the utility of the individuals in skill 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.

3 Equilibrium in the One-Area World

For expositional purposes, we begin with the case of a single manufacturing good ($k = 1$). Many of the points can be made in this context. Some cannot, however, so later we introduce many manufactured goods ($k > 1$).

Recall the timing of events from above. In the first period, the skill group chooses whether or not to erect a barrier: 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 (the superscript "b" denotes barrier; "n" denotes no-barrier). 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 skill group chooses to erect a barrier if and only if $v^b > v^n$.

Competitive Equilibrium in the Second Period With a Barrier.

Suppose the 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.[3] Individuals allocate their unit production 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 $\left\{p^b, m_L^b, x_L^b, y_L^b, m_H^b, x_H^b, y_H^b\right\}$ satisfying three conditions:

i) the choice (m_H^b, x_H^b, y_H^b) maximizes type H's utility; that is, it solves

$$\max_{(m,x,y)} u(x,y) \cdot h_H$$

$$\text{subject to } x + p^b \cdot y \leq (1-m) + p^b \cdot \theta \cdot m$$
$$0 \leq m \leq 1$$

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).

ii) 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 $h_L = h(1)$).

iii) demand must equal supply for both goods,

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

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

[3] 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.

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 $\lambda' \equiv \frac{1-\alpha}{1-\alpha+\alpha\theta}$ 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 $p^b \in (\frac{1}{\theta}, 1)$. Finally, if $\lambda > \lambda''$, then $m_H^b \in (0,1)$ and $m_L^b = 0$. The price of the manufactured good is $p^b = \frac{1}{\theta}$.*

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 have a higher productivity in manufactured goods. Hence, skilled individuals have a comparative advantage in the production of manufactures; unskilled individuals, in the production of food. This means skilled persons 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, unskilled individuals produce both food and the manufactured good in the equilibrium allocation, 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 equals 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 one, 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, $p^b = \frac{1}{\theta}$.

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 $p^b = \frac{1}{\theta}$

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 manufactured goods 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. Figure 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 $p^b = \frac{1}{\theta}$. The utility of the representative skilled individual is constant at its minimum point.

Competitive Equilibrium in the Second Period With No Barrier.

Now suppose the technology was not blocked at the first stage; 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 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, $p^n = \frac{1}{\gamma}$. 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.

Resistance at the First Period.

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

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 figure 1.*

The proof of this proposition is in the appendix. The proposition states that for certain parameters the representative skilled individual is better off with a barrier than without one. Let us describe the intuition behind this result.

Erecting a barrier has two offsetting effects on the utility of the skilled workers. First, erecting the barrier increases the price of the manufactured good. This is a negative effect on utility. If $\lambda \le \lambda'$, then erecting a barrier increases the price from $p^n = \frac{1}{\gamma}$ to $p^b = 1$. The increase in price is smaller the larger is λ. If $\lambda \ge \lambda''$, then the price increases from $p^n = \frac{1}{\gamma}$ to $p^b = \frac{1}{\theta}$. Second, erecting the barrier typically increases the income of a skilled individual. This is a positive effect on utility. If $\lambda \le \lambda'$, then erecting a barrier increases the income of a skilled individual from $p^n \cdot \gamma = 1$ to $p^b \cdot \theta = \theta$, 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 prices of manufactured goods increase 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 manufactured goods is of "small" consequence. The income effect dominates. This is the logic behind the condition $\theta > \gamma^{(1-\alpha)}$ stated in the proposition. This condition is satisfied if α is large.

4 Joining an Area With No Barriers

We now move to examine the impact of trade on resistance to technology. We consider an environment in which there are two areas. The first area, area A, is identical to that 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 technology in area B. In this section we ask, What happens in area A if it joins a free-trade union with area B? In particular, we ask whether or not the skill group in A chooses to erect a barrier given that it is in a free-trade union with area B. We compare this choice to that made when area A is not in a union with B, that is, the outcome in the previous section.

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

4.1 Production Barriers

Recall that a *production barrier* in an area means that goods cannot be produced with the new technology in that area. We have the following proposition:

Proposition 3 *If $\alpha > \frac{1}{2}$, then the skill group in country A does* not *erect a production barrier when it is in a trade union with area B.*

Before we describe the intuition for this result, notice that this outcome in area A is different from that in the one-area world. Under the assumptions of proposition 2, if λ is small, then the new technology is blocked in the one-area world but not in the two-area world. Hence, joining the trade union eliminates barriers to new technology in area A.

The intuition for this is as follows. We derive a contradiction. Suppose a barrier is constructed in A. By assumption, there is no barrier in area B. Hence, area B has a comparative advantage in the production of manufactured goods because it has access to the new technology whereas producers in A do not. Whether area B produces all the manufactured goods for both areas depends on the share of manufactured goods in consumer budgets. The assumption $\alpha > \frac{1}{2}$ 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.[4] 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.

4.2 Consumption Barriers

Recall that a *consumption barrier* in an area makes it illegal to sell goods 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. The basic result

[4] We have not worked out the case of $\alpha < \frac{1}{2}$. Calculating equilibrium in the trade union given a barrier in A and no barrier in 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 skill 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.

of this section is that trade also eliminates consumption barriers, though this kind of a barrier is more difficult to break than a production barrier. 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 in union with area B. The return to the representative skilled individual in A if there is no barrier in A when A is in 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 $\tilde{\lambda} \in (0, \hat{\lambda})$ for $\hat{\lambda}$ as defined in proposition 2. If $\lambda < \tilde{\lambda}$, then $v^b_{union} > v^n$. If $\lambda > \tilde{\lambda}$, then $v^b_{union} < v^n$. This is illustrated in figure 2.*

The proposition states that for certain parameters the representative skilled individual is better off with a barrier than without one. Before we describe the intuition for this result, notice that this outcome in area A is different from that in the one-area world. To see this, we have included in figure 2 not only the curves v^b_{union} and v^n, but also the curve v^b from figure 1. Recall that v^b is the return to the representative skilled individual in area A under a barrier in the one-area world. As seen in figure 2, for $\lambda \in (\tilde{\lambda}, \hat{\lambda})$, the skilled group in area A erects a consumption barrier in the one-area world but not in the union with area B. For $\lambda < \tilde{\lambda}$, they erect a consumption barrier in both the one-area world and the union. Hence, joining the trade union eliminates barriers to new technology in area A.

The key idea for understanding why $\tilde{\lambda} < \hat{\lambda}$, so that there are conditions under which if A joins a trade union with B this results in a dismantling of barriers in A, is as follows. If there is a consumption barrier in A when a union is formed, and if λ is less than λ'', then skilled individuals in area B will produce the manufactured good with the old technology for export to area A. This depresses the manufactured good price in area A. This, in turn, reduces the incentive to constructing the barrier.

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 these goods when there is a 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 the one-area case with a barrier. The equilibrium allocation in area B is the same as 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 $\frac{1}{\gamma}$). Suppose instead a skilled individual in B produces the manufactured good with the old technology for export to area A. Since, by assumption, λ is less than λ'', the manufactured good price in A exceeds $\frac{1}{\theta}$ (see proposition 1). Since output equals θ units and price exceeds $\frac{1}{\theta}$, 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 the exports from B to A and the resulting decrease in the manufactured good price, joining the union reduces the return to erecting a barrier for λ less than λ'', as illustrated in figure 1. 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 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. Joining a union reduces barriers.

We conclude this subsection 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 trade union with B eliminates production barriers but not consumption barriers. Assume, then, that $\alpha > \frac{1}{2}$. Then from proposition 3 we know that forming a union eliminates production barriers. It may not eliminate consumption barriers. From proposition 4 (and figure 2) we know that if λ is small, then $v^b_{union} > v^n$. In this case, consumption barriers are erected.

4.3 The Impact of Trade on Technology Adoption

Thus far the analysis has shown that if it is easier for goods to move between areas, modeled as area A joining a trade union with area B, then there will be less resistance to, and hence greater adoption of, new technology. We think this mechanism is capable of explaining differences in resistance across industries within a country, such as the construction and milk industries in the U.S., as well as differences across countries, such as those between European and U.S. automobile makers. But before presenting these arguments in detail, we finish the development of the model. Later we turn to showing this mechanism at work.

5 Forming a Free-Trade Union

The previous section examined the impact in A of joining a free-trade union with B. It examined the consequences of making it easier for goods to move between areas. But when do we expect areas to form free-trade unions? In this section we analyze the incentives to form a free-trade union.

Thus far the model has contained 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. This "institution-building" stage is described in more detail below.

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 A of forming a 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, whether or not a free-trade union forms depends upon the relative political clout of these two groups. This suggests paying closer attention to the political process than we have done so far. However, by extending the model we can make some important points while continuing to be agnostic about the political process.

The point of this section is to show that when the model is extended to the case of multiple manufactured goods, it is possible for all groups to be better off with a trade union than without one. The trade union case *Pareto-dominates* the alternative of no trade union. Since every individual in the economy is better off with a trade union, we can be confident, without specifying the details of the political process, that a union is set up in period 0.

5.1 The One-Area World With Many Manufactured Goods

Before proceeding to discuss the formation of a trade union, we need to extend the analysis of the one-area world. Consider the one-area world with $k > 1$. We sometimes refer to the different manufacturing goods as different "industries." Recall that in the first stage each skill 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.

Competitive 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 $\lambda' \equiv \frac{k(1-\alpha)}{(\alpha+k-1)\theta+(1-\alpha)}$. Recall that λ is the fraction of the population that is in some skill group and that $\frac{\lambda}{k}$ is the fraction that is in some particular industry i.[5] We can now state

Proposition 5 *Take as given some barrier set $\tilde{a}$ where 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 skill group i completely specialize in production of good i; and individuals that 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 $p_i = \frac{1}{\gamma}$ and the individuals in skill group i have the same consumption and utility as unskilled individuals.*

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

Resistance in the First Period.

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 skill group has a *dominant strategy.*

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

[5]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 $\frac{1-\alpha}{\theta} > 0$ as k goes to infinity.

A proof of this result is contained in the appendix. This result is the extension of proposition 2 to the case of multiple manufactured goods. The condition $\theta > \gamma^{\frac{1-\alpha}{k}}$ 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 previous proposition. If $\theta \in (\gamma^{\frac{1-\alpha}{k}}, \gamma^{1-\alpha})$, then all skill 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 case of $k = 1$ and $k > 1$. With $k = 1$, the interval $(\gamma^{\frac{1-\alpha}{k}}, \gamma^{1-\alpha})$ specified in the proposition disappears. For $k > 1$ there exists a parameter region in which all individuals are better off with no barriers in any industry than with barriers in every industry. However, the unique equilibrium involves barriers in every industry. 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.

5.2 Forming a Free-Trade Union

The analysis of the trade union above examined the consequences in A of joining a trade union with an area that had no barriers. Now we examine the incentives of individuals in the two areas to form a free-trade union. The model in this section is slightly different from that above. First, we assume that $k > 1$. Second, we assume that the costs of resistance are the same in each area. Previously we assumed that the costs of resistance were higher in area B, so high that no barriers were erected in B. Now the skill groups in both areas decide whether to erect barriers. The skill groups in the two areas all move simultaneously in period 1 when choosing to erect a barrier or not. Each skill group takes as given the choices of all the other skill groups in the two areas when making its choice. For example, when choosing its action $a_1^A \in \{b, n\}$, skill group 1 in area A takes as given the actions a_2^A, a_3^A,...,a_k^A of the other skill groups in area A and the actions a_1^B, a_2^B,...,a_k^B, of the skill groups in area B. Our result is

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

The proof is straightforward. Consider the problem of a particular skill group in a particular area. By symmetry we can examine skill group 1 in area A. Suppose that all other skill groups in both areas choose not to erect a barrier. Suppose skill 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 required that group 1 give up some leisure time. This barrier entails costs but delivers no benefits. Hence, skill 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 in proposition 7. If there is no 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 trade union case. For example, under the assumptions of proposition 9, there also exists an equilibrium of the union case in which all skill 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.

6 The Impact of Trade on Technology Adoption

A large part of the analysis above was to show that if it is easier for goods to move between areas, modeled as area A joining a trade union with area B that has no barriers, then there will be less resistance to, and hence greater adoption of, new technology. We now turn to showing this mechanism at work. In this section, we use the theory developed so far to examine episodes of technological change in three industries: the advent of "lean production" in the automobile industry, the introduction of bovine Somatotropin in the dairy industry, and the introduction of preassembled parts in the construction industry.

6.1 Lean Production in the Automobile Industry

We begin by using the model to interpret some of the major changes in the automobile industry over the past twenty or so years. A rough outline of some of the major changes is as follows. Beginning over thirty years ago, a new way of 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 across the world. For example, the new methods are now widely employed in the U.S. In contrast, European car makers have lagged behind their U.S. competitors in adopting these Japanese techniques.

Why has the experience in the U.S. 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 trade with B is possible. We take Europe to be area A in the case where trade with B is not possible. With this interpretation, the new methods were adopted in the U.S. because resistance was less in the U.S. than in Europe—because the U.S. was more open to trade competition with Japan than was Europe.[6] In order to defend this interpretation, we need to document two things: first, that the U.S. was more open to competition and, second, that this led to less resistance to the new methods.

The claim that the United States automobile market is more open than Europe's is fairly easy to substantiate. Japanese-produced cars have penetrated the United States market to a substantial degree as compared to the European market. Table 1 presents evidence on

[6]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 its being more open to imports from Japan than is the European automobile market. The McKinsey studies, the Womack, Jones, and Roos (1991) project, and many others 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.

this point. In 1992, 1,584,000 automobiles were produced in Japan and then exported to the United States. (This figure *does not* include the 1,415,000 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 143,000 cars produced in Japan in 1992 and sold under Chrysler and General Motors nameplates.) Exports of Japanese-produced cars to the United States accounted for 19.7 percent of car sales in the U.S. in 1992.[7]

This can be contrasted with the shares of Japanese-produced cars exported to the markets of European countries. The table divides 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. 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 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 inflow of Japanese cars in Spain, France, Italy, and for that matter even the UK and Germany.[9]

The second thing to document is that there was less resistance to the new 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 U.S. than in Europe. Then we present some discussion that the reason has something to do with less resistance in the U.S.

It is now conventional wisdom that the United States automobile industry has undergone a major transformation. The word "renaissance" is often used to describe the changes in the American automobile industry. A substantial portion (25 percent of all cars produced

[7]We use the new-car registration in 1992 as our measure of car sales in Table 1 because this number is available for all of the countries listed in the table and actual car sales in 1992 is not available for all of the countries. The two figures are close. For example, actual car sales in the United States in 1992 was 8,213 thousand compared to new-car registrations of 8,057 thousand.

[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 Europeans have virtually no sales, except in the small, high-end luxury-car market.

[9]The United States 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.

in 1992) of the cars produced in the U.S. are made in Japanese transplant factories using the latest technology. In addition, Ford and Chrysler, and to a lesser extent GM, have made great strides in adopting the techniques in their factories. This is the conclusion of the MIT International Motor Vehicle Program, a five-year, five million dollar 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 (p. 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 is now equal to that 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 (1.3 percent in 1992) of production is by Japanese transplant firms.[10] And the production by the six volume producers in Europe is anything but "lean." Continuing the above cited passage, Womack et al. (1990, p. 87) write that "Europe, by contrast, has not yet begun to close the competitive gap." A recent report, *Manufacturing Productivity,* 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 has often come from autoworker unions. 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.[11] Unions have resisted the closure of outdated factories and layoffs. As an alternative to laying off workers, Volkswagon is moving to a four-day week, and the company is considering other ways to be more productive without laying off workers. But according to Daniel Jones (one of the authors of the MIT study cited above), in reference to Volkswagon's German operations, "You cannot manage 50,000

[10]This figure will increase in future years since a number of new transplant factories are being built.
[11]This is discussed in Kenney and Florida (1993, p. 315).

people at one site in a lean way."[12]

But has resistance in the U.S. been less severe than in Europe? One piece of evidence is the response in the U.S. 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 Community.[13]

6.2 Bovine Somatotropin in the Dairy Industry

We next use the model to interpret the events surrounding a major recent change in the dairy industry. A rough outline of the facts is as follows. Mansanto genetically engineered bovine Somatotropin (bST), 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 (see Marion and Wills (1990)). Many groups have opposed the use of the hormone. Opponents of the new technology have raised the issue of a health risk to justify a ban of the new technology.

In the U.S., attempts to block the hormone have occurred at both the state and federal level. At the federal level, the Food and Drug Administration (FDA) has jurisdiction over the approval process. Efforts to block bST at the federal level have therefore involved lobbying the FDA.

The efforts by individual states to block the new technology have taken many forms. For example, there have been attempts to pass laws in the states of Wisconsin and Vermont that would block production with the new technology. Recently, opponents in some states have tried another tactic. They are lobbying for labeling requirements that would specify whether or not the milk being purchased by the consumer was produced by a cow treated with the hormone. Bills to this effect have already been passed by Vermont and Maine, and other state legislatures are considering similar bills.[14] The FDA is opposed to this labeling

[12]This quotation is from "Europe's Car Makers: Then There Were Seven," *The Economist*, February 5, 1994, p. 19-22.

[13]The EC later abandoned this policy. There are now no limits on Japanese transplant production in Europe, and transplant production is expanding there.

[14]See "2 States Limit Dairies' Use of Hormone, *New York Times*, April 15, 1994, p. A13.

because in their view such labeling is misleading. It suggests that there is a difference in safety while there is no actual difference in safety in the FDA's view.[15]

After a long battle, the hormone was finally approved by the FDA. Commercial use began in the United States in early 1994. In this section we focus on the failure of individual states to pass laws prohibiting the use of bST. We use the model to offer an interpretation of this failure.

In terms of the model, we think of areas A and B as corresponding to states in the U.S. 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 limits the ability of states to restrict interstate trade. With this interpretation, individual states were not successful at constructing barriers to bST because interstate trade reduces the incentive for interest groups within a state to lobby the state legislature to erect a barrier to the new technology.

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 in the theoretical section, there will be an incentive for old-technology producers in other states to export milk made without bST to Wisconsin, and this limits the benefit of the policy to the old-technology firms in Wisconsin.

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

6.3 Preassembled Parts in the Construction Industry

Finally, we use the model to interpret the events surrounding the introduction of preassembled parts in the construction industry. For a number of years, the construction of housing

[15]In addition to the FDA's opposition, there are a number of difficulties in implementing a labeling policy. Milk produced with the new technology is indistinguishable from milk produced without the technology, so the policy would have to rely on honesty by milk producers. An additional complication is that milk is an intermediate good. If a food producer in California puts powdered milk into a cake mix and sells it to a grocery store in Vermont, is this subject to the labeling law?

in some communities has involved assembling plumbing systems offsite. The advantage of offsite construction is that one can take advantage of assembly line techniques. Despite its use in a number of communities, preassembled parts have been blocked in a number of locations. These restrictions have persisted for years in some locations (see Oster and Quigley, 1977).

Why have some towns been able to block these new production methods when other towns have already adopted them? We give an interpretation in terms of the model.

In terms of the model, we think of areas A and B as corresponding to different municipalities in the U.S. We imagine the model situation in which there is no trade between areas A and B. This is because of the nature of housing services. Housing services are a good that cannot be traded. 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 zoning laws.

Appendix

Proof of Proposition 2

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

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 the 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 $y_H^b = (1-\alpha)\theta\frac{1}{p^b} = (1-\alpha)\theta$. The equilibrium utility level is, therefore,

$$v^b = \left[(\alpha\theta)^{\alpha}\left((1-\alpha)\theta\right)^{(1-\alpha)}\right] \cdot h(1-r). \tag{1}$$

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 $p^n = \frac{1}{\gamma}$ and income is one unit of food. This implies consumption levels of $x^n = \alpha$ and $y^n = (1-\alpha)\gamma$. Equilibrium utility is

$$v^n = \left[\alpha^{\alpha}\left((1-\alpha)\gamma\right)^{(1-\alpha)}\right] \cdot h(1). \tag{2}$$

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

$$\frac{v^b}{v^n} = \frac{\theta}{\gamma^{(1-\alpha)}} \cdot \frac{h(1-r)}{h(1)}. \tag{3}$$

The first term is greater than one by assumption. The second term is less than one. However, it is arbitrarily close to one for small enough r. Hence, $v^b > v^n$ for small enough r, as claimed.

Next, suppose that $\lambda \geq \lambda''$. In this case, with the barrier, the equilibrium price is $p^b = \frac{1}{\theta}$ 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 $p^n = \frac{1}{\gamma}$. 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

We need to show it is a dominant strategy for each skill group to erect a barrier. By symmetry, it is sufficient to consider the choice of skill group 1. Suppose this skill group takes as given that in m of industries 2 through k there are barriers and in $k-1-m$ of industries 2 through k there are no barriers (by symmetry it doesn't matter which of the industries fall in the two groups). Let $v_1^b(m)$ denote the utility of a person in skill 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 $\frac{1}{\gamma}$. The income of an individual in skill 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 $\beta \equiv \frac{1-\alpha}{k}$ (the price of such a good is one 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 $\frac{1}{\gamma}$). The utility of an individual in skill group 1 is, therefore,

$$v_1^b(m) = \left[(\alpha\theta)^\alpha (\beta\theta)^{(m+1)\beta} (\beta\gamma\theta)^{(k-m-1)\beta}\right] \cdot h(1-r). \tag{4}$$

Let $v_1^n(m)$ denote the utility of a person in skill 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 $p_1 = \frac{1}{\gamma}$ while the prices of the other goods are the same as described above. The income of a skill 1 individual 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 a skill 1 individual in this case is

$$v_1^n(m) = \left[\alpha^\alpha (\beta)^{m\beta} (\beta\gamma)^{(k-m)\beta}\right] \cdot h(1). \tag{5}$$

The ratio of the utility to an individual in skill group 1 when there is a barrier and when there is no barrier is

$$\frac{v_1^b(m)}{v_1^n(m)} = \frac{\theta}{\gamma^\beta} \cdot \frac{h(1-r)}{h(1)}. \tag{6}$$

Note that in this ratio there are no terms involving m, the number of other skill groups that erect barriers. Hence, whether or not $v_1^b(m)$ is greater than $v_1^n(m)$ (that is, whether or not the ratio (6) is greater than one) does not depend on the actions of the other skill groups. Recall that $\beta \equiv \frac{1-\alpha}{k}$; if $\theta > \gamma^{\frac{1-\alpha}{k}}$ and if r is small, then skill group 1 chooses to erect a barrier, as claimed. Q.E.D.

Proof of Proposition 7

Suppose that skill group 1 erects a barrier and all the remaining $k-1$ skill groups do so as well. Then the utility of skill group 1 is given by $v_1^b(k-1)$, where $v_1^b(m)$ is defined by (4) above. If skill group 1 does not erect a barrier and no other skill group erects a barrier, then utility is $v_1^n(0)$. The ratio of these utilities is

$$\frac{v_1^b(k-1)}{v_1^n(0)} = \frac{\theta}{\gamma^{1-\alpha}} \cdot \frac{h(1-r)}{h(1)}. \tag{7}$$

The second term is less than one since $r \geq 0$. The first term is less than one if

$$\theta < \gamma^{1-\alpha}. \tag{8}$$

If this holds, then skill group 1 is strictly better off when no barriers are erected than when every barrier is erected. Q.E.D.

Figure 1

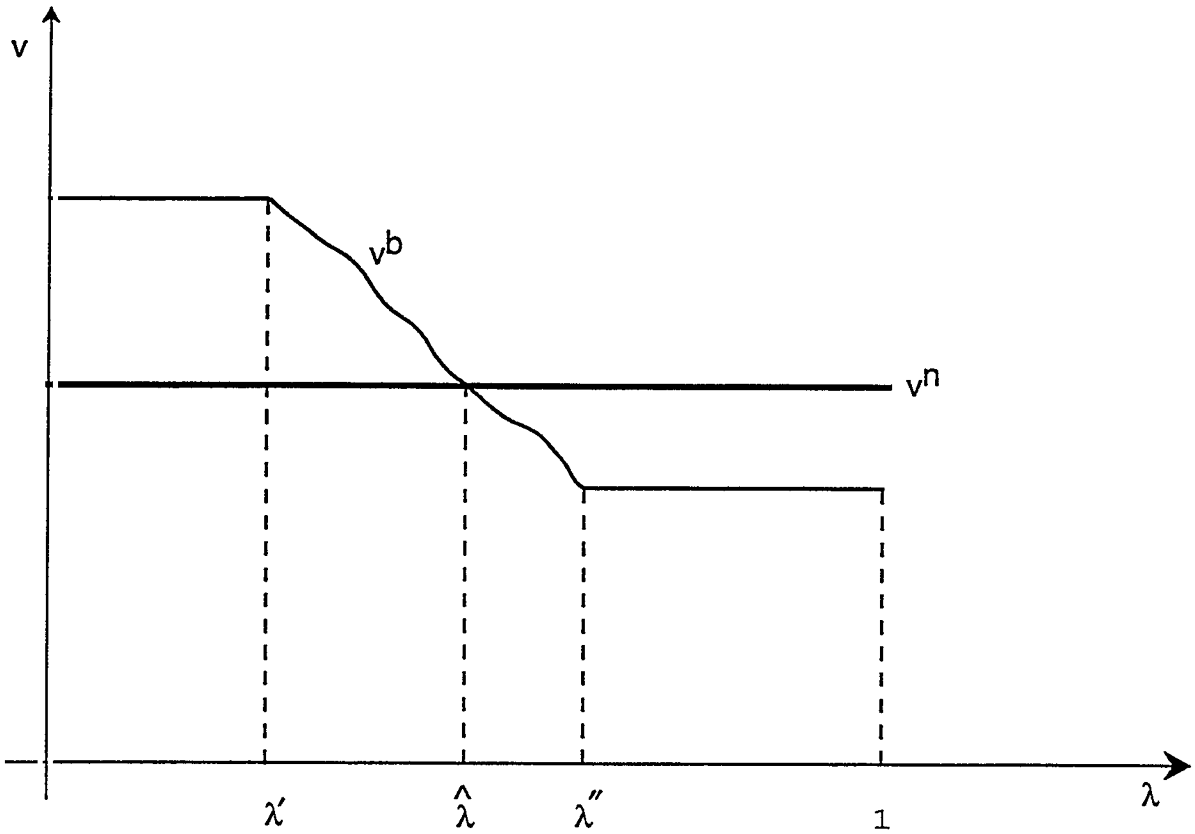

Figure 2

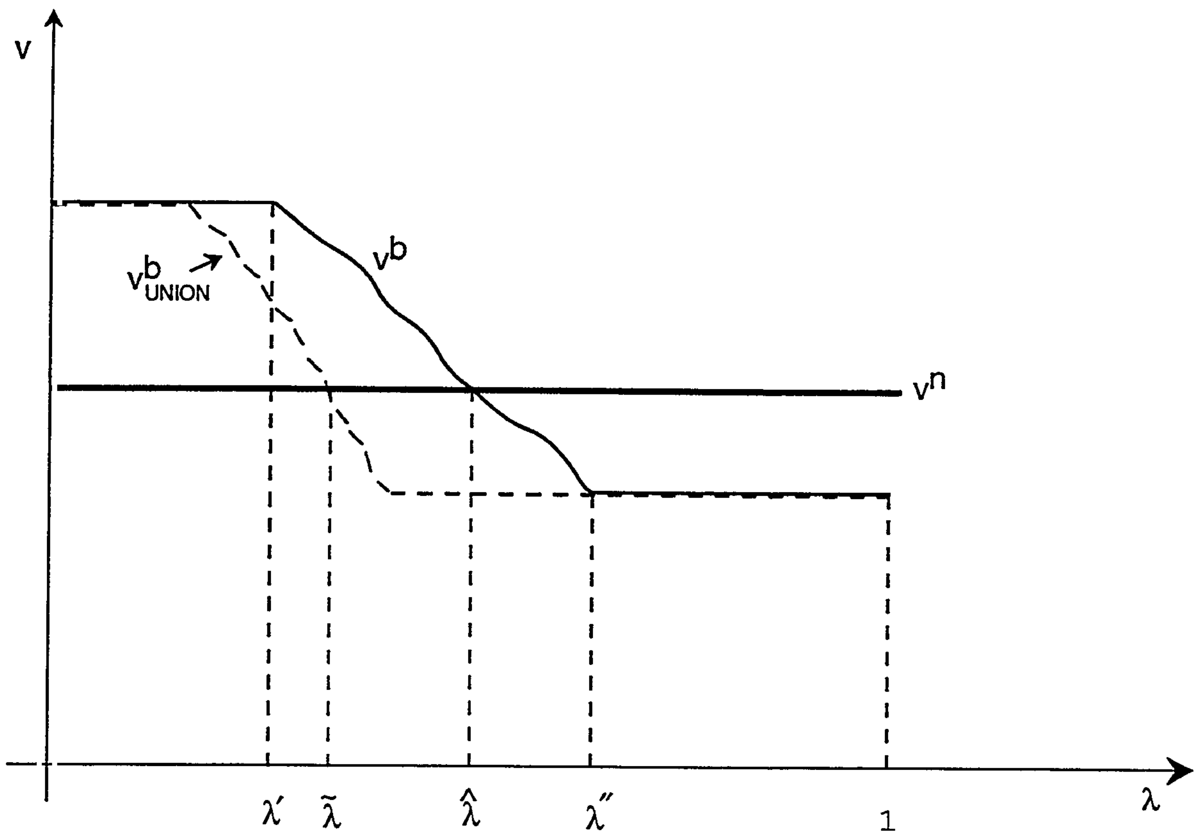

Table 1
The United States and European Automobile Market in 1992

	New Car Production (1,000s)	New Car Registration (1,000s)	Imports of Cars Produced in Japan (1,000s)	Japanese Import Share of Registrations
USA	5,665	8,057	1,584	19.7
European countries with large auto industries				
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	0.1
United Kingdom	1,292	1,594	153	9.6
European countries without large auto industries				
Belgium	268	466	126	27.0
Sweden	294	154	36	23.4
Netherlands	94	494	117	23.7
Austria	15	320	101	31.6
Denmark		85	36	42.4
Ireland		68	28	41.2
Norway		60	30	50.0
Switzerland		286	87	30.4
Finland		68	25	36.8

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