A gain from trade: From unproductive to productive entrepreneurship

Thomas J. Holmes⁠, James A. Schmitz Jr.⁠,*

*Department of Economics, University of Minnesota, 1035 Heller Hall, Minneapolis, MN 55455, USA
and Federal Reserve Bank of Minneapolis, 90 Hennepin Avenue, Minneapolis, MN 55480, USA

Research Department, Federal Reserve Bank of Minneapolis, 90 Hennepin Avenue, Minneapolis, MN 55480, USA

Received 14 April 1999; received in revised form 11 February 2000; accepted 7 June 2000

Abstract

There is a large and growing theoretical literature studying the allocation of individuals and their effort amongst productive and unproductive entrepreneurial activities. Trade and competition between regions have been recognized as potentially powerful forces limiting unproductive entrepreneurial activities. In this paper we extend the technology-ladder model of Grossman and Helpman to study this issue and demonstrate conditions under which lowering of tariffs leads to a shift from unproductive to productive entrepreneurial activities. © 2001 Elsevier Science B.V. All rights reserved.

JEL classification: O31; O40; F10

Keywords: Entrepreneurship; Gains from trade; Resistance to technology; Political economy of growth

We would like to thank an anonymous referee for very detailed and helpful comments. We also thank Andy Atkeson, Pat Kehoe, John Kennan, Pete Klenow, Boyan Jovanovic and Alberto Trejos for comments and encouragement and seminar participants at the University of Chicago, University of Michigan, SED meetings in Oxford, and the Econometrica meetings in New York. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

*Corresponding author. Tel.: +1-612-204-5482; fax: +1-612-204-5515.
E-mail address: jas@res.mpls.frb.fed.us (J.A. Schmitz Jr.).
1. Introduction

There is a large and growing theoretical literature studying the allocation of individuals and their effort amongst productive and unproductive entrepreneurial activities. Some notable recent contributions include Baumol (1990), Murphy et al. (1991, 1993) and Parente and Prescott (1999). While unproductive entrepreneurial activities take many forms, perhaps the greatest amount of this activity occurs through the regulatory process when incumbents attempt to block rivals (both new entrants and producers of substitute products) and limit competition—a process of “regulatory capture” as initially discussed in Stigler (1971). In the next section, we argue that this use of the regulatory process to block rivals is ubiquitous—we discuss examples across many industries—and present evidence that it has significant negative consequences for output and productivity.

A key issue, of course, is understanding the forces that determine the balance amongst productive and unproductive entrepreneurial activities. One force determining the extent of unproductive entrepreneurship is the “state of trade”. For example, Olson (1982) argues that competition between states in a federal system like the United States limits the incentives for special interest groups in a state, say state-A, to set up state regulations blocking a new technology. The reasoning is simple: Because tariffs between states are zero, if groups in state-A block the use of the new technology, goods produced with the new technology in other states, presumably inexpensive goods, will flood state-A. Similarly, Murphy et al. (1991) argue that factors that facilitate trade, including lower communication and transportation costs, promote productive entrepreneurial activities and limit unproductive ones (see their Table 1, p. 519, 1991). While these arguments are sound, they lack a formal analysis (i.e., an analysis in a dynamic general equilibrium trade model) of how trade policy affects the relative incentives to pursue productive and unproductive entrepreneurship.

The purpose of this paper is to provide such an analysis.

We develop a model that is a variant of the technology ladder model of Grossman and Helpman (1991a). Our key modification is to introduce an unproductive entrepreneurial activity. Here, two activities determine the ladder positions of entrepreneurs: research, as in the standard model, and attempts to block the research of rivals. These blocking efforts can be interpreted as an entrepreneur’s use of the regulatory and legal processes to attempt to invalidate innovations of rivals, as in the regulatory capture literature discussed in detail above.

Our main result is that an improvement in the state of trade, by which we mean lower tariffs and/or lower transportation costs, shifts the relative returns away from unproductive entrepreneurship (that is, blocking) and toward productive entrepreneurship (that is, research). Below, we formally study the case of lowering tariffs, though the analysis of a reduction in transport costs follows similar lines. Let us explain our result in two ways. Let us first tell an informal
story; then let us introduce a few more details of the model and present the key parameter assumption (concerning elasticities) under which the result is true.

We start with the story. Suppose that world tariff levels are prohibitively high, and consider a particular industry in a particular country. Consider an entrepreneur who is a “leader” in this industry and has a monopoly position. This entrepreneur can devote effort to innovating (that is, climbing the technology ladder), and, if successful, profits will increase. But this entrepreneur, recognizing that his or her innovation may fail, can also devote effort to blocking the potential innovations of rivals that will erode his or her current profits. By blocking domestic rivals, the entrepreneur can protect his or her monopoly over domestic consumers. Because some effort is devoted to blocking rivals, and not to research, such an entrepreneur may have an extremely inefficient technology relative to the best practice technology in other countries. But this is of little concern to the entrepreneur, since world tariffs are prohibitively high and domestic consumers have no foreign alternative.

Suppose that world tariff levels are reduced in two steps: first the domestic tariff (i.e., tariffs on imports into the country) is lowered, followed by the foreign tariffs (i.e., tariffs that apply to goods sold abroad). Consider the reduction in the domestic tariff. An entrepreneur with an inefficient technology now has little to gain by blocking domestic rivals. Regardless of what happens to domestic rivals (that is, whether they innovate or not), an entrepreneur with an inefficient technology will have few sales because consumers will take advantage of low tariffs to buy low-cost foreign goods. Thus, a reduction in the domestic tariff shifts the incentives away from unproductive entrepreneurship (that is, blocking) and toward productive entrepreneurship (that is, research). Next consider a reduction in foreign tariffs. Here, as well, the returns to research increase relative to the returns to blocking, since an entrepreneur who successfully innovates will be rewarded with substantial exports in the global market. An entrepreneur with an inefficient technology has little hope for exports.

We now introduce a few more details of the model. Again, entrepreneurs devote effort to blocking in order to protect current profits. On the other hand, successful research in the model means a firm takes a step up the technology ladder and produces with a more efficient technology, and this increases profits. The incentives to do research (as opposed to blocking) then depend on the ratio of profits at the next rung to the profits at the current rung. The bigger this ratio, the more incentive there is to do research. We want to argue that, under reasonable conditions, the lower are tariffs, the greater is this ratio.

Now, in the model below, entrepreneurial profit at a rung equals the sum of profits earned in the domestic market and export markets. Moreover, the ratio of total profit at the next rung to the total profit at the current rung can be expressed as a weighted average of two ratios: the ratio of profits in the export market at the next rung to the export profits at the current rung and the same ratio of profits in the domestic market. Let us briefly consider how some of the
terms in this expression, this weighted average of the ratios of export and domestic profits, change as tariffs are lowered.

First, not surprisingly, the lower are tariffs, the greater is the weight placed on the ratio of profits in the export market and the less is the weight on the ratio of domestic profits. We will now argue that under reasonable conditions the ratio of profits in the export market is greater than the ratio of profits in the domestic market. Hence, as tariffs are lowered, greater weight is placed on the larger ratio, and this serves to increase the ratio of total profits. Hence, this means the incentives to do research increase.

The argument has two steps. The first step is to note that a technological advance which lowers cost and price (which happens in the model below) has a proportionately larger effect on profits, the more elastic is demand. A loose way to see this is to note that if marginal cost falls by one dollar and price is lowered by one dollar, then the profit margin on each good stays the same. The decrease in price will then have a relatively larger impact on demand, and hence profit, the more elastic is demand. Another way to say this is that the ratio of profits in a market as we climb the ladder will be larger, the more elastic is demand.

The second step is to show that, under reasonable conditions, the elasticity of demand in the export market is greater than that in the domestic market. Consider an entrepreneur who in the current period is a monopolist in a particular good, say good $x$, in a particular country, say $i$. The entrepreneur sells $x$, say cars, to domestic consumers and foreign consumers. If the entrepreneur cuts his or her price in the domestic market, then the increase in demand depends on the elasticity of substitution between $x$ and the other domestic goods that consumers buy, say $y$, say restaurant meals. If the entrepreneur cuts his or her price in the export market, then the increase in demand depends on the elasticity of substitution between the domestic $x$ and the $x$ produced in other countries, that is, for example, Japanese and American cars. The “reasonable” assumption discussed above, under which lowering tariffs leads to more research and less blocking, is that Japanese and American cars are better substitutes for one another than are American cars and American restaurant meals.

Theoretical models related to that below include the model in Holmes and Schmitz (1995), which shows that reductions in tariffs can lead special interest groups to drop resistance to new technologies. However, the paper does not model research effort and the evolution of new technology. Grossman and Helpman (1991b) study a small open economy model and show that the imposition of a quota on an imported good leads to a shift in entrepreneurial effort, from research to rent-seeking efforts, to obtain import licenses.¹

¹ There are other strands of the literature on the relationship between trade and productivity. A set of older papers stresses the importance of the link without using formal models (e.g., Balassa, 1967; Leibenstein, 1966). More recently there has been some theoretical work discussing how trade policy affects management contracts in environments with principal-agent problems (Hörn et al., 1995).
The rest of the paper proceeds as follows. In the next section, we describe the blocking activities that occur in modern economies. The model is described in Section 3. The definition of equilibrium is given in Section 4. Section 5 presents a characterization of equilibrium. Section 6 presents the main comparative statics result. The last section contains a number of remarks about the model and its assumptions.

2. Some background on blocking activities

In this section, we first discuss some of the blocking activities that occur in modern economies, as well as evidence that such activities significantly lower output and productivity. We then argue that the state of trade plays an important role in determining whether it is profitable to pursue these blocking activities.

2.1. Blocking activities

Entrepreneurs/organizations often use the legal process to impede the progress of competitors. Perhaps the greatest amount of this blocking activity—and the blocking we discuss here—occurs through the regulatory process. That the regulatory process is used by incumbents to block rivals (both new entrants and producers of substitute products) is an old idea, starting with the famous article by Stigler (1971). This view has become known as the “regulatory-capture” hypothesis or the private-interest theory of regulation. In this subsection, we present a list of some major industries, discussing regulatory restrictions that incumbents have attempted (often successfully) to place on rivals, as well as evidence showing that such restrictions have significantly reduced output and productivity.

2.1.1. Banking

For much of the past century in the United States, there were significant restrictions on the ability of banks to open branches within their states of operation. Many states were in fact “unit banking” states, where no branching whatsoever was permitted. It has long been thought that these state regulations were kept in force by politically connected small banks (often rural banks) in order to limit competition from larger competitors (often urban banks). Kroszner and Strahan (1999) find strong support for this view in their study of banking deregulation in the United States over the last quarter century. While branching restrictions have been lifted in most states, Kroszner and Strahan show that deregulation occurred much earlier in states where small banks had a minor presence, for example, where small bank assets made up a small share of
industry assets and where small banks made up a small share of the number of firms.

There is substantial evidence that the removal of intrastate banking restrictions influenced output and productivity. For example, Jayaratne and Strahan (1996) estimate that the growth in real per capita state income increased by over 0.5 percent per year when a state dropped its branching restrictions. Let us emphasize that this is a claim about overall per capita growth—not simply an increase in the banking industry’s growth.

2.1.2. Communication

The U.S. telephone industry has been subject to extensive regulation during the last century. For much of this century, there was a monopoly producer in both the long-distance segment and local market segment, with regulation prohibiting the entry of any competitors into these markets.

In the long distance market, AT&T was the sole provider of services until the 1960s when technological change—microwave communications—“began to erode the monopoly position of AT&T and to induce the Federal Communications Commission (FCC) to modify the regulatory support it gave the monopoly” (Gort and Sung, 1999). AT&T fought strenuously to maintain its monopoly in long distance, with top AT&T management devoting considerable effort to legal battles to limit entry. As the regulatory environment finally began to swing away from AT&T’s monopoly in long distance, and with MCI’s and other firms’ entries into the market, top-executive effort at AT&T shifted away from these legal battles (and presumably toward more entrepreneurial, market-creating activities).

The local telephone markets are a somewhat different story. AT&T was able to maintain its monopoly in these local markets through the 1960s and 1970s. In the early 1980s, AT&T was required to divest its local telephone market assets. Eight regional telephone companies were established—the Baby Bells. These Baby Bells have had great success in maintaining their monopoly positions in local markets to this day.

Gort and Sung (1999) have used this different experience in the long distance and local markets as a way to examine the costs of regulations limiting entry. In particular, they compare the productivity record of AT&T Long Lines (the long distance component of AT&T), where entry has occurred since the 1970s, with that of the regional companies, where entry has been blocked. During the period 1977–91, the average annual total factor productivity (TFP) growth in AT&T Long Lines was 5.7 percent, while for the regional monopolies, the average annual TFP growth was 2.5 percent. These differences in productivity growth are, of course, very significant.

Another segment of the US telephone industry is the telecommunications equipment industry. This industry was also subject to extensive regulation, which allowed AT&T, through its manufacturing subsidiary Western Electric,
to control the market for much of the century. In recent years, regulatory changes have provided the opportunity for new manufacturers to enter the industry. Deregulation has led to a burst of new products and, as Olley and Pakes (1996) show, to significant increases in the industry’s productivity growth.

2.1.3. Distribution industries

During the past quarter century, there has been a technological revolution in the distribution industries—that is, the retail and wholesale industries. Many innovations have been introduced, such as the computerization of checkout and inventory management. One important consequence of these developments, the Wal-Mart phenomenon, has been the integration of the distribution system, thus minimizing wholesaling as a separate activity for many lines of business. This process has threatened, of course, the survival of small retailers, and these small retailers have fought to put restrictions on the Wal-Marts of the world.

In the United States, small retailers have had only limited success in slowing the growth of these high productivity retailing formats. However, in Europe and Japan small retailers have had the political clout to limit the spread of these new formats (Baily, 1993). For example, small retailers have kept in force laws that limit the floor size of stores. Such limits on store floor size will often serve as a block to stores like Wal-Mart and their new technologies, since the new technologies require investments that are “financed” with high volumes of sales.

These restrictions in Japan have limited the new retail formats, leading to an industry that, relative to the United States, has much smaller store sizes and lower productivity. Baily (1993) estimates that Japanese retailing productivity is about one-half that in the United States, and he attributes much of the difference to the strict regulations on store size in Japan.

2.1.4. Transportation

One of the first examples used to support the private-interest theory of regulation was that of the railroad industry using the regulatory process in the 1930s to hamper its emerging competitor, the long-haul trucking industry. In

---

2 But the efforts by traditional retailers to block new retail formats continue in the United States. For example, see “Repackaging the Big Box”, (New York Times (NYT), December 20, 1999), a story describing how zoning restrictions in New York City have forced superstores to change the structure of their stores. Also, see the recent stories regarding how traditional car dealers are lobbying state legislatures to block two new retail formats in their industry: first, “superdealerships”, that is, publicly traded companies that are national chains and, second, Internet sales. “A Breakdown on the Sales Lot: Superdealerships have trouble turning a profit” (NYT, December 15, 1999) describes how traditional car dealers have used state laws to block the expansion of national chains. “Car Dealers’ Driveway Blues: Pushing for a crackdown on sales done directly online” (NYT, January 25, 2000) describes the threat to traditional car dealers from Internet sales and begins “Internet companies that sell cars directly to consumers are encountering stiff opposition from auto dealers, who are using their influence in state legislatures and with state regulators to protect their businesses”.

fact, Stigler (1971) found a smoking gun: Louisiana and Texas placed a weight limit of 14,000 pounds on trucks that moved between two points, only one of which had a railroad station (hence, the truck did not directly compete with rails) and a much lower weight limit of 7000 pounds on trucks that moved between two points, both of which had a railroad station (hence, the truck directly competed with rails).

The trucking industry learned well from the railroad industry. Established trucking firms used the Interstate Commerce Commission (ICC) to place severe restrictions on the ability of new trucking firms to enter “their” industry. The Motor Carrier Act of 1935 gave the ICC the objective of restricting entry and protecting existing carriers from excessive competition. Potential new entrants had to apply to the commission to provide service on a route, and existing carriers could protest the application. New entrants often found the commission “hostile” to these requests (Moore, 1986). Because it was so difficult to obtain licenses for some routes, and impossible for others, these restrictions placed severe obstacles on any firm attempting to grow and consolidate across territories.

Significant deregulation of the trucking industry began in 1980 with the passage of the Motor Carrier Act of 1980. In his commentary on the Act, Moore (1986) argues that changes in how licenses for routes were granted was the most significant part of the Act: “Its most significant provision shifts the burden of proof from the applicant to the protestor. Formerly the applicant had to show that any requested new authority was ‘required by the present or future public convenience and necessity’; now the protestor must show that it is ‘inconsistent with the public convenience and necessity’” (Moore, 1986). Since deregulation, there have been dramatic changes in the industry and the introduction of very advanced technologies. For example, some companies use satellites to keep track of their trucking fleets across the country to improve the efficiency of truck dispatching. The full benefits of such technology could only be captured in the deregulated environment, where a company is able to operate relatively freely over a national market.

It is widely believed that deregulation has led to significant productivity gains in the industry, though there are not a large number of studies. Moore cites a Federal Trade Commission staff report on the Motor Carrier Act of 1980, which argues that “competition among an increasing number of carriers has created downward pressure on rates and forced firms to increase productivity, e.g., by seeking removal of restrictions on operating certificates and by seeking concessions from labor”. Ying (1990) also demonstrates that productivity increased following deregulation.

2.1.5. Biotechnology/agriculture

The biotechnology industry has developed many new products through genetic engineering, and many more are expected in the future. Many of these
products have met resistance at their introduction, both from existing producers that are threatened by the products and by consumer groups fearful of genetically engineered food.

An early example of this phenomenon was the development (by the Monsanto Company) of genetically engineered bovine somatotropin (Bst), a naturally occurring hormone in cows (see Holmes and Schmitz, 1995). When this hormone is injected into cows, milk production increases in the range from 10 percent to 15 percent. But while milk production improved, the new process required that farmers had certain types of skills (e.g., a familiarity with modern computers to monitor cow health, since the process compromised cow immune systems to some extent). Hence, this ratcheting-up of the required skills pitted those lacking the skills, call them traditional-producers, against those that had the skills, call them modern-producers. These traditional-producers were in large part opposed to the process and tried to block it. These blocking efforts mostly failed in the United States.

2.1.6. Construction

Innovations in the construction industry often involve ways to economize on labor at construction sites. One such innovation is the use of preassembled parts in constructing buildings. For example, bathroom fixtures can be assembled offsite in factories and then shipped to construction sites for installation. This provides efficiency advantages, since it is more efficient to assemble parts in large batches rather than one-by-one on site, and cost advantages, since factory workers typically earn less than construction workers. Such innovations, not surprisingly, have met resistance since they economize on labor at the sites. Groups opposed to the innovations typically include unions and perhaps some small firms; those supporting the innovations are typically the larger construction firms and offsite manufacturers, such as producers of preassembled parts.

These two opposing groups push their agendas at the local level, where building codes are set. Oster and Quigley (1977) show that the building codes of many cities ban many of these innovations that economize on labor, such as preassembled parts. Oster and Quigley suggest that such restrictions are the result of lobbying efforts of groups opposed to the innovations. For example, these restrictions in a city’s building code are highly correlated with the fraction of the construction workforce that is unionized in the city. These restrictions are estimated to increase the cost of housing by as much as 15 percent (see Oster and Quigley, 1977, for a discussion of these estimates).

Not only do these restrictions in building codes blocking new technology raise the cost of buildings, they also stifle the development of new innovations. As Field and Rivkin (1975) argue, “...the potential benefits of innovation and industrialization in housing can never be known so long as the market rigidities and exclusions attributable to the present deficiencies of building regulation
persist. Only by removing the building code burden can the prospects of innovation be fully and fairly explored” (p. 6).

2.2. Blocking activities and the state of trade

The discussion above has shown that blocking activities are prevalent and reduce productivity and innovation. The theme of this article is that the incentives to pursue these blocking activities—using the regulatory apparatus to block new technologies—depend on the state of trade. In this subsection, we argue that many of the examples above lend support to this theme.

Let’s begin with the biotechnology/agriculture example. One front on which traditional-producers of milk attacked Bst was in state legislatures. Traditional-producers in some states—such Vermont and Wisconsin—asked their legislatures for a complete ban on the use of Bst in their respective states. But it became clear that because the movement of milk across state borders was possible, given that the U.S. Constitution prohibits states from interfering with interstate commerce, traditional-producers would need to succeed in every state for such a lobbying effort to be successful. If they failed in a single state, then Bst-produced milk in this state could be shipped to other nearby states. Hence, the efforts to block Bst at the state level quickly withered away.

In the construction industry, in contrast to the Bst example, blocking activities at the local level have persisted for decades. In our view, this persistence is due, in large part, to the fact that it is difficult to trade construction goods, not because tariffs are high on such goods, but because the transport of such goods is difficult. If local unions are able to block the introduction of labor-saving innovations in local building construction, then it is extremely costly to ship cheaper products—that is, buildings—into the local market.

Given that there are no tariffs on the movement of goods across state lines in the United States, the majority of blocking is in industries where there are very high costs of transport (relative to the value of the product)—such as in the construction industry. Banking, of course, is an industry where it was difficult to transport the good for much of this century (the Internet is certainly changing this). So, if a “small” local bank, in conjunction with similar small banks, was able to keep in force laws that prohibited branching, small bank customers needed to travel to the nearest “large”, more efficient bank to use the services of such a large bank. This travel was often not a very good option; hence, blocking was often a profitable opportunity for small banks.

Retail, of course, is similar to banking in that customers must travel to the firm to consume the service. So, if small retailers are able to use, for example, zoning laws to block the opening of superstores, customers must travel beyond the locality to consume the services of a superstore. Again, this travel is costly. While superstores have continued spreading throughout the United States, it is perhaps not surprising that they continue to meet resistance in some areas (since
the costs of travel provide incentives for blocking) and that they first appeared in rural areas (where travel is relatively cheap).

There are certainly examples of blocking in the United States in industries where goods have low transport costs (relative to value). As we discussed above, AT&T in its role as a telecommunications manufacturer (that is, Western Electric) was able to block new entrants and new products into this industry. But this, of course, was primarily because of regulations in the telephone markets that gave AT&T a monopoly in this market. AT&T was able to parlay its telephone service monopoly into a near-monopoly position in the manufacture of telephone equipment. We now turn to develop our model that attempts to capture the spirit of the cases described above.

3. Model

Time is discrete; \( t \in \{0,1,2,\ldots\} \). Countries (or locations) are indexed by \( i \in [0,1] \). At each location, there is a unit measure of households and two entrepreneurs indexed by \( e \in \{1,2\} \).

At each location, there are two sectors: a manufacturing sector and a service sector. The main action is in the manufacturing sector. This is where all the research and blocking activity occurs. At any point in time, one of two entrepreneurs has a monopoly in the local manufacturing sector in the country and the other entrepreneur is vying for this position. The service sector is competitive. The role of the service sector in the analysis is to be a means for consumers to escape the clutches of the local manufacturing monopolist. Consumers can use earnings in the service sector to pay for imports of foreign manufactured goods. Also, by having a service sector, innovating entrepreneurs have a sector from which they can pull in labor resources to use in expanding production for exports.

There is a productivity ladder in the manufacturing sector with two rungs, \( a \in \{1,2\} \). This differs from the standard Grossman and Helpman technology ladder model, which has infinite rungs. They are able to consider an infinite ladder because they restrict attention to unit elastic preferences. With such preferences, the equilibrium innovation levels in each period are independent of the initial state, a considerable simplification. It is crucial for our analysis that we don’t use unit elastic preferences, so we adopt a two-rung ladder to keep the state space manageable.

The main focus of the analysis is what happens when productivity is at the bottom rung. Here one of the entrepreneurs (the leader) has a monopoly right to the bottom-rung technology. The other entrepreneur (the follower) attempts, through research, to leapfrog the leader to advance to the top-rung technology. The leader divides his or her entrepreneurial time between research, to help raise his or her own technology state to the top rung, and blocking, to impede the
research program of the follower. The allocation of time between these two activities is the key margin studied in the analysis.

Once one of the entrepreneurs reaches the top rung ($a = 2$), there is no room for further advance by the leader and so there is no interesting margin between research and blocking at this point. We allow for a random event that causes the leader to fall off the top rung. This random event can be interpreted as a taste change (see footnote 2). When the random taste change occurs, one of the entrepreneurs is randomly assigned the leadership position at $a = 1$. By allowing for this random event, the fundamental problem of how to divide time between research and blocking when at the bottom rung recurs over and over in the model.

We now turn to the details of the model.

Preferences: Households live a single period (being replaced by another unrelated household at the end of a period). Each household is endowed with a unit of time in each period. Households are immobile. A household at location $j$ has a utility function

$$u(x, y) = \left[ (1 - \lambda) x^{(1 - \eta)/\eta} + \lambda y^{(1 - \eta)/\eta} \right]^{\eta/(\eta - 1)},$$

where $x$ is units of a composite manufacturing good, $y$ is units of the service good, and $\eta$ is the elasticity of substitution between $x$ and $y$. The manufacturing composite is given by

$$x = \left[ (1 - \lambda) x_c^{(\sigma - 1)/\sigma} + \lambda x_D^{(\sigma - 1)/\sigma} \right]^{\sigma/(\sigma - 1)},$$

where $x_c$ is a composite (“C”) of foreign manufacturing goods, $x_D$ is the domestic (“D”) manufacturing good, $\lambda \in (0, 1)$, and

$$x_c = \left[ \int_{i \neq j} x(i)^{(\sigma - 1)/\sigma} \, di \right]^{\sigma/(\sigma - 1)}.$$

The parameter $\sigma$ is the elasticity of substitution between $x_c$ and $x_D$ and between any two foreign manufactured goods. Below we will be interested in the situation in which (1) the domestic and foreign manufactured goods are reasonably good substitutes for each other, namely, $\sigma > 1$ and (2) the domestic and foreign manufactured goods are better substitutes for each other than are manufactured goods and the service good, namely, $\sigma > \eta$.

We also assume that $\eta \geq 1$. This is not a necessary condition for our main result. However, it considerably simplifies the technical analysis.

Entrepreneurs live forever, are immobile, and have a unit of time each period. To keep the analysis as simple as possible, we assume that entrepreneur period utility depends only on the service good and is given by $u(y) = y$. Over the infinite horizon, entrepreneurs have preferences given by $E(\sum_{t=0}^\infty \beta^t y_t)$.

Production technologies: The service good is constant returns to scale in household time. One unit of service output is produced per unit of household time employed.
As mentioned above, there are two technology levels for the manufactured good, rung 1 and rung 2. Each technology is constant returns to scale with household time as the only input. Let $c_j$ be the amount of household time required to produce one unit of manufacturing output with technology $j$. Assume these production function parameters are such that $c_2 < c_1$, so that the rung-2 technology is more productive and therefore requires less input.

At any point in time, one of the entrepreneurs is the leader. The leader has a monopoly on the leading edge technology at the location. The other entrepreneur is the follower.

A location can be at three different states in terms of the positions of the leader and follower, $s \in \{1, 2, 3\}$. In state $s = 1$, the leader is at rung 1 and the follower has no technology. In state $s = 2$, the leader is at rung 2 and the follower again has no technology. In state $s = 3$, the leader is at rung 2, the follower is at rung 1, and the two compete in a Bertrand fashion. We now explain the transition process across these states.

The first event to explain is what we call the reshuffling shock. This is a random event that reshares the industry and nullifies any previous technological advance. This event happens with probability $\delta$, which is independent of the current state. In the event of the reshuffling shock, one of the two entrepreneurs is randomly selected with equal probability to be the leader at state $s = 1$ (i.e., where the leader is at rung 1 and the follower has no technology).

The state $s = 1$ is arrived at because of a reshuffling shock. The state $s = 2$ is attained next period if the current leader successfully innovates—here the leader moves up from rung 1 to rung 2, and the follower continues to have no technology. The state $s = 3$ is attained next period if the current follower leapfrogs the current leader. The follower leapfrogs if the leader is not successful in research, the follower is successful, and the leader’s blocking fails. Here the follower gets on the ladder at rung 2, and the former leader stays at rung 1 and is now the follower.

Let us be more formal. Suppose $s = 1$. The leader has an endowment of one unit of entrepreneurial time that is divided between two activities: Research activity $r$ helps propel the leader up the ladder, and blocking activity $b$ impedes the progress of the follower. If the leader allocates $r$ units of time to research, with probability $f(r)$ this research program will be successful. We assume $f(r)$ satisfies $f(0) = 0$, $f(1) < 1$, $f' > 0$, $f'' < 0$, and $\lim_{r \to 0} f(r) = \infty$. If the leader allocates $b$ units of time to blocking, with probability $g(b)$ this blocking program

---

3 Suppose there are many potential manufactured goods that can be produced at a location. Each of these goods enters the utility function in the same manner. At a particular date, households desire to consume one of these goods. Entrepreneurs develop new methods of producing this good. Periodically there is a shock to preferences so that households now desire to consume some other good from this set. Hence, the industry must start from scratch in developing new methods for producing this good.
is successful. The assumptions on the blocking probability function are the same as for the research success function, i.e., increasing and concave.

The follower also has a unit endowment of entrepreneurial time. For simplicity, we assume the follower only does research. We argue later that allowing the follower to also engage in blocking does not affect the main result. The probability that the follower has a successful research program when the follower’s full unit time endowment is allocated to research is a scalar $\phi$.

Given that the current state is $s = 1$, there are four events that can happen next period. First, there is a probability $\delta$ of a reshuffling. Here, we return to $s = 1$ (though the identity of the leader may change). Second, the current leader may advance to the top rung $a = 2$ tomorrow. This happens if there is no reshuffling and if the current leader is successful in research, i.e., with probability

$$q_2(r) = (1 - \delta)f(r),$$

where the subscript “2” indicates that $s = 2$ is the next-period state. (Note that in the event of a tie where both researchers are successful, we assume the leader is granted leader status the next period; the results do not depend upon the particular tie-breaking rule.) Third, today’s follower may be the leader tomorrow; i.e., state $s = 3$ may occur. This happens if there is no reshuffling, if the follower’s research is successful, and if the leader’s research and blocking programs both fail, i.e., with probability

$$q_3(r, b) = (1 - \delta)[1 - f(r)][1 - g(b)].$$

The fourth and last possibility is that there is no reshuffling and the current leader at $s = 1$ remains the leader at $s = 1$, i.e., with probability

$$q_1(r, b) = 1 - \delta - q_2(r) - q_3(r, b).$$

To avoid confusion note that $q_1$ is not the probability that $s = 1$ next period because it does not include the event that someone is at $s = 1$ because of a reshuffling. Rather, $q_1$ is the probability there is no reshuffling and the current leader is still at rung 1. Below we will refer to this event as maintaining the status quo.

Note that we are implicitly assuming a patent system here in that if the leader is at rung 1, the leader need not worry about the follower getting to rung 1. The only concern is that the follower might get to rung 2, which has not been patented yet. If the leader is at rung 2 and arrived there after being the leader at rung 1, then the leader has nothing to worry about, since the leader has a patent on both rungs of the ladder. This assumption helps simplify the analysis, as there are fewer states than there would otherwise be. However, our results can easily be extended to allow for alternative possibilities. For example, suppose that at state $s = 2$, we allow for some probability that the follower gets to ladder rung 2. This adds a fourth state in the model with both firms at ladder rung 2. The results can be extended for this case with only minor changes in the proofs.
**Technology for moving goods:** There is an ad valorem tariff of $\tau$ on manufactured goods produced at one location and sold at another. We assume there is no tariff on the service good. This simplifies the analysis because services can then be costlessly traded across locations, which is a convenient property to have for the numeraire good (see the brief discussion below for the case where there is a tariff on services). To simplify the analysis, we assume that tariff revenues are not returned to households or entrepreneurs and are instead either dumped into the ocean or used to buy some outside government good (see the brief discussion below about the role of this assumption).

4. **Definition of equilibrium**

In this section, we define a *multi-country equilibrium* for this environment. The service good is the numeraire. Households sell their time endowment to entrepreneurs and service firms. Households use their income in a period to purchase services and manufactured goods (from domestic and foreign manufacturers). Entrepreneurs sell their product to households at home and abroad. They purchase services using current period profits.

The state of the economy is $\mu = (\mu_1, \mu_2, \mu_3)$, where $\mu_s$ is the fraction of countries at state $s$. For an entrepreneur, the state is $(\mu, s, z)$, where $z \in \{F, L\}$ specifies whether the entrepreneur is the follower or leader. Below, we focus on equilibria where entrepreneur and household choices depend on time only through $s$. In these equilibria, individual countries move across industry states over time. However, at the world level, $\mu$ is constant. Before defining multi-country equilibrium, we need two definitions.

**Research/blocking (R&B) equilibrium:** In the equilibria we study, the profits (measured in numeraire) earned by the leader at a given industry state do not vary over time. Let $\pi_e$ be the leader’s current profit at industry state $s$, $s \in \{1, 2, 3\}$. The follower’s current profit is always zero because the two firms compete in a Bertrand fashion. Taking the vector of leader profits $(\pi_1, \pi_2, \pi_3)$, we can define an infinite-horizon research/blocking (R&B) game between the two entrepreneurs in a given country starting at date $t = 0$ at, say, $s = 1$. The objective of each entrepreneur is to maximize the expected sum of discounted profits over the infinite horizon. The choices of entrepreneur $e$ are simply what research level $r_{et}$ to choose if $e$ is the leader when the industry state is $s = 1$ at date $t$ (where blocking activities are given by $b_{et} = 1 - r_{et}$). Note that the entrepreneur chooses $r_{et}$ and $b_{et}$ before learning whether or not the reshuffling has occurred.

We focus on symmetric, Markov-perfect equilibria of this game. In order to define such equilibria, let $r$ denote the constant research choice the leader selects when at state $s = 1$. Let $v_{e,s,z}$ be the expected sum of discounted profits of an entrepreneur who has status $z$ when the industry at the location is at state $s$. T.J. Holmes, J.A. Schmitz / Journal of Monetary Economics 47 (2001) 417–446
Let $V = (v_{1,L}, v_{1,F}, v_{2,L}, v_{2,F}, v_{3,L}, v_{3,F})$ denote the vector of values. We then have the following definition.

**Definition 1.** The pair $(r, V)$ is a symmetric, Markov-perfect equilibrium of the R&B game if

- $r = \arg \max_{r \in [0,1]} [q_1(r,1-r)v_{1,L} + q_2(r)v_{2,L} + q_3(r,1-r)v_{3,F} + \delta[\frac{1}{2}v_{1,L} + \frac{1}{2}v_{1,F}]]$,
- $v_{1,L} = \pi_1 + \beta[q_1(r,1-r)v_{1,L} + q_2(r)v_{2,L} + q_3(r,1-r)v_{3,F} + \delta[\frac{1}{2}v_{1,L} + \frac{1}{2}v_{1,F}]]$,
- $v_{1,F} = 0 + \beta[q_1(r,1-r)v_{1,F} + q_2(r)v_{2,F} + q_3(r,1-r)v_{3,L} + \delta[\frac{1}{2}v_{1,L} + \frac{1}{2}v_{1,F}]]$,
- $v_{2,L} = \pi_2 + \beta[(1-\delta)v_{2,L} + \delta[\frac{1}{2}v_{1,L} + \frac{1}{2}v_{1,F}]]$,
- $v_{2,F} = 0 + \beta\delta[\frac{1}{2}v_{1,L} + \frac{1}{2}v_{1,F}] + \theta(1-\delta)v_{2,F}$,
- $v_{3,L} = \pi_3 + \beta[(1-\delta)v_{3,L} + \delta[\frac{1}{2}v_{1,L} + \frac{1}{2}v_{1,F}]]$,
- $v_{3,F} = v_{2,F}$,

where $q_1(r, b), q_2(r)$, and $q_3(r, b)$ are given in (3), (1), and (2), respectively. We refer to this symmetric, Markov-perfect equilibrium as the R&B equilibrium.

**Product–market (P–M) equilibrium:** In the equilibria we study, the prices of the manufactured good for domestic consumption and for export depend only on the state $s$ at the location. Let $p_{D,s}$ and $p_{E,s}$ denote these prices (in units of numeraire). If a household purchases a good from a foreign country in state $s$, then that household must pay $p_{E,s}(1 + \tau)$ per unit for the good, where $\tau$ is the tariff on the good. Households form their demands given prices $p_{D,s}, p_{E,s}, p_y = 1$, their income, and the tariff $\tau$. In states $s = 1$ and $2$, the leader has a monopoly. In state $s = 3$, the leader and the follower compete in a Bertrand fashion. A P–M equilibrium is a list of quantity choices and prices such that household choices are utility maximizing, entrepreneur prices are profit maximizing, and markets clear.

Given these preliminaries, we can give the following definition.

**Definition 2.** A list $((\pi^1, \pi^2, \pi^3), (r^\pi, V^\pi), \mu^\pi)$ is a stationary, symmetric, multi-country equilibrium if (i) given $(\pi^1, \pi^2, \pi^3)$, the vector $(r^\pi, V^\pi)$ constitutes an R&B equilibrium; (ii) given $r^\pi$, the vector $\mu^\pi$ is the implied stationary distribution of rung proportions, and (iii) given $\mu^\pi, (\pi^1, \pi^2, \pi^3)$ is the current period profit vector emerging from the P–M equilibrium.

5. Characterization of equilibrium

In this section, we show that a multi-country equilibrium exists, and we characterize properties of the equilibrium. We do this in three steps corresponding to the three parts of Definition 2 above. First, in Section 5.1, given the
current-profit vector \((\pi_1, \pi_2, \pi_3)\), we calculate the R&B equilibrium. Second, in Section 5.2, given \(r\), we calculate the stationary distribution of rung proportions \(\mu\). Third, in Section 5.3, given \(\mu\), we calculate the P–M equilibrium and \((\pi_1, \pi_2, \pi_3)\). We put this all together in Section 5.4.

5.1. The R&B equilibrium

Recall that given a vector \((\pi_1, \pi_2, \pi_3)\), we can define an R&B game between the two entrepreneurs in a given country. This subsection examines the R&B game.

We begin with an analysis of the special case where the reshuffling probability \(\delta\) equals zero. This case has the simplest notation. It also will turn out that the equilibrium research level in the R&B game is independent of \(\delta\) for a fixed profit vector \((\pi_1, \pi_2, \pi_3)\).

Suppose then that \(\delta = 0\). Suppose the initial state is \(s = 1\) so the current leader is at the bottom rung. If either entrepreneur gets to the top rung, that entrepreneur will stay at the top rung forever, given the assumption of \(\delta = 0\). Hence, only the current leader will ever be in the situation of deciding how to allocate time between research and blocking. So the R&B game is not really a game in the case of \(\delta = 0\); it is a single-agent optimization problem.

Let \(\bar{r}\) be the optimal research level. The value to the leader at \(s = 1\) and 2 is

\[
v_{1,L} = \pi_1 + \beta[q_1(\bar{r}, 1 - \bar{r})v_{1,L} + q_2(\bar{r})v_{2,L}],
\]

\[
v_{2,L} = \frac{\pi_2}{1 - \beta}.
\]

Note that the \(v_{3,F}\) term is omitted above since \(v_{3,F} = 0\) when \(\delta = 0\). (The follower at \(s = 3\) can only be a leader if there is a reshuffling, but this happens with zero probability.) By standard dynamic programming logic, the optimal \(\bar{r}\) must solve the static problem of picking the current level of \(r\) to maximize discounted value, taking as fixed that \(\bar{r}\) is used in the future; i.e.,

\[
\bar{r} = \arg\max_r q_1(r, 1 - r)v_{1,L} + q_2(r)v_{2,L}.
\]

It is straightforward to derive the first-order necessary condition for this static problem:

\[
f'[1 - \phi(1 - g)](v_{2,L} - v_{1,L}) + f'\phi(1 - g)v_{2,L} - g'(1 - f)\phi v_{1,L} = 0. \tag{4}
\]

The first two terms are the benefits of increasing \(r\) on increasing the success probability of the leader’s research program. The incremental value of such a success is equal to \(v_{2,L} - v_{1,L}\) in the event that the follower would not have advanced. This is the first term. The incremental value is equal to \(v_{2,L}\) in the event that the follower would have advanced. (The current leader gets \(v_{2,L}\) if he
or she advances, but 0 if the follower advances.) This is the second term. The third term is the opportunity cost of the time spent on research that could have been spent on blocking. The effect of that time on blocking success is \( g' \). It only matters in the event that the leader’s research program fails while the follower’s is successful, i.e., with probability \((1 - f)\phi\). By blocking, the leader holds on to \( v_{1,L} \) rather than ending up with zero.

Differentiating (4), is straightforward to show that a sufficient condition for the static problem to be a concave problem is that

\[
f''(r)[1 - g(1 - r)] + g''(1 - r)[1 - f(r)] + 2f'(r)g'(1 - r) \leq 0
\]  

(5)

holds for all \( r \). We assume this holds.\(^4\) Note also that the Inada conditions on \( f \) and \( g \) imply that \( 0 < \frac{\partial}{\partial r} < 1 \).

Divide (4) through by \( v_{1,L} \). It is clear that the larger is the ratio of \( v_{2,L} \) to \( v_{1,L} \), the larger is the \( r \) solving the first-order necessary condition. Relatively more weight is placed on the benefit of innovating and less on the opportunity cost of foregone blocking. If the ratio of the static profits \( \pi = \frac{\pi_2}{\pi_1} \) increases, it is intuitive that the ratio of the present values \( \frac{v_{2,L}}{v_{1,L}} \) should increase. With straightforward arguments along these lines, we can show that the optimal research level strictly increases in the profit ratio \( \pi = \frac{\pi_2}{\pi_1} \). Denote the relationship \( r^*(\pi) \). Again, it is independent of \( \pi_3 \), because the \( s = 3 \) profit level will never apply to the current leader. Further, the optimum only depends upon the ratio \( \pi = \frac{\pi_2}{\pi_1} \) because proportionate changes in \( \pi_1 \) and \( \pi_2 \) have the effect of multiplying a scalar times the objective function. Given that the leader has a unit time endowment to divide between the two tasks, only the relative profits matter.

The above discussion assumes the reshuffling probability \( \delta = 0 \). Now assume \( \delta > 0 \). A helpful result that simplifies our analysis is that in the class of Markov-perfect equilibria, the equilibrium research level does not change if \( \delta \) is changed (holding the ratio \( \pi = \frac{\pi_2}{\pi_1} \) fixed). The key insight here is that if there is a reshuffling next period, the current leader’s particular division of time between \( r \) and \( b \) is irrelevant. The choice only matters conditioned upon the reshuffling event not occurring, so the optimal choice is independent of the probability that it occurs. Thus, our earlier claim for the \( \delta = 0 \) case holds generally for \( \delta \geq 0 \); namely, the equilibrium research level \( r^*(\pi) \) is strictly increasing in \( \pi \).

\(^4\) An example of functions that satisfy this condition is as follows. Suppose that the research and blocking functions are power functions and have the same form, namely, \( f(r) = \theta r^r \) and \( g(b) = \theta b^\zeta \). The parameters \( \theta \) and \( \zeta \) must lie between zero and one. For these functions, condition (5) is satisfied if \( \theta \leq (1 - \zeta)2^\zeta \). So, for example, if \( \zeta = \frac{1}{2} \), then \( \theta \leq 0.71 \) is required to satisfy the concavity condition.
5.2. The stationary distribution of rung proportions

Given \( r \), we solve for the stationary distribution of rung proportions as follows. Suppose that \( \mu_1 \) industries are at state \( s = 1 \), where the leader is at rung 1. In stationary equilibrium, the following must be true:

\[
\mu_1 = \delta + q_1(r,1-r)\mu_1.
\]

The first term is all locations that experience a reshuffling, as all such locations will have a leader at rung 1 in the next period. The second term is those locations for which there is no reshuffling, which have a leader at 1 in the current period, and for which neither entrepreneur advances. (This is the “maintain the status quo” event defined earlier; recall that \( q_1 \) is the probability of that event.) The equation for the measure of locations at \( s = 2 \) is

\[
\mu_2 = (1 - \delta)\mu_2 + q_2(r)\mu_1.
\]

It equals the number of locations that are initially in that state and do not experience a reshuffling shock plus the number of locations where the leader advances in the next period to the top rung. Solving these equations and using \( \mu_1 + \mu_2 + \mu_3 = 1 \) yields

\[
\mu_1 = \frac{\delta}{1 - q_1(r,1-r)},
\]

\[
\mu_2 = \frac{q_2(r)}{1 - q_1(r,1-r)},
\]

\[
\mu_3 = 1 - \mu_1 - \mu_2.
\] (6)

5.3. The P–M equilibrium

Given the vector of state proportions \( \mu \), we can solve for the P–M equilibrium and then calculate the leader profits at each state in that equilibrium. In order to discuss the P–M equilibrium, we must solve the demand behavior of households. Then we consider the price setting behavior of entrepreneurs, given household demand behavior. Finally, we determine the key profit ratio \( \pi = \pi_2/\pi_1 \).

Household demand behavior: This subsection discusses results from the household problem. Most of the technical derivations are contained in the separate appendix available from the authors.

Households maximize utility given a unit income and given prices. Let \( p_D \) and \( p_E \) denote the domestic price and the export price set by the leader at a particular location (the leader is assumed to be able to price discriminate between the two markets). In equilibrium, leaders in locations at the same state will set the
same price. Let $p_{D,s}$ and $p_{E,s}$ be the equilibrium domestic and export prices at state $s$.

Taking into account the tariff, a household importing from a location at state $s$ pays a price of $(1 + \tau)p_{E,s}$ per unit imported. The household uses imports to construct the foreign composite. Let $p_c$ be the cost of constructing one unit of the foreign composite in the cost-minimizing way. Standard calculations show that

$$p_c = \left[ \sum_{s=1}^{3} \mu_s((1 + \tau)p_{E,s})^{-(\sigma-1)} \right]^{-1/(\sigma-1)}.$$

Note that the price of the foreign composite is the same at each location. The export price set by the leader at any particular location has no effect on the composite price because the share of any particular foreign good is “small”.

The manufacturing composite is constructed by combining the domestic manufactured good with the foreign composite. Given $p_{D}$ and $p_{C}$, the minimum cost to make a unit of the composite manufactured good is

$$p_x = [(1 - \lambda)(p_{c})^{-(\sigma-1)} + \lambda(p_{D})^{-(\sigma-1)}]^{-1/(\sigma-1)}.$$

Let $x(p_x)$ be a household’s utility-maximizing demand for the composite given a composite price of $p_x$. Straightforward calculations show that the own-price elasticity of demand equals

$$\varepsilon_x(p_x) = \frac{\eta x^\eta (1 - \lambda)^{-\eta} p_x^\eta + p_x}{x^\eta (1 - \lambda)^{-\eta} p_x^\eta + p_x}.$$  \hspace{1cm} (7)

Let $x_D(p_D, p_C)$ and $x_C(p_D, p_C)$ be the household’s utility-maximizing demand for the domestic manufactured good and the foreign composite given a domestic price of $p_D$ and a foreign composite price of $p_C$. The own-price elasticity of domestic demand is

$$\varepsilon_{D,p_D}(p_D, p_C) = -\frac{p_D}{x_D} \frac{\partial x_D}{\partial p_D} = \varepsilon_x(p_x) \frac{p_D x_D}{p_C x_C + p_D x_D} + \sigma \frac{p_C x_C}{p_C x_C + p_D x_D},$$  \hspace{1cm} (8)

where the functional dependence of $p_x$, $x_D$, and $x_C$ on $p_D$ and $p_C$ is left implicit.

The elasticity of demand for the domestic good is a weighted average of the final manufactured good elasticity $\varepsilon_x$ and the elasticity of substitution $\sigma$ between the domestic good and the foreign composite. This formula is intuitive as can be seen by a discussion of the two extreme cases. The first extreme case is where $p_C x_C$ is zero, so all the weight is on the first term (this happens in the limit where $\tau$ goes to infinity). Here only the domestic good is used to make the manufactured final good. As $p_D$ increases, consumers substitute away from the domestic good to the service good. The second limiting case is where $p_D x_D$ is zero, so all the weight is on the second term. Here the substitution that occurs when $p_D$ is
changed is between the domestic manufactured good and the foreign composite, and this depends on the technology parameter $\sigma$.

Now consider the export market of a leader at a particular location. Let $x_E(p_E, p_C)$ be the quantity of exports of a leader setting an export price of $p_E$, given the foreign composite price of $p_C$. Note again that the export price $p_E$ of a particular leader has no effect on the foreign composite price since each individual leader is small. The elasticity of export demand is constant

$$e_{E,p_E} = -\frac{p_E \hat{c}X_E}{X_E \hat{c}p_E} = \sigma.$$

This follows from the CES nature of the composite function for producing $x_C$.

The key result for the comparative statics analysis in the next section is that domestic demand is less elastic than export demand.

**Lemma 1.** $\dot{\varepsilon}_{D,p_0} < \sigma$.

**Proof.** From inspection of (7), it is clear that the assumption of $\eta \geq 1$ implies that $\varepsilon_x \leq \eta$. The result that $\dot{\varepsilon}_{D,p_0} < \sigma$ then follows from (8) and the fact that $\eta < \sigma$. $\square$

The main thing driving this result is that a particular leader’s product is a higher share of expenditure for the leader’s domestic consumers than for the leader’s export consumers. The higher the expenditure share, the more important is the service good as a substitution possibility. But since the service good is a worse substitute for the manufacturing good than the differentiated manufacturing goods are for themselves (i.e., $\eta < \sigma$), domestic demand is less elastic than export demand.

It is worth noting that the key result in Lemma 1 continues to hold if we allow $\eta < 1$. Thus, our assumption that $\eta < 1$ will not be crucial for our main comparative statics result that we present in the next section. However, the assumption that $\eta \geq 1$ comes in handy in a few steps. The next result is one of them.

This next result refers to the cross-price elasticity of demand, defined as

$$\varepsilon_{D,p_C}(p_D, p_C) = \frac{p_C \hat{c}X_D}{X_D \hat{c}p_C} = \left[ \sigma - \varepsilon_x(p_x) \right] \frac{p_CX_C}{p_CX_C + p_DX_D}. \quad (9)$$

**Lemma 2.** The own-price $\varepsilon_{D,p_C}(p_D, p_C)$ and the cross-price $\varepsilon_{D,p_0}(p_D, p_C)$ elasticities are both strictly increasing in the own-price $p_D$. 
The proof is in the separate appendix. As the domestic price \( p_D \) increases, the share of total manufacturing expenditure spent on the domestic good decreases, so the substitution possibility between the domestic manufactured good and the services becomes relatively less important and the substitution between the domestic and foreign manufactured goods becomes more important. This increases both the own-price and the cross-price elasticities.

**Profit-maximizing prices:** We begin by discussing the case of \( s = 1 \) and 2, where the leader has a monopoly over the local manufactured good. The profit-maximizing monopoly price satisfies the standard inverse elasticity rule. In the export market this rule implies that

\[
\frac{p_{E,s} - c_s}{p_{E,s}} = \frac{1}{\varepsilon_{E,p_0}}.
\]

Substituting in \( \varepsilon_{E,p_0} = \sigma \) yields

\[
p_{E,s} = \frac{\sigma}{\sigma - 1} c_s.
\]

Analogously, the profit-maximizing domestic price satisfies the following equation:

\[
p_{D,s} - \frac{\varepsilon_{D,p_0}(p_{D,s}, p_C)}{\varepsilon_{D,p_0}(p_{D,s}, p_C) - 1} c_s = 0.
\]

It is straightforward to use the earlier results to show that there is a unique profit-maximizing solution \( p_{D,s} \) to the above equation.\(^5\) Note that the domestic price \( p_{D,s} \) exceeds the export price \( p_{E,s} \) since domestic demand is more inelastic than export demand.

Now consider the case of \( s = 3 \). Here the leader is at rung 2, but now the leader competes with the follower who is at rung 1. There is Bertrand competition between the two entrepreneurs, and in equilibrium the follower sets the price equal to its marginal cost of \( c_1 \). The optimal price for the leader in each market is the minimum of the unconstrained price (the price set at \( s = 2 \)) and the follower's marginal cost,

\[
p_{E,3} = \min\{p_{E,2}, c_1\}
\]

\[
p_{D,3} = \min\{p_{D,2}, c_1\}.
\]

Note that this section has implicitly assumed that each location is at an interior allocation in which there is positive production of services. For

---

\(^5\) Lemma 2 implies that the LHS of (10) is strictly increasing. The LHS evaluated at \( c_s \) is negative, and the LHS evaluated at \( \sigma c_s / (\sigma - 1) \) is positive. Hence there is a unique \( p_{D,s} \) between these bounds where the LHS equals zero.
tractability, the analysis focuses on this case. It is straightforward to make assumptions on the model to guarantee that this is the case.

Finally, note that the assumption that tariff revenues are not returned to individuals is useful in the analysis of the leader’s pricing problem. If tariff proceeds were distributed to households, the leader’s pricing problem would be complicated by the fact that the choice of price would affect household income, through its effect on the demand for imports and hence tariff revenues. We believe, however, that incorporating this effect into the analysis would not change the results in the two propositions below (in examining the effects of moving from \( \tau = \infty \) to 0, for example, the results do not depend on the assumptions of how tariff revenues are dispersed since tariff revenues are zero in both cases). It is also worth noting that if we were to extend our model to allow for a large number of different manufacturing industries, rather than one industry as assumed, this income effect in the price-setting problem would become negligible.

**The profit ratio:** We can now calculate the ratio of profit of the leader’s profit between state \( s = 2 \) and 1 arising in the product market equilibrium. The leader’s profit at state \( s \) is the sum of domestic and export profit,

\[
\pi_s = (p_{D,s} - c_s)x_{D,s} + (p_{E,s} - c_s)x_{E,s},
\]

where \( x_{D,s} \) and \( x_{E,s} \) are units sold in the domestic and foreign markets, respectively. The profit \( \pi_s \) depends on \( \mu \) since \( x_{D,s} \) and \( x_{E,s} \) depend on \( p_C \) (which depends on \( \mu \)). Hence, the ratio of profits \( \pi = \pi_2/\pi_1 \) depends on \( \mu \). Since \( \mu \) can be expressed as a function of \( r \) (as in Section 5.2 above), we can express \( \pi \) as a function of \( r \). Let \( \pi^{**}(r) \) be the profit ratio implied by the research choice \( r \).

### 5.4. Existence of equilibrium

In the analysis of the R&B game, we determined the research effort given the ratio \( \pi \), namely, \( r^*(\pi) \). In the analysis of the P–M equilibrium, we determined the profit ratio given \( r \), namely, \( \pi^{**}(r) \). Note that a multi-country equilibrium corresponds to a pair \((\pi^e, r^e)\) such that \( r^e = r^*(\pi^e) \) and \( \pi^e = \pi^{**}(r^e) \). In graphical terms, a multi-country equilibrium corresponds to the point in Fig. 1 where the \( r^* \) and \( \pi^{**} \) curves intersect. The function \( r^*(\pi) \) is strictly increasing on the range \([1, \infty)\) and is bounded between zero and one. The function \( \pi^{**}(r) \) is bounded

---

6 The key issue is to ensure that the leader’s demand for household time to produce manufactured goods does not exceed the unit of time available at the location. Otherwise, we could not focus on the interior equilibrium that has implicitly been assumed. Let the units of time demanded by a leader at state \( s \) be denoted \( L_s \). The condition that demand not exceed one can be written as \( L_s = [x_{D,s} + x_{E,s}]x_s \leq 1 \), where \( x_{D,s} \) and \( x_{E,s} \) are the outputs produced by the leader. For the special case of \( \eta = 1 \) (that is, Cobb–Douglas demand for the final goods \( x \) and \( y \)), it is straightforward to show that \( L_s \) is proportionate to \((1 - \alpha) \). Hence, the condition holds if \( \alpha \) is close enough to one.
and is greater than one for all $r \in [0,1]$. Hence, a multi-country equilibrium exists.

In the figure, the $\pi^{**}$ curve is illustrated as upward-sloping, as it is in the numerical examples we have looked at. Since the $r^*$ and $\pi^{**}$ curves are both upward-sloping, one issue is the possibility they might intersect more than once, in which case there would be multiple stationary equilibria. We have looked at a number of numerical examples, and in each case the $\pi^{**}$ curve is almost a vertical line (that is, $\pi^{**}(r)$ is relatively flat as a function of $r$). The possibility of multiple equilibria seems remote, but a formal proof of this is beyond our grasp. For the remainder of the paper, we assume that there is a unique equilibrium.

6. Lower tariffs: From unproductive to productive effort

This section presents the main results of the paper. It considers the effects of two kinds of tariff reductions. In the case of a multi-lateral tariff reduction, the tariff $\tau$ is everywhere decreased. In the case of a unilateral tariff reduction, the tariff is reduced at one location and held fixed everywhere else.

We will use Fig. 1 to conduct the comparative statics. A reduction in the tariff has no effect on the $r^*$ curve. However, the maximized profits $\pi_1$ and $\pi_2$ in (11) depend on $\tau$. Hence the $\pi^{**}$ curve depends on $\tau$. Thus a change in $\tau$ shifts the $\pi^{**}$ curve. We begin with an analysis of a multi-lateral reduction in tariffs. Write the function $\pi^{**}$ as $\pi^{**}(r,\tau)$ to make explicit the dependence of the profit ratio on the tariff. We now show that $\pi^{**}$ increases as the multilateral tariff $\tau$ is reduced.

**Lemma 3.** $\pi^{**}(r,\tau)$ strictly increases as $\tau$ decreases.
To prove this result, it is helpful to write the ratio of total profits as the weighted sum of the ratio of domestic profits and the ratio of export profits,

\[
\frac{\pi^{**}}{\pi_{D,1}^* + \pi_{E,1}^*} = \frac{\pi_{D,2}}{\pi_{D,1}} \frac{\pi_{D,2}}{\pi_{D,1}} + \frac{\pi_{E,1}}{\pi_{D,1}} \frac{\pi_{E,1}}{\pi_{E,1}}
\]

\[
= \text{share}_{D,1} \frac{\pi_{D,2}}{\pi_{D,1}} + (1 - \text{share}_{D,1}) \frac{\pi_{E,2}}{\pi_{E,1}},
\]

where \(\text{share}_{D,1}\) is the share of state 1 profits that are obtained from domestic sales.

The proof of the result has four steps:

**Step 1:** \(\pi_{D,2}/\pi_{D,1} < \pi_{E,2}/\pi_{E,1}\).

**Step 2:** The share \(\text{share}_{D,1}\) decreases as \(\tau\) decreases.

**Step 3:** The domestic profit ratio \(\pi_{D,2}/\pi_{D,1}\) increases as \(\tau\) decreases.

**Step 4:** The export profit ratio \(\pi_{E,2}/\pi_{E,1}\) is constant in \(\tau\).

Step 1 says that the ratio of domestic profits between state 2 and state 1 is less than the ratio of export profits. Step 2 says that a decrease in \(\tau\) decreases the domestic market’s share of total profit. Thus, as tariffs are lowered, more weight is placed on the ratio of export profits and less weight is placed on the ratio of domestic profits, and this increases the ratio of total profits. Steps 3 and 4 say that the ratio of domestic profits and the ratio of export profits do not fall as \(\tau\) is lowered. Together these steps imply that the ratio of total profits must increase.

**Proof of Step 1.** The export profit at location \(j\) is

\[
\pi_{E,j} = (p_{E,j} - c_j)x_{E,j}
\]

\[
= \left(\frac{\sigma}{\sigma - 1} c_j - c_j\right)x_{E,2}
\]

\[
= \frac{1}{\sigma - 1} c_j x_{E,2},
\]

using the fact that \(p_{E,j} = (\sigma/(\sigma - 1))c_j\). The ratio of export profits is

\[
\frac{\pi_{E,2}}{\pi_{E,1}} = \frac{c_2 x_{E,2}}{c_1 x_{E,1}}
\]

\[
= \frac{c_2}{c_1} \left(\frac{p_{E,2}}{p_{E,1}}\right)^{-\sigma}
\]

\[
= \frac{c_2}{c_1} \left(\frac{c_2}{c_1}\right)^{-\sigma}
\]

\[
= \left(\frac{c_2}{c_1}\right)^{1-\sigma}.
\]
The second equality above follows from the fact that export demand has constant elasticity equal to \( \sigma \). The third equality follows from the fact that the ratio of export prices equals the ratio of the marginal costs (since price is a markup \( \sigma/(\sigma - 1) \) over cost).

Now consider the ratio of profits in the domestic market. Again, the profit-maximizing domestic prices are \( p_{D,1} \) and \( p_{D,2} \) in states 1 and 2, as calculated above. Consider an alternative price in state 1 defined by

\[
\hat{p}_{D,1} = \frac{c_1}{c_2} p_{D,2}.
\]

This sets the price in state 1 relative to state 2 in the same proportion as the cost difference. Let \( \tilde{\pi}_{D,1} \) be the profit in market 1 that would be obtained with this price.

Next we show that

\[
\frac{\pi_{D,2}}{\tilde{\pi}_{D,1}} < \frac{\pi_{E,2}}{\pi_{E,1}}. \tag{12}
\]

This inequality follows from

\[
\frac{\pi_{D,2}}{\tilde{\pi}_{D,1}} = \frac{(p_{D,2} - c_2)x_{D,2}}{(\hat{p}_{D,1} - c_1)\hat{x}_{D,1}}
\]

\[
= \frac{c_2x_{D,2}}{c_1 \hat{x}_{D,1}}
\]

\[
< \frac{c_2}{c_1} \left( \frac{p_{D,2}}{\hat{p}_{D,1}} \right)^{-\sigma}
\]

\[
= \frac{c_2}{c_1} \left( \frac{c_2}{c_1} \right)^{-\sigma}
\]

\[
= \left( \frac{c_2}{c_1} \right)^{1 - \sigma}
\]

\[
= \frac{\pi_{E,2}}{\pi_{E,1}}.
\]

Note that the inequality \( x_{D,2}/\hat{x}_{D,1} < (p_{D,2}/\hat{p}_{D,1})^{-\sigma} \) in the third line follows from Lemma 1, which states that the elasticity of domestic demand is everywhere less than \( \sigma \).

Since \( \pi_{D,1} \geq \tilde{\pi}_{D,1} \) is true (because the profit-maximizing entrepreneur could always choose to set \( \hat{p}_{D,1} \) but selects \( p_{D,1} \) instead), inequality (12) implies the inequality in Step 1.
Proof of Step 2. To show that domestic profit share of total profit decreases as \( \tau \) is lowered, it is sufficient to show that domestic profit decreases and export profit increases. To see that domestic profit decreases, note that a decrease in \( \tau \) decreases \( p_C \). This shifts the domestic demand curve to the left, lowering maximized domestic profit. To show that export profit increases, it is necessary to show that export quantity increases, since the export price is independent of \( \tau \). It is intuitive that export quantity should increase as \( \tau \) decreases, but the formal proof is tedious, so we relegate it to the appendix.

Proof of Step 3. We need to show that the ratio of domestic profits is increasing as the tariff decreases. The appendix shows that this follows directly from Lemma 2, that the cross-price elasticity is increasing in \( p_D \).

Proof of Step 4. We need to show that the ratio of export profits is independent of the tariff. This follows from the result above that the ratio equals \( (c_2/c_1)^{1-\sigma} \).

According to Lemma 3, a multilateral reduction in tariffs increases \( \pi^{**} \) and hence shifts the curve to the right in Fig. 1. (Under the initial tariff, the \( \pi^{**} \) is the solid line; after the tariff reduction, the curve shifts right to the dotted line.) Since the \( r^* \) curve does not shift, equilibrium research must increase from \( r^0 \) to \( r' \). Since total time doing research or blocking is fixed at 1, equilibrium blocking must decrease. An increase in research, combined with a decrease in blocking, implies that the probability \( q_1 \) that the status quo is maintained decreases. From (6), this implies that the equilibrium fraction of locations \( \mu_1 \) with the leader at the bottom rung must decrease. In summary, we have the following.

Proposition 1 (Multi-lateral tariff reduction). If there is a multi-lateral reduction in the tariff \( \tau \), then (i) equilibrium research increases, (ii) equilibrium blocking decreases, and (iii) average productivity \( \mu_1 1/c_1 + \mu_2 1/c_2 + \mu_3 1/c_2 \) increases.

Now consider a second experiment. What happens when one country unilaterally reduces its tariff while all other locations keep the tariff fixed? The result is the following.

Proposition 2 (Unilateral tariff reduction). If a given country unilaterally lowers tariffs, research effort in the country increases and blocking effort decreases.

The proof for the unilateral case is exactly the same as the multilateral case with one exception. The exception is in the proof of Step 2 that the domestic share of total profit falls as the tariff decreases. In the case of a multilateral tariff reduction, the domestic share falls for two reasons: domestic profits \( \pi_{D,1} \) fall and
export profits $\pi_{E,1}$ increase. With a unilateral tariff reduction, only the first effect is present. Domestic profits fall, but export profits remain the same. Thus, a unilateral tariff reduction is less powerful in spurring research than a multilateral tariff reduction.\(^7\)

7. Alternative blocking technologies

Our model assumes a blocking technology of a particularly limited form. This section discusses the robustness of our results to alternative assumptions about the blocking technology.

Blocking by the follower: In the model, when a manufacturing industry is at $a = 1$, the leader can engage in research or blocking, but the follower engages only in research. Consider a more general model where the follower can engage in blocking at $a = 1$. If the follower is successful in blocking in a given period, then the leader will not be permitted to advance to leadership at $a = 2$ in the following period. Given the Inada-type conditions assumed for $g(b)$, the follower will engage in some blocking. So, this change in the model requires additional analysis. However, we can show that a reduction in the tariff will have no effect on the follower's research and blocking choice at $a = 1$. Hence, a reduction in the tariff has the same effect as before: it increases the leader's research at $a = 1$. Thus, our fundamental comparative statics result contained in the proposition will not change.

Blocking the research of foreign rivals: In the model, the leader can block the research of its domestic rivals, but there is no possibility of blocking the research of foreign rivals. We might expect that if this latter possibility were incorporated into the model, then a reduction in tariffs might lead to an increase in the time spent blocking the research of foreign rivals. However, this factor is limited by a free-rider problem: firms have the incentive to free-ride on the blocking efforts of other firms. In fact, in this model with a continuum of countries, leaders would spend zero effort on blocking the research of foreign rivals. Thus, adding this activity into the model would have no effect on the results, since it would never be used.

Blocking imports: One can imagine an extension of our model where entrepreneurs can also lobby for tariffs. Suppose there is some probability that a tariff $\tau$ is

\(^7\)If tariffs are also placed on services, does Proposition 1 still hold; that is, will reducing tariffs across the board lead to more research? We can show that this is true for a particular change in tariffs. Let $\tau_s$ and $\tau_m$ denote the tariffs on services and manufacturing, respectively. From Proposition 1, we know that if we move from $(\tau_s = 0, \tau_m = \infty)$ to the pair $(\tau_s = 0, \tau_m = 0)$, research increases. But then it is also true that research increases if we move from $(\tau_s = \infty, \tau_m = \infty)$ to the pair $(\tau_s = 0, \tau_m = 0)$ (because the equilibrium with $(\tau_s = 0, \tau_m = \infty)$ is identical to that with $(\tau_s = \infty, \tau_m = \infty)$, since with infinite tariffs in manufacturing there is no trade and the tariff rate on services does not matter).
imposed that depends upon how much effort the domestic leader expends in lobbying for the tariff. There are then three uses of entrepreneurial time: research, blocking of domestic rivals (through regulations), and lobbying for tariffs. In this kind of environment, a reduction in the tariff \( \tau \) obviously diminishes the incentive to lobby for the tariff, inducing the entrepreneur to shift toward the two other activities of research and blocking the domestic rival. The arguments of this paper suggest that the reduction in the tariff will increase the relative benefit of research rather than blocking. Hence, we expect that a reduction in \( \tau \) will increase research, though the effect on blocking appears ambiguous.

References