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Igor D. Livshits

James C. MacGee

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Department of Economics
Department of Political Science
Social Science Centre
The University of Western Ontario
London, Ontario, N6A 5C2
Canada

Barriers to Technology Adoption and Entry*

Igor D. Livshits†
University of Western Ontario, CIFAR
James C. MacGee
University of Western Ontario

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Abstract

A key feature of recent work on barriers to technology adoption is the assumption that monopoly rights of insiders are limited by the ability of industry outsiders to enter. This paper endogenizes the decision of a government to provide barriers to technology adoption alone or in combination with barriers to entry of outsiders. Using a political economy model, we find that a government provides barriers to *both* technology adoption and outsider entry. If governments are not too "corrupt", restricting their ability to provide barriers to entry may eliminate barriers to adoption. However, for sufficiently "corrupt" governments, prohibiting barriers to entry leads to more extreme barriers to technology adoption.

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†Corresponding author. Department of Economics, University of Western Ontario, London, Ontario, N6A 5C2, Canada. Tel.: + 1-519-661-2111, ext. 85539; fax: + 1-519-661-3666. E-mail: livshits@uwo.ca

1 Introduction

The possibility that monopoly rights play a significant role in accounting for the large differences in per capita GDP and total factor productivity (TFP) across countries (see Prescott (1998)) has received considerable recent attention. This is largely due to important contributions by Parente and Prescott (1999, 2000), who show that monopoly rights acquired by vested interests can have large effects on productivity. Herrendorf and Teixeira (2005b) build upon the work of Parente and Prescott (1999, 2000), and show that monopoly rights arising from barriers to entry could generate large differences in per capita output across countries.[1]

A key element of both Parente and Prescott (1999) and the work of Herrendorf and Teixeira (2005b) is the gap between the productivity of industry insiders and outsiders. In Parente and Prescott (1999), industry outsiders are assumed to be able to enter an industry, but are less efficient when operating the existing technology than industry insiders. This gap plays a key role in generating the incentives for insider groups to acquire barriers to the adoption of superior technologies. However, in both of these papers, the size of this productivity gap is viewed as an exogenous parameter.

In this paper, we ask whether barriers to entry emerge as an equilibrium outcome of a dynamic political economy model of barriers to the adoption of superior technologies. Endogenizing the government's decision to provide entry barriers also allows us to ask whether restricting the ability of governments to block entry would lead to a reduction in barriers to technology adoption.

To answer these questions, we analyze a political economy model where barriers to the adoption of superior technology can be provided with or without barriers to entry of industry outsiders. The demand for these barriers to entry and adoption comes from industry insiders who are more experienced and hence more productive than industry insiders in using current

[1]In related work, Holmes and Schmitz (1995) and Herrendorf and Teixeira (2005a) examine the linkages between monopoly rights, trade policy, and productivity.

technology.[2] The supply of barriers is provided by a government regulator which is able to choose between providing barriers only to the adoption of superior technology and providing barriers both to adoption jointly with barriers to entry.[3] This framework also allows us to examine how barriers to entry influence the dynamic evolution of coalitions of industry insiders.

The model environment extends Bridgman, Livshits and MacGee (2005) to allow the government to choose to provide barriers to the adoption of superior technologies with and without barriers to entry. The production environment has three key elements. First, to capture the idea that industry insiders (vested interests) are affected asymmetrically by the adoption of new technology, we assume that workers productivity (skill level) increases via learning by doing. As a result, older workers are more productive in the technology used in the previous period than younger workers. Formally, our environment builds upon the vintage human capital model of Chari and Hopenhayn (1991). Workers are two-period lived and are skilled when old in the technology they used when young. These skills cannot be transferred across industries or vintages. Hence, skilled workers have a vested interest in incumbent technologies, since the adoption of new technology renders their skills obsolete. As a result, the benefits from the non-adoption of new technology in an industry are highly concentrated, while the costs are broadly spread among all other workers. Second, as we see protection arising in both small and large industries, we assume that there are (infinitely) many industries. This assumption plays a key role in generating the concentrated benefits and diffused costs of policies favoring specific industries. Finally, we abstract from innovation, and assume that new, more productive vintages become available for adoption in each industry each period. Our decision to focus on technology adoption rather than innovation is based on the premise that the large differences in productivity across countries are largely due to the non-adoption of best practice technologies (Jovanovic (1997)).[4]

[2] We abstract from the possibility of inefficient work practices.

[3] Some common examples of government regulation restricting entry are the allocation of production quota's, the assignment of import licenses for critical inputs and government mandated monopolies.

[4] Differences in adoption exist between developed countries with similar relative factor prices. Bailey and

The political economy part of the model features (vested) interest groups that lobby the government for their desired policy. We assume that the only policy dimension in which the government is active is the decision of whether or not to regulate an industry. The government can choose between two types of regulation. The first type of regulation consists of a ban on the adoption of superior technology *and* a ban on entry by industry outsiders into the industry. The second type of government regulation involves *only* a prohibition on the adoption of new technology, but does not prohibit the entry of industry outsiders (workers who are not skilled in that technology) from working in the industry. We say that an industry is protected if the government imposes either of these policies on that industry.

The lobbying game builds upon Grossman and Helpman (1994). The government's payoff is a weighted sum of real GDP (a measure of social welfare) and contributions (bribes) from lobby groups. The government announces which type of regulation it may be willing to provide in exchange for contributions (bribes). Workers (households) then choose whether or not to form coalitions to lobby (bribe) the government for regulation. We also assume that "broad based" lobby groups which oppose protection are unable to exclude non-contributing members from the benefits of lower protection.

The trade-off facing the government when deciding between providing a barrier to adoption with versus without a barrier to entry is relatively simple. On the one hand, bundling the barrier to entry with the barrier to adoption provides industry insiders with additional monopoly rents – which increases their willingness to make larger contributions to the government in return for protection. However, the cost of creating these additional rents is a larger distortion in relative prices across industries and hence in output. As a result, the government faces a trade-off between providing relatively non-distortionary barriers to the adoption of superior technologies to many industries or providing much more distortionary barriers to a smaller number of industries.

Since the complexity of our model makes it impossible to make general statements, we

Gersback (1995) examine manufacturing industries in the U.S., Germany and Japan and argue that much of the variation in relative productivities is due to the non-adoption of best practice technologies.

resort to numerical methods to characterize equilibria. What we find is that the equilibrium outcome of the political economy game is that governments choose to impose both barriers to entry and barriers to technology adoption. In effect, the government finds that the higher contributions (bribes) associated with providing entry barriers and barriers to technology adoption together justify the reduction in real GDP due to the larger distortions.

Based on this, one might conclude that restricting the ability of governments to limit entry would reduce the extent and cost of barriers to the technology adoption. We find that this intuition holds for governments which do not place too high a weight on "bribes" paid by lobby groups relative to GDP. However, we show via a numerical example that for sufficiently "bad" (corrupt) governments, a prohibition on entry restrictions can lead to more extreme barriers to the adoption of superior technologies and much larger deviations in TFP from the frontier. When the government can bundle barriers to adoption with barriers to entry, "bad" governments lead to modest levels of short-lived protection. In contrast, when barriers to entry are prohibited, "bad" governments can generate several periods of non-adoption of new technologies in *all* industries. This leads to much larger gaps between the level of TFP and the world technology frontier than can occur in when barriers to entry are permitted. Hence, restricting the ability of ("bad") governments to restrict entry can sometimes lead to extremely perverse outcomes.

This counter-intuitive result is driven by two underlying forces. First, allowing the entry of unskilled workers into protected industries limits the distortion in relative prices caused by protection. This dramatically reduces the cost to the government of protecting a large fraction of industries. The second underlying force is a dynamic one. Prolonged protection requires the perpetuation of industry lobby groups across generations. In the monopoly rights environment, young workers do not work in protected industries, and hence protection is never demanded by industries more than 1 vintage behind the technology frontier. In contrast, in the environment without monopoly rights, we find equilibria where young work in protected industries. This leads to a perpetuation of the industry lobby into the following period.

Although much of the intuition about the interaction between political process and vested interests are discussed in Olson (1982), there have been few attempts to formalize these stories. In an important contribution, Krusell and Rios-Rull (1996) construct an overlapping generations model in which agents vote on whether to allow innovation to take place. Bellettini and Ottaviano (2003) modify the political economy framework of Krusell and Rios-Rull (1996), and examine a lobbying game based on the framework of Grossman and Helpman (1994). In these papers, the (political) conflict is primarily between generations, as older skilled workers resist the adoption (innovation) of new technologies that would lower their productivity while increasing the productivity of the young. However, in Krusell and Rios-Rull (1996) and Bellettini and Ottaviano (2003), barriers to new technologies arise only when some workers are rendered less productive by new technologies. Bridgman, Livshits and MacGee (2005) show that incorporating many small interest groups can, for reasonable parameter values, generate barriers to technology adoption in equilibrium of a political economy model of lobbying when *all* workers are made more productive by the adoption of new technology.

The paper is organized as follows. The next section outlines the model. Section 3 specifies our equilibrium concept. In section 4, we first characterize the equilibria of each of the two subgames (with and without entry barriers) and then study the government's choice of the type of protection. Section 5 discusses the implications of different entry barriers for political and economic outcomes and examines an illustrative numerical example. Section 6 concludes.

2 Model

The economy is populated by two-period lived overlapping generations households and a government. There is a continuum of measure one of consumption goods. All variables are in per capita terms.

2.1 Technology

There are a continuum of industries of measure one. Each industry produces a distinct consumption good and takes as inputs unskilled labor l and skilled labor s. Productivity is determined by the vintage of the technology v_t employed at date t. A new vintage, $\gamma > 1$ times more productive than the previous, arrives exogenously at the beginning of each period for each industry. Output of industry i is:

$$y_t(i) = \gamma^{v_t(i)} \left(\lambda s_t\left(i\right) + l_t\left(i\right)\right). \tag{1}$$

Skilled labor is industry and vintage specific, and is $\lambda > 1$ times as productive as unskilled labor. Skill in a particular industry and vintage can only be acquired by working as an unskilled worker in that industry using that vintage.

2.2 Households

At the beginning of each period t, a continuum of measure $(1+n)^t$ of generation t households is born. Each household lives for two periods and is endowed with one unit of time in each period. The household inelastically supplies labor to firms and consumes consumption goods $c_t(i)$. Households have identical preferences represented by:

$$u^t(c^t) = \int_0^1 \ln c_t^t(i)di + \beta \int_0^1 \ln c_{t+1}^t(i)di \tag{2}$$

We assume Cobb-Douglas utility for analytical tractability. Households choose which industry to work in and the quantity of each good to consume.

2.3 Barriers

The government can impose barriers to adoption of a new technology in any industry. The government can choose to couple this protection from adoption with a barrier to entry of (unskilled) labor into the industry. The government chooses whether protection will include a barrier to entry before the lobbying game begins.[5]

[5]It turns out that an equivalent (in terms of the resulting equilibria) way of specifying the barrier to entry is to require that any outsider (unskilled) who works in a protected industry has to pay the same bribe

2.4 Lobby Groups

Each period, all workers (both skilled and unskilled) can form coalitions to lobby the government. Lobbying is an offer of a bribe payment to the government in exchange for enacting a desired policy. Lobby groups behave non-cooperatively with respect to each other.

A key issue is the ability of coalitions to force individual members to make contributions towards the bribe payment. Industry specific coalitions can exclude any skilled worker who fails to pay the bribe from working in that industry. However, if the entry of industry outsiders into a protected industry is not prohibited, unskilled workers are free to choose to work in that industry using whatever technology is permitted.

It is worth emphasizing that all workers are free to form coalition(s) to lobby against industry protection. Such lobbies, however, are unable to exclude members from working in any industry or punish them in any other fashion for failure to contribute towards the bribe.

2.5 Government

The government consists of a positive measure of agents who cannot provide labor to firms. The government may provide protection to industries. They choose between two types of protection. Protection for an industry can either only consist of a ban on the adoption of a new vintage or also include a prohibition of entry of (unskilled) workers into the protected industry. A government policy is given by a binary choice χ, which takes value 1 if entry into protected industries is banned and 0 otherwise, and an integrable function $\pi : [0, 1] \to \{0, 1\}$ where $\pi(i)$ takes the value 1 if industry i is protected and 0, if it is not protected.

The government acts myopically. It has preferences over social welfare and the bribes it receives. The income received by the government as bribes (B) is used to purchase consumption goods. The government's preferences over consumption goods are identical to those of

contribution as an industry insider. This suggests that one mechanism that could be used to implement the barrier to entry is to require that all workers must belong to an industry "union" which collects fees from all members.

households. Its objective is:

$$U^G = \frac{Y + \phi B}{P} \tag{3}$$

where Y is nominal GDP, B is total bribes and P is the price index. The price index P is given by $\ln P = \int_0^1 \ln p(i)di$. The parameter ϕ denotes the venality of the government. Note that since bribes are included in GDP the parameter ϕ is the *extra* weight that government places on its own consumption. Taking government preferences to be the weighted sum of real GDP and real bribes (also used by Grossman and Helpman (1994)) provides us with a tractable way of varying the relative weight the government puts on private gains versus social welfare.

2.6 Timing

At the beginning of each period, new agents are born and new vintages become available. The number (density) of skilled workers in industry i, $\overline{s}_t(i)$, is the number (density) of old workers who worked in that industry at $t-1$.

The game in each period proceeds as follows. First, the government decides whether it will let insiders exclude unskilled from working in a protected industry, and announces that decision. Then, each lobby group simultaneously presents a bribe offer to the government. The government either accepts or declines each bribe offer. After the policy is announced, adoption occurs, and people decide where to work. Finally, the government collects bribes from lobby groups whose industries were protected.

3 Equilibrium

This section defines political economy equilibrium. We begin by defining a competitive equilibrium for any given outcome of the lobbying game. This determines the payoffs to agents for any outcome of the lobbying game. We then define our equilibrium concept for the lobbying game.

3.1 Competitive Equilibrium

The state of the economy at the beginning of the period is the distribution of vintages v and the density of skilled workers $\overline{s}$. $v_t(i)$ denotes the vintage of industry i while $\overline{s}_t(i)$ denotes the (per capita) density of skilled workers in industry i that are skilled in $v_t(i)$.

Firms act competitively, and choose inputs and vintages so as to maximize profits, taking prices and policies as given. If adoption is not prohibited ($\pi_t(i) = 0$), industry i solves:

$$\max_{y,s,l,v'} \left[p_t(i)y - w_{l,t}(i)l - w_{s,t}(i)s\right] \tag{4}$$
$$\text{s.t. } y = \gamma^{v'}(\lambda s + l) \qquad 0 \leq v' \leq t$$

where $w_{l,t}(i)$ and $w_{s,t}(i)$ are the wages paid to an unskilled and skilled worker in industry i, respectively. If the industry is protected ($\pi_t(i) = 1$), then the firm can no longer choose whether to adopt. In this case, the last constraint becomes $v' = v_t(i)$. If, in addition, entry of unskilled into the industry is banned ($\chi = 1$), then firms cannot hire unskilled workers ($l = 0$).

Households take the sequence of policies $\{\pi_t\}_{t=0}^{\infty}$, bribe offers $\{b_t\}_{t=0}^{\infty}$, prices $\{p_t\}_{t=0}^{\infty}$, wages $\{(w_{s,t}, w_{l,t})\}_{t=0}^{\infty}$, and firm's adoption decisions $\{v_t'\}_{t=0}^{\infty}$ as given. Each period, households decide in which industry to work. In addition to the aggregate state variables, an old agent's state is determined by the industry (i) she is skilled in. The old agent's value function is

$$V_t^O(\pi_t, b_t, w_t, p_t, i) = \max_c \int_0^1 \ln c_t(j)\, dj \tag{5}$$
$$\text{s.t. } \int_0^1 c_t(j)p_t(j)\, dj \leq \max\left\{\pi_t(i)\left(w_{s,t}(i) - b_t(i)\right);\quad \overline{w}_{l,t}\right\},$$

where $\overline{w}_{l,t}$ is the highest unskilled wage. If entry into protected industries is allowed ($\chi = 0$), then $\overline{w}_{l,t} = \max_i w_{l,t}(i)$; otherwise $\overline{w}_{l,t} = \max_{\pi(i)=0} w_{l,t}(i)$.

The problem of a young agent is to choose the industry i and $\{c_t(j)\}_{j=0}^{1}$ to solve:

$$\max_{i,c} \int_0^1 \ln c_t(j)\, dj + \beta E_t V_{t+1}^O\left(\pi_{t+1}, b_{t+1}, w_{t+1}, p_{t+1}, i\right) \tag{6}$$
$$\text{s.t. } \int_0^1 c_t(j)p_t(j)dj \leq w_{l,t}(i).$$

The density (number) of old people skilled in industry i who choose to work in i in period t is denoted $\sigma_t(i)$ ($\sigma_t(i) \leq \overline{s}_t(i)$). Similarly, the density (number) of people who choose to work as unskilled in industry i is $\vartheta_t(i)$. In equilibrium, labor markets clear: $\vartheta_t(i) = l_t(i)$ and $\sigma_t(i) = s_t(i)$. Since the population each period is normalized to one:

$$\int_0^1 l_t(i)\, di + \int_0^1 \pi_t(i)\, s_t(i)\, di = 1\ . \tag{7}$$

Goods markets clear: $\int c_t(i,\omega)d\omega = y_t(i)$ for all $i \in [0,1]$, where ω's are consumers' names.

Definition 1 *Given sequences of government policy functions* $\{\chi_t, \pi_t\}$*, bribes* $\{b_t\}$ *and initial state* $(\overline{s}_0, v_0)$*, a Competitive Equilibrium is sequences of states* $\{\overline{s}_t(i), v_t(i)\}$*, prices* $\{p_t(i)\}$*, wages* $\{w_{s,t}(i), w_{l,t}(i)\}$*, and household allocations* $\{(c_\tau(\omega), i_\tau(\omega))_{\tau=t,t+1}\}$ *and firm allocations* $\{l_t(i), s_t(i), y_t(i), v_t'(i)\}$ *such that*

1. *Given the state, policy, bribes, prices and wages, each household's allocation solves the household's problem.*

2. *Given policy, state, prices, and wages, each firm's allocation solves the firm's problem.*

3. *Markets clear.*

4. *The state variables* $\overline{s}_{t+1}(i)$ *evolve according to the density of young people working in industry* i *at time* t*, and* $v_{t+1}(i) = v_t'(i)$*.*

3.2 Game between the Government and Industry Insiders

Free rider problems prevent many possible coalitions from making a credible bribe offer. This follows from their inability to "punish" members who do not contribute towards the bribe. For this reason, in the game specified below, we do not explicitly model coalitions other then those of skilled (old) workers in a given industry. These coalitions of industry insiders are able to exclude non-paying members from working in the industry, which allows them to overcome the free rider problem.

Policy and contributions are determined by a game between the government and the coalitions of industry insiders. In the first stage of the game, the government choose whether to protection will include a barrier to entry, χ. The choice is made by comparing the value of the government's objective in equilibria of the two subgames (with and without the entry barrier).

In each subgame, coalitions of industry insiders simultaneously select bribe offers to maximize the expected value of the skill premium, net of bribes, for their members. The value of protection to a member of lobby group i is the difference between the wage that workers could earn if adoption of the new vintage in their industry was prohibited and the wage they could otherwise earn as an unskilled worker:

$$V_t^p(i) = w_{s,t}(i) - \overline{w}_{l,t} \tag{8}$$

For a given state and schedule of per worker bribes $(b(i), b^u(i))$, each government policy induces a competitive equilibrium. In turn, each competitive equilibrium generates a price index $P(\pi)$, skilled wages $w_s(i)(\pi)$, and nominal GDP $Y(\pi)$. The total amount of bribes collected is

$$B = \int_0^1 \pi(i) \left(b(i)s(i) + b^u(i)l(i) \right) di. \tag{9}$$

In the last stage of the game, the government chooses a which industries to protect, taking the bribe offers announced by coalitions of industry insiders as given, to maximize its objective function. Formally, an equilibrium is:

Definition 2 *A Markov Perfect Equilibrium is strategies* (χ^*, Π^*), $(B_i^*)_{i\in[0,1]}$ *such that*

1. *For every vector of bribe offers* $\mathbf{B}$*, the government policy function* $\Pi^*(\mathbf{B})$ *solves*

$$V^G(\mathbf{B}) = \max_{\pi} \frac{Y(\pi) + \phi \int \pi(i) B_i \, di}{P(\pi)}. \tag{10}$$

2. *The bribe function for each coalition of industry insiders,* $B_i^*(\overline{s}, v)$*, solves*

$$\max_{B_i} E\left[\Pi_i^*(B_{-i}^*, B_i) \left(w_s(i) - \overline{w}_l - \frac{B_i}{\overline{s}(i)} \right) \right]. \tag{11}$$

3. The government choice χ^* maximizes $V^G(B^*(\chi), \chi)$.

We restrict our attention to Symmetric Markov Perfect Equilibria. The symmetry restriction we impose is that all industries which operated the same vintage in the previous period have the same number of skilled workers. This implies that industries which operate the same vintage are identical.

Definition 3 *A Markov Perfect Equilibrium is symmetric if along the equilibrium path all industries of the same vintage are indistinguishable: $\overline{s}_t(i) = \overline{s}_t(j)$ whenever $v_t(i) = v_t(j)$.*

Restricting attention to symmetric equilibria dramatically reduces the state space. Instead of tracking allocations for each industry, we merely track allocations for a finite number of classes of industries, where each class is indexed by the distance $d_t(i) = t - v_t(i)$ of the vintage operated from the most advanced vintage available. The state becomes $(\overline{s}(d), x(d))$, where $x(d)$ is the measure of industries d vintages behind at the beginning of the period.

In a symmetric equilibrium, all coalitions of industry insiders whose skill is d vintages behind offer the same bribe $B(d)$. The government's policy is fully specified by the choice of the subgame, χ, and the measure of industries d vintages behind that are protected ($\mu(d) \in [0, x(d)]$). Since all unprotected industries adopt, $\mu(0)$ denotes the measure of industries not granted protection.

A symmetric equilibrium path is fully specified by the sequences of state variables $\{x_t, \overline{s}_t\}_{t=0}^{\infty}$ and strategies $\{\chi_t, \mu_t\}_{t=0}^{\infty}, \{B_t\}_{t=0}^{\infty}$. The law of motion of $x(d)$ is:

$$x_t(d) = \mu_{t-1}(d-1) \quad \forall d \geq 1, \qquad\qquad x_t(0) = 0. \tag{12}$$

$\overline{s}_t(d)$ evolves according to the number of young workers who worked in industries $d-1$ vintages behind at $t-1$. In characterizing equilibria, we specify the distribution of young workers across industries, and use this to construct $\overline{s}_t(d)$. Note that $\sum\limits_{d=1,2,..} \overline{s}(d)x(d) = \frac{1}{2+n}$.

4 Characterizing Equilibria

We assume that the government makes its announcements on which type of monopoly rights will be available at the beginning of the period. We present the structure of the equilibria for each of the two possible subgames below, before characterizing the governments choice of which subgame to choose in section 4.3.

Before examining the subgames, several general points are worth noting. First, we restrict attention to symmetric Markov perfect equilibria of the lobbying game. Subgame perfection implies that an industry lobby will never offer a bribe more than minimally sufficient to guarantee protection. When not all industries d vintages behind are protected ($\mu(d) < x(d)$), the government extracts all of the surplus from protection of these industries. This results from the "Bertrand-type" competition between industries. In this case, the per member bribe offer equals the value of protection (equation (8)). Note that a lobby knows that its actions cannot affect the aggregate protection level.

We assume throughout our analysis that $\gamma > \lambda$. In words, we restrict attention to cases where the new technology strictly dominates the previous vintage. This implies that unskilled workers using the new vintage are always strictly more productive than a skilled worker using an older vintage.

4.1 Subgame 1: Barrier to Adoption and Entry

Several classes of dynamic equilibria arise when unskilled workers can not work in a protected industry. Here, we present two classes of stationary equilibria: *Constant Protection Levels (CPL)* and *Two-Period Cycles* (TPC).[6] CPL occurs when the government venality (ϕ) is low, with zero protection as a special case. As the government's venality increases, cycles arise.

[6] Our description of these equilibria is deliberately terse, as a more detailed analysis and complete characterization of the set of dynamic equilibria for this subgame can be found in Bridgman, Livshits and MacGee (2005).

4.1.1 Static Lobbying Game

To illustrate the workings of the dynamic equilibria, we begin by characterizing the equilibrium of the (static) lobbying game in period t, taking the aggregate state $(x_t(d), \overline{s}_t(d))$ as given. We assume that all old workers are skilled in vintage $t-1$ (this is always the case in this environment).

For a given government policy μ (the fraction of industries protected) and lobby contribution $b(1)$ (bribe per worker), it is straightforward to solve for the competitive equilibrium. We normalize the price of unprotected goods to 1. Since workers are paid their marginal products, the unskilled wage in unprotected industries is $w_{l,t}(d = 0) = \gamma^t$, and the skilled wage in protected industries is $w_{s,t}(1) = \gamma^{t-1}\lambda p_t(1)$. Workers are employed either as skilled workers in a protected industry or as unskilled workers in an unprotected industry.[7]

The number of unskilled workers in each unprotected industry is

$$l_t(0) = \frac{1 - \mu_t(1)\overline{s}_t(1)}{1 - \mu_t(1)} \tag{13}$$

and the price of protected goods is

$$p_t(1) = \frac{\gamma}{\lambda \overline{s}_t(1)} l_t(0). \tag{14}$$

We now turn to the payoffs of the lobbying game players. The value of protection to an old worker is

$$V_t^p(1) = w_{s,t}(1) - w_{l,t}(0) = \gamma^t \frac{1 - \overline{s}_t(1)}{\overline{s}_t(1)(1 - \mu_t(1))} \tag{15}$$

Clearly, skilled workers demand protection only if $\overline{s}_t(1) < 1$. Otherwise, no protection is the unique equilibrium outcome. When $\overline{s}_t(1) < 1$, protection increases the relative price of protected goods. Protection also lowers the level of output in protected sectors, while

[7]As mentioned earlier, an equivalent way to specify the model involves requiring unskilled workers in a protected industry to pay the same bribe as skilled workers. Using the fact that the unskilled wage in a protected industry would be $w_{l,t}(1) = \gamma^{t-1}p_t(1)$, it is straightforward to verify that unskilled workers do not want to work in protected industries: $w_{l,t}(1) - b(1) \le w_{l,t}(0)$. In most equilibria, the entire surplus from protection is extracted, $w_{s,t}(1) - b(1) = w_{l,t}(0)$. Since $w_{s,t}(1) = \lambda w_{l,t}(1)$, unskilled workers strictly prefer working in unprotected industries.

increasing the output in unprotected industries. This is primarily driven by young workers being spread across fewer (unprotected) industries.

Taking into account the effects of its policy choice on the competitive equilibrium, the government chooses $\mu_t(1)$ to maximize:

$$U^G(\mu_t(1)) = \frac{\gamma^t \left(\frac{1-\mu_t(1)\overline{s}_t(1)}{1-\mu_t(1)}\right) + \phi B_t(1)\mu_t(1)}{\left[\frac{\gamma}{\lambda \overline{s}_t(1)}\left(\frac{1-\mu_t(1)\overline{s}_t(1)}{1-\mu_t(1)}\right)\right]^{\mu_t(1)}}. \tag{16}$$

Protection increases nominal GDP and nominal bribes, but also increases the price index. In fact, a sufficient condition for real GDP to be decreasing in the level of protection is $\gamma > \lambda$. Hence, the unique equilibrium for $\phi = 0$ is no protection.

If some industries one vintage behind are not protected in equilibrium, then the government extracts all of the surplus from protection. In other words, the contribution of each industry insider to the bribe equals the value of protection. The bribe offer from each lobby is the product of the value of protection to each worker and the number of workers:

$$B_t(1) = V_t^p(1)\overline{s}_t(1) = \frac{\gamma^t}{(1-\mu_t(1))}\left(1-\overline{s}_t(1)\right). \tag{17}$$

If $\overline{s}_t(1) \leq \ln\left(\frac{\gamma}{\lambda \overline{s}_t(1)}\right)$, then the equilibrium of this static game is unique. Furthermore, there is an open set of parameter values for which not all industries one vintage behind are protected.

4.1.2 Dynamic Equilibria

The dynamic aspect is the endogeneity of the state variables – the number of old workers in each industry $\{\overline{s}_t(d)\}$ and the measure of industries d vintages behind $\{x_t(d)\}$. Since unskilled workers cannot work in a protected industry have to pay the same bribe, all of the young work in unprotected industries, and there are no workers skilled in vintages more than one generation behind the frontier ($\overline{s}_t(d) = 0 \; \forall \, d > 1$). Thus there is no one with a vested interest in any technology more than 1 vintage behind the frontier. This implies $x_t(d) = 0 \; \forall \, d > 2$ and $\mu_t(1) + \mu_t(0) = 1$. Using the law of motion (12), $x_t(1) = 1 - \mu_{t-1}(1)$ and $x_t(2) = \mu_{t-1}(1)$.

Below we characterize stationary symmetric Markov perfect equilibria. Since young workers spread evenly across unprotected industries,

$$\overline{s}_t(1) = \frac{1}{(2+n)\mu_{t-1}(0)} = \frac{1}{(2+n)(1-\mu_{t-1}(1))}. \tag{18}$$

In equilibrium, old workers who were not granted protection also spread evenly across the unprotected industries.

4.1.3 Constant Protection Levels

The easiest equilibria to characterize are *Constant Protection Levels (CPL)*. While a constant fraction of industries (less than half) are protected each period, the specific industries protected vary from period to period. Since $\mu_t(1) < 0.5 < x_t(1)$, the equilibrium bribe offers are equal to the value of protection. While stationary equilibrium may not be unique, the equilibrium path is pinned down by the initial condition. A special case is zero protection equilibrium, which occurs when $\phi \leq \frac{2+n}{1+n} \ln\left(\frac{(2+n)\gamma}{\lambda}\right) - 1$.

4.1.4 Cycles

Cycles are driven by the endogeneity of the state variables. The "size" of vested interest groups ($\overline{s}_t(1)$) is pinned down by the allocation of young workers in the previous period, which in turn is determined by the extent of protection in that period ($\mu_{t-1}(1)$).

The easiest cycles to characterize are *Two-Period Cycles (TPC)*. They feature periods of zero protection alternating with periods of extensive, but not complete, protection. Suppose that all industries adopted in the previous period ($x_t(1) = 1,\ \overline{s}_t(1) = \frac{1}{2+n}$). A sufficiently venal government would then choose to protect a large fraction of industries. If $\mu_t(1) \geq 1 - \frac{1}{2+n}$, then the young are squeezed into so few industries that in the following period $\overline{s}_{t+1}(1) \geq 1$, and hence protection is not demanded (see equation (15)). This leads to a period of no protection, which confirms our conjectured equilibrium.

While there are other types of stationary equilibria (discussed in Bridgman, Livshits and MacGee [2005]), none of them features a period of full protection. Regardless of the initial conditions (state variables), even the most venal government will never want to protect *all* industries. As the fraction of industries protected approaches one, roughly half of the population (all of the young) are crammed into the vanishing set of unprotected industries. This drives the price of unprotected goods relative to protected goods to zero. In effect, the young's contribution to real GDP goes to zero. Although the share of output going to bribes converges to one, the real value of bribes declines as $\mu_t(1)$ nears one.

4.2 Subgame 2: Barrier to Adoption and No Barrier to Entry

We now turn to the second subgame, in which the government provides a barrier to the adoption of superior technology and no barrier to the entry of unskilled workers in protected industries.[8]

The results in the previous subsection relied upon the assumption that no unskilled worked in protected industries. Hence, protection increased the skilled wage (before bribes) relative to unskilled wages, and hence rents from protection were high. One might think that the equilibrium level of protection would be reduced if unskilled workers could not be excluded from working in a protected industry, as this limits the wage gap between skilled and unskilled. While this intuition sometimes goes through, for some parameter values, equilibria exist with extensive and protracted protection that are not possible when unskilled workers are prohibited from working in protected industries. Moreover, if the government is sufficiently corrupt, there are equilibria where *all* industries are protected in a given period, which was not possible in the previous environment.

CPL equilibria of the type described in section 4.1.3 exist in this environment when skilled workers are much more productive than unskilled (i.e. λ is large) and venality of government (ϕ) is low. In this case, unskilled workers do not find it in their interest to join protected industries and the analysis of section 4.1.3 applies directly. For parameters

[8] Note that this game contains several of the key elements of Parente and Prescott (1999). In particular, the skill premium λ can be interpreted as the difference between the productivity of industry insiders π_1 and industry outsiders π_0 in Parente and Prescott (1999).

that generate CPL equilibria with higher $\mu_t(1)$ in the original environment, the counterparts of these equilibria in the altered environment may feature lower levels of protection. The possibility of unskilled workers joining a protected industry introduces an upper bound on the skill premium, and thus lowers the value of protection.

The employment of unskilled in protected industries limits the distortions created by protection. Ironically, this allows for equilibria where the economy is sometimes completely closed ($\mu_t(0) = 0$). In fact, for some parameter values, multi-period cycles featuring several consecutive periods of non-adoption exist.

We begin our description of these cycles in the period t following zero protection.[9] Then the state in period t is as in section 4.1.1 – all skilled workers are in industries one vintage behind. As in section 4.1.1, the price of unprotected goods is 1, the unskilled wage in unprotected industries is $w_{l,t}(0) = \gamma^t$, and the skilled wage in protected industries is $w_{s,t}(1) = \gamma^{t-1}\lambda p_t(1)$. When unskilled workers work in protected industries, they receive the same wage in protected and unprotected industries: $w_{l,t}(0) = w_{l,t}(1) = w_{s,t}(1)/\lambda$. It follows that $p_t(1) = \gamma$. Equation (7) reduces to $\mu_t(1)\left(\overline{s}_t(1) + l_t(1)\right) + \mu_t(0)l_t(0) = 1$. Since the value of output is the same for all industries, $y_t/\gamma^t = l_t(0) = \lambda\overline{s}_t(1) + l_t(1)$. It follows that

$$l_t(0) = 1 + \mu_t(1)\left(\lambda - 1\right)\overline{s}_t(1) \tag{19}$$

and the government maximizes

$$U^G(\mu_t(1)) = \frac{\gamma^t\left(1 + \mu_t(1)\left(\lambda - 1\right)\overline{s}_t(1)\right) + \phi B_t(1)\mu_t(1)}{\gamma^{\mu_t(1)}}. \tag{20}$$

The value of protection is

$$V_t^p(1) = w_{s,t}(1) - w_{l,t} = \gamma^t\left(\lambda - 1\right). \tag{21}$$

Since U^G is concave with respect to $\mu_t(1)$, an equilibrium features complete protection in period t if and only if $\frac{\partial U^G}{\partial \mu_t(1)}|_{\mu_t(1)=1,\ B=\overline{s}_t(1)V_t^p(1)} \geq 0$. This is equivalent to $(1+\phi)(\lambda - 1)\overline{s}_t(1)(1-\ln\gamma) \geq \ln\gamma$. So long as $\ln\gamma < 1$, a sufficiently venal government (high ϕ) will protect all industries.

[9]A numerical example of this type of cycle is provided in 5.

In the period following full protection ($t+1$), all old are distributed evenly across protected industries, which are now two vintages behind the frontier: $x_{t+1}(2) = 1$, $\overline{s}_{t+1}(2) = \frac{1}{2+n}$. This situation is the same as described above, with the frontier technology being γ^2 more productive than the incumbent (simply replace γ with γ^2). Hence, if $2 \ln \gamma < 1$, a sufficiently venal government would protect all industries for the second period in the row. This could continue for up to $N-1$ periods, where $N \ln \gamma \geq 1 > (N-1) \ln \gamma$. However, in the example we construct in the next section, this continues for $N-2$ periods (where $N = 4$). In period $t+N-1$, roughly half the industries are protected. In this period, all of the young work in the unprotected industries, and the demand for unskilled workers in protected industries is satisfied by old workers whose industries are not protected. Since the young are concentrated in roughly half the industries, they do not demand protection in the following period as $\overline{s}_{t+N}(1) \geq 1$ (see section 4.1.1). Industries N vintages behind no longer have any skilled workers. Hence, the economy is completely open in period $t+N$, the young spread evenly across the industries, and the cycle is ready to repeat itself.

4.3 Which Subgame Would the Government Choose?

We are now in a position to evaluate which of the two subgames the government would choose. The answer to this question has important implications for how we should view the Parente and Prescott (1999, 2000) assumption of only barriers to adoption and no barriers to entry matter for the costs of vested interests.

We find that the government chooses the subgame with entry barriers. While we cannot establish this result analytically, we were unable to construct a single example where the government chooses to offer only barriers to adoption and not restrict entry by outsiders in the dynamic game.

To verify this finding, we undertook a grid search over parameter values in the static game. Note that a necessary (but not sufficient) condition for a dynamic equilibrium is that, given some initial condition $\overline{s}$, the government would choose the subgame without entry barriers. The grid search exercise involves comparing the value of the government objective in equilibria of subgames with and without entry of unskilled for various parameters and initial conditions.

We consider the following ranges for the parameter values: $\phi \in [0, 20]$, $\gamma \in [1.1, 1.5]$, $\lambda \in [1.05, \gamma)$. We conjecture that the government in the preceding period chose the subgame with entry barriers. In that case insiders exist only in industries one vintage behind. For simplicity, we vary only the density of skilled workers in these industries, $\overline{s}(1) \in [0.05, 0.95]$, and let the government protect up to measure 1 of them.

We find, for all (interesting) parameter values and all plausible initial conditions, that the government objective is higher in the equilibrium of the subgame with no entry of unskilled. The only exceptions in this static setup arise when λ is close to γ (barriers are not very distortionary) *and* $\overline{s}(1)$ is very high (greater than 0.8). However, in *all* of these cases, the static counter-examples violate dynamic equilibrium conditions, and hence cannot be part of a dynamic equilibrium.[10]

To summarize we have found ***none*** of these equilibria where government would chose to let unskilled enter.

The intuition for this result is natural, but not obvious. On the one hand, the ability of outsiders to enter an industry where adoption of new technology is prohibited reduces the rents available to insiders and thus lowers the value of protection. This in turn leads to lower bribe offers to the government, which reduces their incentive to provide barriers to adoption. This effect is offset by the fact that barriers have a smaller adverse effect on real GDP when outsiders can enter a protected industry. On balance, however, the reduction in the value of protection dominates, so that the government prefers to play the subgame where they trade

[10] When evaluating the static examples, we assumed unlimited demand ($x(1) = 1$), which cannot be the case when $\overline{s}(1) > 0.8$. In every counterexample, the government chose to protect measure 1 of industries. Besides from violating the dynamic constraint, we overstate the

of industries. However, when $\overline{s}(1)$ is that high, there cannot be many industries that demand protection. Thus, by evaluating the government's objective at $\mu(1) = 1$, we overstate the value of no-entry-barrier subgame to the government for two reasons: 1) we let them collect from more lobbies than are out there; 2) if the government grants protection to all who ask, the bribe falls below the value of protection.

barriers to adoption and a prohibition on entry by outsiders for contributions (bribes) from vested interests.

5 Discussion and Illustrative Example

The characterization of equilibria above suggests that barriers to entry and barriers to technology adoption are likely to be complementary outcomes of a political economy game. We view this result as contributing towards the theoretical underpinnings for the quantitative work of papers such as Herrendorf and Teixeira (2005b), which explore the implications of barriers to entry and adoption for cross-country income differences.

The finding that barriers to adoption and entry would be jointly chosen by a government may seem to suggest that limiting the ability of governments to limit entry would lead to less barriers to the adoption of superior technology. To explore this argument, we can use our characterization of the two subgames to see what would happen if governments were prohibited from limiting entry into any industry.

It turns out that the intuition that prohibiting restriction of entry should lead to fewer barriers to adoption holds for governments which are not too "corrupt". Indeed, for the benchmark parameter values of Bridgman, Livshits and MacGee [2005], if the government is prohibited from providing barriers to the entry of unskilled workers into protected industries, then the equilibrium outcome features all industries adopting the frontier technology (zero protection). Thus, for some parameter values, barriers to entry turn out to be essential for barriers to technology adoption.

This finding, however, is not robust to variations in parameter values. Indeed, for very bad governments (ones with large values of ϕ), this result is dramatically reversed. When barriers to entry are permitted, these parameters lead to (relatively) modest levels of short lived protection. However, if governments cannot provide barriers to entry, then with the relaxation of monopoly rights to labor supply they can generate several periods of non-adoption of new technologies in *all* industries. This leads to large gaps between the level of TFP and the world technology frontier. These large TFP gaps cannot be generated in a world with monopoly rights. Hence, relaxing monopoly rights can sometimes lead to extremely perverse outcomes.

This reversal is driven by two underlying forces. First, since protected industries employ (young) unskilled workers, the distortion in relative prices caused by protection is reduced. This is due both to an expansion in output of protected industries and a reduction in the output of unprotected industries. Recall that in the environment with monopoly rights, full protection could never be an equilibrium outcome. As the fraction of industries protected approaches one, all of the young workers are "crammed" into increasingly few industries. This "cramming" effect does not occur in the absence of monopoly rights.

The second underlying force is a dynamic one. Prolonged protection requires the perpetuation of industry lobby groups across generations. Since in the monopoly rights environment, young workers do not work in protected industries, protection is never demanded by industries more than 1 vintage behind the technology frontier. In contrast, in the environment without monopoly rights, we find equilibria where young work in protected industries. This leads to a perpetuation of the industry lobby into the following period.

To help illustrate these arguments, consider the following illustrative example. Given our demographic structure, we assume that each period corresponds to 20 years. We abstract from population growth ($n = 0$). The technology growth factor is set to $\gamma = 1.42$, which corresponds to a 1.8% annual growth rate. $\lambda = 1.25$, which implies that skilled workers are 25% more productive then unskilled workers. The venality of government (ϕ) is 0.75, which implies that the government values its own consumption 1.75 times as much as the consumption of others. In all equilibria we analyze, the discount factor is irrelevant since all members of the same generation have the same net income and intergenerational trade is impossible. For simplicity, we set $\beta = 1$.

With these parameter values, the stationary equilibrium of the monopoly rights economy is a constant protection equilibrium. Each period, 27.5% of industries are protected. The resulting reduction in real GDP due to this protection is roughly 5.5%. For the same parameter values, the environment without monopoly rights generates no protection in equilibrium. This confirms the basic intuition that limiting the value of protection should lead to lower levels of protection.

This result, however, is reversed for high values of government venality. Increasing ϕ to 18 generates a two period cycle in the monopoly rights environment. This cycle features alternating periods of complete openness and partial adoption, when 50.2% of industries are protected. The reduction in real GDP in periods of partial protection is 18.8%. Both the extent and longevity of protection are much higher when insiders do not have monopoly rights on labor supply. The equilibrium in this environment is a four period cycle which features 2 periods of complete protection, which leads to a drop in real GDP relative to the frontier of a factor of 2.[11] In the third period of the cycle, 53% of industries are protected, while the remaining industries adopt frontier technologies. In the last period of the cycle, protection is not demanded so all industries adopt best practice technologies.

What should we take from this example? Clearly, this example relies upon the assumptions of linearity of production and overlapping generations structure. Despite the stylized nature of the model, we view this example as suggesting two important points. First, this example provides an example where increased competition is not sufficient to remove barriers. This suggests an important caveat to the argument of Holmes and Schmitz (1995) that increased competition will lead to reduced incentives for the provision of barriers to adoption. A related message is that even in cases where entry cannot be easily prohibited (such as in the informal sector in developing countries) if local governance institutions are very bad, one may still observe barriers to technology adoption.

[11] This goes a long way in accounting for measured differences between rich and poor countries, which vary by roughly a factor of three (see Parente and Prescott (2000), page 80).

6 Conclusion

In this paper, we asked what the political economy outcome would be if a government regulator was able to chose between providing barriers to the adoption of superior technology with or without a barrier to the entry of industry outsiders. Our analysis suggests that, whenever barriers to the adoption of superior technology is an equilibrium outcome, governments would prefer to provide both types of barriers to industry insiders'. However, we also find that barriers to entry are not always essential for barriers to technology adoption to arise in equilibrium. When governments are not too "bad", restrictions on monopoly rights can lead to the elimination of barriers to technology adoption. However, for "bad" governments, restrictions on monopoly rights can lead to more extreme barriers to the adoption of superior technologies and much larger deviations in TFP from the technology frontier.

The key driving force behind these surprising results is the endogenous dynamics of the formation of vested interests. Having young workers acquire skills in obsolete technologies perpetuates insider groups who have a vested interest in industries whose productivity is falling further and further behind the frontier. This, combined with lower relative price distortions, can (surprisingly) generate much larger and long-lived barriers to technology adoption than are possible in an environment with monopoly rights.

We view our findings as suggesting that the costs of monopoly rights may be even larger than those suggested by Parente and Prescott (1999) or Herrendorf and Teixeira (2005b). However, our results also suggest that further work on the interaction between monopoly rights and the dynamic evolution of interest groups may be worthwhile. While the stylized nature of our model contributes to the large effect of barriers to entry on the evolution of industry insiders, we view our findings as suggesting that further work may yield useful insights.

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