Formation and Destruction of Coalition Groups under Economic Growth

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Abstract

This paper introduces a model economy in which formation of coalition groups under technological progress is generated endogenously. The coalition formation depends crucially on the rate of arrival of new technologies. In the model, an agent working in the same technology for more than one period acquires skills, part of which is specific to this technology. These skills increase the agent productivity. In this case, if he has worked more than one period with the same technology he has incentives to construct a coalition to block the adoption of new technologies. Therefore, in every sector the workers have incentives to construct a coalition and to block the adoption of new technologies. They will block every time that a technology stay in use for more than one period.

1 Introduction

Evidences indicate that groups resist to adopt new technologies and that this resistance affects the productivity and the income per capita of the

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countries.[1] Less resistance is associated with higher productivity and higher income per capita and more resistance is associate with smaller productivity and smaller income per capita. In this paper we ask the following question: is the resistance to adopt new technologies greater or smaller as the (exogenous) arrival of new technologies increases?

The assumption of this paper is that "(technological) progress and growth, ..., involve costs that usually fell disproportionately on some groups".[2] In this case, those groups would resist to adopt new technologies. These costs are not related with the production of the new technique. In fact, we are assuming an exogenous and cost-less technological progress.

In this paper the costs of adopting a new technology is introduced in the following way. Workers acquire skills, on the job training basis, part of each is specific to the technology that is being used. That is, if a worker uses the same technology for more than one period his/her skills increase. Part of these acquired skills is specific of this technology and is lost in case of changing of the technology. Therefore, the costs of the technological progress come from the lost of skills or human capital, suffered by the workers of the sectors where the technological progress is happening.[3]

In the model, the arrival of new technologies in each sector is random. Every period, each sector can be hit with a new technology. The probability to be hit with a new technology is independent and identical distributed across sectors. If the sector has a new technology, workers decide if they will form a coalition to block the new technology. If they choose to form a technology to block the new technology they have to pay a cost.

Our main finding is the following. The faster is the technological progress, that is the higher is the probability of arriving a new technology in a sector, the smaller is the resistance to adopt the new technologies. In this case economies can experience different cycles. On the one hand, if the technology is advancing fast no interest group is formed, there is no resistance and the new technology is always adopt. On the other hand, if the technological progress slows down, interest groups are formed, resistance to adopt new technologies increases and the adoption of new technologies slows down even more than the technological progress.

This paper is related with Parente and Prescott [8, 9], Holmes and Schimitz [1],

[1]See Mokyr [4, 5, 6], Olson [7], Holmes and Schmitz [1], Parente and Prescott [9], Krussel and Ríos-Rull [2] and Teixeira [11].

[2]Mokyr [10, page 328].

[3]See Section 2 for quantitative evidences of this loss.

Teixeira [11] and more particularly with Krussel and Ríos-Rull [2]. The basic idea of these papers is that groups of interest decide if a new and exogenous given technology will be used or not. In Krussel and Ríos-Rull [2] an old technology represents the "status quo" generating vested interest. More specifically, they constructed an overlap generation model where the old generation loses if the technology changes since their skills are based in the knowledge of the current technology in use. We extended the above models in the following way. First, in our model the formation of a coalition is endogenous. Second, there is a cost to adopt a new technology. This cost is given by the loss of human capital specific to the technology which is being abandoned and by the cost to form a coalition. An important point stressed in our model, is that technological progress has a cost for the workers of the sector where it happens as well as for the whole economy since it destroys part of the aggregate stock of human capital. But even with the introduction of the cost to adopt, the opportunity cost of blocking is higher than adopting measured in forgone output.

The remainder of this paper is divided into three sections. In Section 2 we present some evidence for wage increase as a result of on the job training. Section 3 we present the model. Section 4 concludes.

2 Wages and Accumulation of Skills

The basic point that we want to stress in this section is that the workers acquire skills or human capital in each passing year that they work in the same firm. Besides, part of these skills are specific to this technology. In this case, "workers with longer prior job tenures suffer substantially greater losses from displacement"[4]. In other words, with each passing year working with the same technology a worker acquires skills. Part of these skills are general and part are specific to this technology. The worker would loose the skills that are specific once he starts a new job. What Toppel [14] estimative indicates is that this loss is substantial.

Clearly, not every job lost by a worker can be used to support the above hypothesis. For example, a new match between a labor and a firm can have a problem of private information. The labor knows his skills, but the firm does not know. In this case, the labor can have less skills than he originally sad. The firm, after realizing that, can fire the labor.

[4] Toppel [14, page 148].

Table 1: Predicted Growth Rate of Wages - By Years of Job Tenure

Years of Tenure	1	2	3	4	5	6	7	8	9	10
Rate of Growth	0.068	0.06	0.052	0.046	0.041	0.037	0.033	0.03	0.028	0.026

Table 2: Wage Index

Years of Tenure	0	1	2	3	4	5	6	7	8	9	10
Wage Index	1	1.068	1.132	1.191	1.246	1.297	1.345	1.389	1.43	1.47	1.509

To eliminate this and other problems, Toppel [14] use a sample of men that have been displaced from a job because of layoffs or plant closing. He found that the wage loss varies from 9.5% for a worker with 5 years of seniority or tenure to 43.9% for workers with more than 20 years of tenure[5].

The results of Toppel [14] are summarized in the Tables 1-3[6]. Table 1 shows the sample growth rate of the wage generated by accumulation of skills (general and specific). Table 2 is generated from Table 1, by constructing a wage index. Thus, in period zero the wage is 1. Then, we increase this wage following the growth rate given in Table 1. We see that the growth rate is higher in the beginning and it reduces over time.

Table 3 shows the estimated wage loss of a worker by years of job tenure. The estimation is based in two different procedures, that we call Method 1

[5] See Toppel [14, page 149]. The sample consists of 4,367 men.

[6] The wage of a labor almost double during his career. Although, this growth is not linear and it is faster in the first years (Toppel [15]). But, Toppel [14] use workers with 10 years of seniority. In this case, this estimative could underestimate the accumulation of skills. In any case, they still give us a good indicative of the process of accumulation of skills that take place in the job.

Table 3: Wage Loss By Years of Job Tenure

Years of Tenure	5	10	15	20
Method 1	0.19	0.28	0.33	0.40
Method 2	0.26	0.35	0.38	0.42

and Method 2. Method 1 is the lower bound of the wage loss[7].

From Tables 1-3 we can summarized the following conclusions:
(i) Wages grow faster in the first periods of a new job than in the later periods. Thus, wages are concave in years of job tenure;
(ii) The wage loss by job displacement is quite substantial, varying between 19% for a period of 5 years tenure to 42% for a 20 years tenure.

3 The Model

There are M goods at each date and a competitive firm producing each of these goods with a constant return to scale technology. There is no borrowing or lending and no physical capital accumulation. There are measure $\lambda > 0$ of households that live forever. The period commodity space is $L = \mathbb{R}^{M+1}$, the space of M final goods and efficiency units of labor. A point of L is $x = (c_1, ..., c_M, h)$.

We now turn to define the consumption set of a household. First, we need to specify the amount of labor that a household can supply in each period. there are two kinds of labor: skilled and unskilled with measure λ_s and λ_u respectively. Sectors $i = 1, ..., M-1$ are intensive in skilled labor. Sector M is intensive in unskilled labor. We assume that any worker, skilled or unskilled, can supply unskilled labor. Besides, since sector M just uses unskilled labor, any worker employed in this sector does not accumulate skills. In contrast with sector M, skilled workers in sectors $i = 1, ..., M-1$ can accumulate human capital. That is, in the first period working with a technology, each skilled worker is endowed with one unit of time. But, after each period working with a technology, an skilled worker accumulates or acquires more skills. We measure this new skills in units of time of the unskilled labor and we are assuming that the accumulation of skills follow some concave and bounded assumptions. That is, the marginal increase of skills for each period of work in the same technology reduces over time. Moreover, there is a maximum amount of skills for each technology. But, every time that a firm starts to use a new technology, an old employee looses part of his skills accumulated in the previous technology.

For example, suppose that in the first period, an agent starts to work with

[7]Method 1 uses a two step procedure to estimate and separate the effects of experience and job tenure over the wage. Method 2 is the OLS estimator, that in this case is biased. See Toppel [14, pages 148–154].

some technology. He can sell the services of one unit of unskilled labor. In the second period, for example, he would have 1.10 units of unskilled labor. In the third, he would have 1.15 and so on. Now, if in the fourth period he changes sectors or the technology that he is working with then he can supply only 1.07 units of labor. Thus, there is no external effects for other workers. The increase in his productivity comes only from his accumulation of skills in a "learning by doing" way. From the firm point of view, everything happens as if the agent was selling one unit of time in his first period, 1.10 in the second and so on.

Define H the space of functions $h : I\!N \times I\!N \times I\!N \rightarrow I\!R_+$ piece-wise monotone increase, piece-wise concave, piece-wise continuous and $h'(a_j, a'_j, n_j) \geq 1$, where a_j is the current technology index for workers of sector j, a'_j is the next period technology index for workers of sector j, and n_j is the number of periods that worker i has been working with technology index a_j.

The consumption set of a skilled worker is

$$X(h_i) = \{x \in L_+ : 1 \leq h \leq h_i,\ h_i \in H\} \tag{1}$$

Finally, let us look at the consumption set of an unskilled worker. There is a measure λ_u os unskilled workers. They are endowed with one unit of time per period and they do not accumulate skills.

The consumption set of an unskilled worker is

$$X(l_i) = \{x \in L_+ : 0 \leq l_i \leq 1\} \tag{2}$$

- **Preferences**

All households admit a utility function of the form

$$\sum_{t=0}^{\infty} \beta^t \frac{(c_{1t}^{\alpha_1} \cdot \ldots \cdot c_{Mt}^{\alpha_M})^\rho}{\rho} \tag{3}$$

where $\sum_{j=1}^{M} \alpha_j = 1$, $\rho \leq 1$ and $\beta \in (0, 1)$.

- **Technologies**

The technological set of a firm of sector $j = 1, ..., M-1$ is

$$Y_j(a_j) = \{x \in L_+ : c_j \leq \gamma^{a_j}\, h,\ c_i = 0,\ if\ i \neq m\} \tag{4}$$

where $\gamma > 1$ and a_j is an integer that indexes the technology in sector j and is determined by past policy decisions of workers of sector j.

We are assuming that there is an exogenous technological progress in sector $j = 1, ..., M-1$. The advance in technologies happens in the following way. There is a draw technology given by $\Phi(t)$. At each period t, $\Phi(t)$ is a M-vector that shows the sectors that will have a new technology available in the next period. That is, $\Phi_j(t) = 1$ if sector j will have a new technology in period $t+1$ and $\Phi_j(t) = 0$ if not. Finally, the most advanced technology for sector j in period t, $A_j(t)$, and the technology used in sector j in period t, $a_j(t)$, are defined as

$$A_j(t) = \sum_{j=1}^{t} \Phi_j(j)$$

$$a_j(t) \in \{0, ..., A_j(t)\}$$

For simplicity we will suppress time symbols from $A_j(t)$ and $a_j(t)$ leaving them implicit from now on.

The technology advance step by step. Besides, as we will see below, there is no uncertainty with respect to next period since the announcement of a new technology is made in the current period and known before the relevant decisions.

The technological set of a firm in sector M is

$$Y_M = \{x \in L_+ : c_M \leq l,\ c_i = 0,\ if\ i \neq M\} \tag{5}$$

The last technology in this economy is a blocking technology. That is, there is a technology that blocks the adoption of new technologies, allowing workers of a sector to keep using an old one. But, this blocking is costly. We measure this cost in units of time that workers have to give up in order to obtain the block of the new technology. This blocking technology is $G : \mathbb{N} \times \mathbb{N} \rightarrow \mathbb{R}_+$ that transforms technology index A in technology index a at a cost $d^\theta \kappa$, where κ is a positive constant, $d = A - a$

$$G(d) = d^\theta \kappa \tag{6}$$

where $\theta \geq 0$ and $a \leq A$.

• Policy Arrangement

1) The integers a_j index the technological set Y_j that produces good $j = 1, ..., M-1$. This integer belongs to the set $\{0, ..., A_j\}$, and $A_j \leq t$.

In the beginning of period t, the workers of a sector $\Phi_j(t) = 1$ decide the technology that they will use next period. That is, workers of sector j such that $\Phi_j(t) = 1$ choose $a'_j \in \{a_j, ..., A_j, A_j + 1\}$.

2) If a skilled worker looses his job, he keeps receiving the same amount that the others skilled workers receive in the sector.

3) A non skilled worker can be hire in any skilled intensive sector. But, they are the first to be fired in any sector.

• Blocking

We will say that workers of sector $j = 1, ..., M-1$ are blocking the adoption of new technologies if $a_j < A_j$.

• Timing

In the beginning of period t, the value of $\Phi(t)$ is known. Workers of each sector $j = 1, ..., M-1$ such that $\Phi_j(t) = 1$ get together and decide if they will construct a coalition to block or not the new technology. That is, after $\Phi(t)$ is announced the workers of each sector that will have a new technology available get together. If they choose to block they divided the amount $G(\cdot)$ among themselves and use the blocking technology to create a barrier. The best technology will not be used in the subsequent period. After these decisions, the amount of labor that each agent can supply is known and markets are opened.

• Accumulation of Skills: an example

To make clear how an agent accumulates skills, let us write one example. Suppose that a skilled agent i works in a sector $j = 1, ..., M-1$. Define a function $h'_i : \mathbb{N} \to \mathbb{R}_+$ by

$$h'_i(a_j, a'_j, n'_j) = 2 - e^{-n'_j}$$

$$n'_j = \begin{cases} 0, & \text{if } a'_j > a_j \\ n_j + 1, & \text{if } a'_j = a_j \end{cases} \tag{7}$$

where h'_i is the amount of labor services that agent i can supply next period and n_j is the number of periods that agent i has been working with technology a_j.

Now, from Equation (7) we can see that, fixing a'_j and making $n_j \to \infty$ the marginal rate of accumulation of skills goes to 0. That is, $h'_i \to 2$.

3.1 Definition of Equilibrium

This is a discrete time infinite dynamic game with 2 stages in each period. In stage one, the draw technology $\Phi(t)$ chooses randomly which sectors will have a new technology available in the next period. This becomes a public knowledge. Given $\Phi(t)$, the workers of each sector $j = 1, ..., M-1$ such that $\Phi_j(t) = 1$ get together and decide if they will construct a coalition and stop the adoption of the new technology available. In the second stage, price and allocations are determined competitively.

We will work with a Markov equilibrium[8]. But, we will restrict our analysis to the set of Markov equilibrium which is symmetric with respect to the workers of the same sector.

In each period we will analyze the game using backward induction from stage 2 to stage 1. In the second stage, the economy state variables are (s, H, s') where $s = (t, A_1, ..., A_{M-1}, a_1, ..., a_{M-1}, n_1, ..., n_{M-1})$, t indicates the current period, A_j is the index of the most advanced technology available for sector j in period t, a_j is the index of the technology in use in sector j in period t and n_j is the number of periods that technology indexed by a_j has been in use in sector j. $H = \sum_{i=1}^{\lambda_s} h_i$ is the aggregate stock of human capital in period t. For simplicity, we will write $s = (t, A, a, n)$. We are abusing notation, using n_j to represent the number of periods that a worker in sector j has been working with technology a_j as well as the number of periods that firms of sector j have been using technology a_j. For the set of symmetric Markov equilibrium that we are working here they are the same. In the second stage, consumers and firms solve their problem. That is, prices and allocations are determined competitively. The maximization problem of a consumers and firms are static.

In the first stage $\Phi(t)$ is announced and workers choose the technology

[8] See Maskin and Tirole [3].

that they will use next period. Once $\Phi(t)$ is known the economy state variables are (s, H) and A'. Let $S = I\!N^{3M-2}$ be the space of state variables and F the space of functions $g_j : S \to I\!N$. Let $D_j : F \to F$ be the best response correspondence (for workers of sector j). That is, if $g_j \in D_j(g)$ then

$$g_j \in argmax_{a'_j \leq A'_j} E \left\{ \Phi \sum_{t=0}^{\infty} \beta^t \frac{\left(\gamma^{\alpha_1 a_1} \cdot ... \cdot \gamma_{M-1t}^{\alpha_{M-1} a_{M-1}} \hat{h}_i\right)^\rho}{\rho} \right\}$$

where $\Phi = \alpha_1^{\alpha_1} \cdot ... \cdot \alpha_M^{\alpha_M}$

Finally, let $D(g)$ be a M vector of best response correspondence of all sectors.

- **Dynamic Equilibrium**

The equilibrium that we are working with is a Markov equilibrium[9] with respect to the state variables (s, H). We are restricting our attention to the Markov equilibrium which is symmetric with respect to workers of the same sector. An equilibrium is the following set of elements:

(i) price functions $p(s, H) = \{p_1, ..., p_M, w = 1\}$;

(ii) households allocations $\{x_i(s, H)\}$ for all i;

(iii) firms allocations $\{x_j(s, H)\}$ for all j;

(iv) laws of motion $a' = g(s, H)$, $H' = G(s, H, s')$;

1) Given $p(s, H)$, and $a'_j = g_j(s, H)$, $\{x_i\}_{i=1}^{\lambda}$ solve the consumers' problem and $\{x_j\}$ solves the firms' problem;

3) Markets clear;

4) $g(s)$ is a fixed point of $D(g)$, That is, $g \in D(g)$.

3.2 Dynamic Equilibrium

In this section we will show that there exist conditions under which workers of any sector will block the adoption of new technologies, as long as (i) the technological index in use is not far from the technological frontier; (ii) the workers have been working with the same technology for some periods; and

[9]See Maskin and Tirole [3].

(*iii*) the arrival of new technologies is not frequently . The intuition is as follows. On the one hand, the further a sector is from the frontier more the workers of this sector have to pay to block the new technology that arrives. Since their income is bounded and the cost to block is unbounded then, there is a distance d^* from the frontier after which they will not block anymore. This happens because in this case their income is smaller than the cost to block. On the other hand, if the distance from the technological frontier is less than d^* it would be better for workers to pay the cost of blocking, as long as, the probability to be hit every period with a new technology is very small. In this case, the workers avoid loose part of their income for many periods compensating the cost of blocking.

In the next proposition, $\sigma = \frac{m}{M}$ is the probability that a sector will have a new technology available next period, λ_j is the number of workers in sector j. We should stress that in equilibrium λ_j is constant. The reason is the following. If a worker changes sector he looses part of his skills, reducing his income. In this case, he would change sector only when his sector changed technology. But, in this case he will be indifferent. Therefore, in the model there will have no movement of workers across sectors and λ_j will be constant.

Now, we will introduce the assumptions that we will use to prove the propositions below.

A1: $h(\cdot,\cdot,t+1) - h(\cdot,\cdot,t) > (1-\sigma)^t\,\sigma.$

The intuition behind A1 is as follows. Suppose that we are in period T. The probability that until period $t+n$ our sector will not be hit by a new technology reduces. Therefore, the increment in our income has to compensate this reduction in the probability, making our expected income non decreasing over time.

Proposition 1 *If A1 holds then there exist a $n^* > 0$, $d^* > 1$ and $\epsilon^* > 0$ such that for $\beta \in (1-\epsilon^*, 1)$, $\sigma \in (0, \epsilon^*)$ and $\rho \in (1-\epsilon^*, 1)$*

(i) If $n > n^*$ and $d < d^*$ then a coalition will be constructed and $a_j' = a_j$.

(ii) If $d > d^*$ then no coalition will be constructed and $A_j' = a_j'$

Proof: From the utility function of a worker i working in sector j we can calculate the demand function of each good j.

$$c_j = \alpha_j \gamma^{a_j} \hat{h}_i \tag{8}$$

where $\hat{h}_i = h_i(\cdot)$ if there is no block or it is equal to $\hat{h}_i = h_i(\cdot) - \frac{G(d)}{\lambda_j}$ if there is block in sector j; $\frac{G(d)}{\lambda_j}$ is the cost per worker of blocking since $G(d)$ is the total cost and λ_j is the number of workers in sector j.

$$\sum_{t=0}^{\infty} \beta^t \frac{(c_{1t}^{\alpha_1} \cdot \ldots \cdot c_{Mt}^{\alpha_M})^\rho}{\rho} = \Phi \sum_{t=0}^{\infty} \beta^t \frac{\left(\gamma^{\alpha_1 a_1} \cdot \ldots \cdot \gamma_{Mt}^{\alpha_M a_M} \hat{h}_i\right)^\rho}{\rho} \tag{9}$$

where $\Phi = \alpha_1^{\alpha_1} \cdot \ldots \cdot \alpha_M^{\alpha_M}$.

Workers of sector j will choose n and d to maximize the last equation. Since we are looking for sufficient conditions, we will take the following steps. Suppose two strategies that are identical and without block in every period but period T. Suppose that in a period T a new technology for period $T+1$ is announced. In strategy 1 there will be a block of the new technology and in the strategy 2 there will be no block. This will be the only difference between these two strategies. We will show that the above conditions are sufficient to guarantee that the block of the new technology will increase the utility (pay off) of this strategy. We generalize and show that the block will occur for some fix number of technologies and then the newest technology will be used. That is, if $d \leq d^*$ new technologies will be blocked and for $d > d^*$ no block will occur.

Again, suppose that in period T a new technology for period $T+1$ is announced. If the workers decide to block this new technology, in the next period the amount of labor services that a worker of sector j can supply will increase to $h_i(\cdot, \cdot, n+1)$ but each worker will pay an amount $\frac{G(d)}{\lambda_j}$ in period T. In period $T+1$ another technology can be announced. If another technology is not announced then the amount of labor services that a worker of sector j can supply will increase to $h_i(\cdot, \cdot, n+2)$ and so on. Here we will show just a sufficient condition to have a block of technology.

Call U_1 and U_2 the pay offs of the strategies 1 and 2 respectively. We will show that under the above hypothesis $U_1 - U_2 > 0$. Besides, we will show that for some d and n the block will occur. Basically, $\exists\, d^* \geq 1$ such that for $d \leq d^*$, $\exists\, n^* > 1$ such that for $n \geq n^*$ and $d \leq d^*$ they will block.

If we subtract U_1 and U_2 we get

$$U_1 - U_2 = \beta^T A_0 \left[\frac{\left(\gamma^{\alpha_j a_j} \left(h(\cdot, \cdot, n) - \frac{G(1)}{\lambda_j}\right)\right)^\rho}{\rho} - \frac{(\gamma^{\alpha_j a_j} h(\cdot, \cdot, n))^\rho}{\rho} \right] +$$

$$\beta^{T+1}A_1\left[\frac{(\gamma^{\alpha_j a_j}h(\cdot,\cdot,n+1))^\rho}{\rho}-\frac{\left(\gamma^{\alpha_j(a_j+1)}h(\cdot,\cdot,0)\right)^\rho}{\rho}\right]+$$

$$\sum_{t=2}^{\infty}\beta^{T+t}A_t\left[\frac{(\gamma^{\alpha_j a_j}h(\cdot,\cdot,n+t))^\rho}{\rho}-\frac{\left(\gamma^{\alpha_j(a_j+1)}h(\cdot,\cdot,t-1)\right)^\rho}{\rho}\right](1-\sigma)^{t-1} \quad (10)$$

where the terms A_i come from Equation (9) once we isolate the expressions between brackets; $\sigma=\frac{m}{M}$ is the probability to have available a new technology in the next period and $(1-\sigma)^{t-1}$ is the probability in period T that no new technology will be available until period $T+t$, for $t\geq 2$.

As we can see from Equation (10), as $\sigma\to 1$ then U_1-U_2 reduces. That is, the incentive to block a new technology reduces as the probability to be hit by a new technology increases.

Proof of (ii): From the first term of Equation (10) and since $h(\cdot,\cdot,\cdot)$ is bounded and $G(\cdot)$ is not bounded there is a d^* such that $\forall d>d^*$ there will be no blocking.

Proof of (i): Now, let us show that under the above assumptions for $\forall d<d^*$ and $n>n^*$ there there will be a block.

Looking at the second and third expressions of Equation (10) we see that if $\alpha_j\to 0$ then for any value of γ these two expressions are positive. Therefore, $\exists\alpha_j^*$ such that for $\alpha_j>\alpha_j^*$ the second and third expressions of Equation (10) are positive for any value of γ.

We have $A_0\leq A_1\leq A_t\leq A_{t+1},\forall t\geq 2$ since technological index does not reduce. Taking limit in Equation (10) making $\rho\to 1$ and $\alpha_j\to 0$ we get

$$U_1-U_2\geq$$

$$\beta^T A_0\left\{-G(1)+\sum_{t=2}^{\infty}\beta^t\left[(h(\cdot,\cdot,n+t))-h(\cdot,\cdot,t-1)\right](1-\sigma)^{t-1}\right\} \quad (11)$$

We are looking for some properties for the difference $\left[(h(\cdot,\cdot,n+t))-h(\cdot,\cdot,t-1)\right](1-\sigma)^{t-1}$. That is, we will show that if this difference is greater than or equal to $\beta^t\left[(1-\sigma)^t-(1-\sigma)^{n+t+1}\right]$ then for $\kappa<n+1$ Equation (11) is positive. Define

$$h(\cdot,\cdot,n+t)=b-(1-\sigma)^{n+t} \quad (12)$$

Substitute Equation (12) into Equation (11) and use assumption 1 to get

$$U_1 - U_2 \geq \beta^T A_0 \left\{ -G(1) + \beta \frac{[1 - (1 - \sigma)^{n+1}]}{1 - \beta(1 - \sigma)} \right\} \tag{13}$$

Take limit in Equation (13), making $\beta \to 1$

$$U_1 - U_2 \geq \beta^T A_0 \left\{ -G(1) + \frac{[1 - (1 - \sigma)^{n+1}]}{\sigma} \right\} \tag{14}$$

Once more, take limit in the above expression, making $\sigma \to 0$ we get

$$U_1 - U_2 \geq \beta^T A_0 \left\{ -G(1) + \frac{[1 - (1 - \sigma)^{n+1}]}{\sigma} \right\} \to \beta^T A_0 \{-\kappa + n + 1\}$$

Therefore, there exists $\epsilon^* > 0$ such that for $\beta \in (1 - \epsilon^*, 1)$, $\sigma \in (0, \epsilon^*)$ and for a given κ, then there exist a n^* such that for all $n > n^*$ we have $U_1 - U_2 > 0$. This concludes the proof. ■

Given Proposition 1, the next step is to prove the following result:

Proposition 2 *If all the assumptions of Proposition 1 hold then there exists a dynamic equilibrium such that for every sector j such that $n_j > n^*$ and $d_j < d^*$ workers will block the adoption of new technologies. Otherwise there the workers will allow the adoption of the new technologies available*

Looking at Equation (9) we see that the strategy of blocking is dominant. That is, the workers of one sector, will be better off if they block the adoption of new technologies, independent of what the workers of the other sectors are doing (once the conditions stabilized in Proposition 4 are satisfied).

This result has a resemblance with the Prisoner's Dilemma. That is, looking at Equation (9), we can see that workers of one sector are better off if the workers of the other sectors do not block the adoption of new technologies. But, if the workers of all other sectors are not blocking than it is better for workers of one sector to block. In this case, we can also conjecture that there exists an other equilibrium. You do not block if workers of the other sectors do not block. If anybody deviates, them you return to your behavior given by Proposition 2. In the line of the the Folk Theorem, an equilibrium would it be that nobody blocks.

In the next proposition we show that the incentive to block reduces if the probability of arriving a new technology (σ) increases and/or the cost of blocking increases (κ). The intuition for the cost of blocking is straightforward. Higher costs implies less benefits of blocking for the same number of years working with the same technology. Therefore, the higher is the cost of blocking a new technology, the higher is the required number of years working with the same technology to make the workers choose to block. On the other hand, if σ increases the expected income of blocking decreases, reducing the incentive to block.

Proposition 3 *If all the assumptions of Proposition 1 hold then for every sector j,*
(i) $n_j^* = n(\kappa, \sigma)$ is a increasing function of κ and σ;
(ii) $d_j^* = d(\kappa)$ is a decreasing function of κ.

Proof: To proof this proposition we will make use of expression (10). As before, to make things easier I will drop the subscript j from n and d. If all the assumptions of Proposition 1 hold then we know that in equilibrium $U_1 - U_2$ is a positive constant. Call it D that is, $D = U_1 - U_2 > 0$

$$D = \beta^T A_0 \left[\frac{\left(\gamma^{\alpha_j a_j}\left(h(\cdot,\cdot,n) - \frac{G(1)}{\lambda_j}\right)\right)^\rho}{\rho} - \frac{(\gamma^{\alpha_j a_j} h(\cdot,\cdot,n))^\rho}{\rho} \right] +$$
$$\beta^{T+1} A_1 \left[\frac{(\gamma^{\alpha_j a_j} h(\cdot,\cdot,n+1))^\rho}{\rho} - \frac{\left(\gamma^{\alpha_j (a_j+1)} h(\cdot,\cdot,0)\right)^\rho}{\rho} \right] +$$
$$\sum_{t=2}^{\infty} \beta^{T+t} A_t \left[\frac{(\gamma^{\alpha_j a_j} h(\cdot,\cdot,n+t))^\rho}{\rho} - \frac{\left(\gamma^{\alpha_j (a_j+1)} h(\cdot,\cdot,t-1)\right)^\rho}{\rho} \right] (1-\sigma)^{t-1}$$

(i) The argument used here goes in the same line of the Implicit Function Theorem. Suppose that σ increases. Looking at last part of expression (10) we see that D decreases. Therefore, to compensate this reduction n has to increase. That is, since the arrival of a new technology is independent and identically distributed, if σ increases the workers will require a longer period of experience with a technology to block the adoption of new technology. That is, n_j^* is increasing in σ.

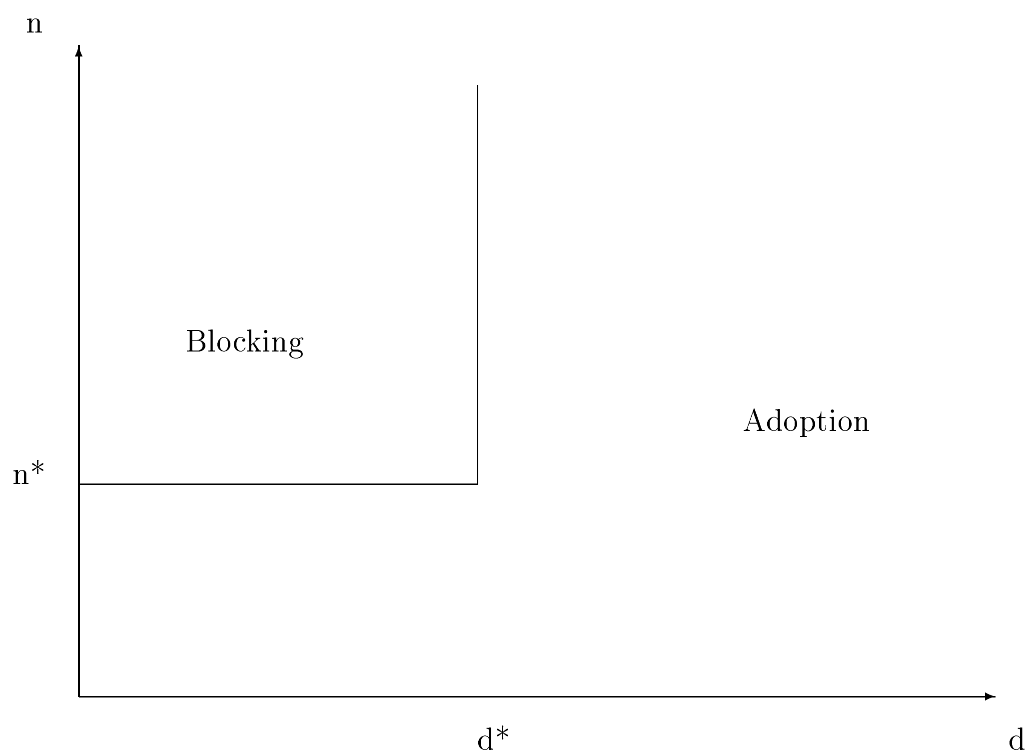
Now, let us analyze the effect of variations in κ over n^*. If κ increases, then the cost of blocking increases. that is, the function $G(\cdot)$ move up.

From the first part of the above expression, we see that n has to increase to compensate the cost of blocking.That is, n_j^* is increasing in κ.

(ii) the effect of a variation on κ over d^* it is similar to the effect of κ over n^* as we can see in the first brackets of the above expression. ■

The results of Propositions 1-3 are summarized in Graph 1.

Graph 1



The area where $n > n^*$ and $d < d^*$ there is blocking since the cost of blocking for workers is smaller than the cost of adopting. The opposite is true in the other part of the graph.

The above proposition show an important relation between the speed of technological progress (or the rate of arrival of new technologies) and their adoption. If the technological progress speed up, then the workers loose their incentive to construct coalitions and to block the adoption of the new technologies available. On the other hand, the slower is the technological progress the slower is the adoption of the new technology available. In the first case, I would say that the economy is a virtuous cycle. In the second case, I would say that the economy is in a vicious cycle.

An empirical implication of our model is that we should see less resistance to adopt new technologies among sectors where the technological progress is fast. On the other hand, the resistance to adopt new technologies should be higher among sectors where the technological progress is slow or we should see an increment in the resistance to adopt new technologies as the technological progress slow down[10].

4 Conclusions

In this paper we study the relation between the speed of technological progress or the rate of arrival of new technologies and the level of resistance to adopt them. Our main conclusion is that resistance (and adoption of new technologies) and the speed of technological progress are inversely related. That is, the faster is the technological progress the smaller is the resistance to adopt new technologies. The reason is that workers acquire skills specific to a technology. The longer a worker has been working with a technology, the higher is the capital specific skills acquired. In this case, the worker has incentive to resist to adopt the new technology, keeping his skill level, his productivity and his income.

A slow technological progress would generate this environment. Without the arrival of a new technology the worker would keep working for a long period with old one. In this case, once a newer technology arrive the worker would resist to adopt this new technology.

On the other hand, sector where the technology advances fast, we should see less resistance, more adoption and higher growth rates.

[10] We have not analyzed the effect of international competition on this behavior. We should mention that this result can be effected by the existence of international trade. See Teixeira [12], Teixeira [13] and Holmes and Schmitz [1].

References

[1] T Holmes and J Schmitz. Resistance to new technology and trade between areas. *Federal Reserve Bank of Minneapolis Quarterly Review*, 19:2–17, 1995.

[2] Per Krussel and Jose-Víctor Ríos-Rull. Vested interests in a positive theory of stagnation and growth. *Review of Economic Studies*, 63:301–29, 1996.

[3] Eric Maskin and Jean Tirole. Markov perfect equilibrium. Discussion Paper 125, Southern European Economics Discussion Series, 1994.

[4] Joel Mokyr. *The lever of riches: technological creativity and economic progress*. Oxford University Press, 1990.

[5] Joel Mokyr. Technological inertia in economic history. *Journal of Economic History*, 52:325–38, June 1992.

[6] Joel Mokyr. *Progress and inertia in technological change*, chapter 8. The University of Chicago Press, 1994.

[7] Mancur Olson. *The rise and decline of nations*. Yale University Press, 1982.

[8] S Parente and E Prescott. Barriers to technology adoption and development. *Journal of Political Economy*, 102:298–321, April 1994.

[9] S Parente and E Prescott. Monopoly rights: a barrier to riches. *American Economic Review*, 89:1216–33, 1999.

[10] Robert M. Solow. A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, LXX:65–94, 1956.

[11] Arilton Teixeira. *Effects of trade policy on technology adoption*. PhD thesis, University of Minnesota, 1999.

[12] Arilton Teixeira. Effects of trade policy on technology adoption and investment. In *Anais do Encontro Brasileiro de Econometria*, volume 1. Sociedade Brasileira de Econometria, 1999.

[13] Arilton Teixeira. Explainning over time difference in tfp across countries. *Latin American Econometric Meeting*, 2000.

[14] Robert Topel. Specific capital, mobility, and wages: wages rise with job seniority. *Journal of Political Economy*, 99:145–76, 1991.

[15] Robert Topel and Michael P. Ward. Job mobility and the careers of young men. *The Quarterly Journal of Economics*, CVII:439–80, 1992.