Special Interests and Technological Change

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Summary

We study an OLG economy where productivity growth comes from two alternative sources: process innovation and learning-by-doing. There is a trade-off between the two in so far as frequent technological updates reduce the scope for learning on existing technologies. A conflict is shown to arise between the young and the old, because the former favor innovation while the latter prefer learning. We model the interaction between overlapping generations and policy makers as a dynamic common agency problem, where competing generations invest a certain amount of resources to lobby either for the maintenance of the current technology or the adoption of a new one. By focusing on truthful Markov perfect equilibria, we characterize the political equilibrium and show its dependence on the underlying demographic, technological and preference parameters.

Keywords: Technological change, Technology option, Pressure goups, Dynamic common agency

JEL: C72, C73, D72, O38, O41

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1 Introduction

Technological creativity, that is the application of new ideas to production, has an inherently cyclical nature. This regularity is sometimes called *Cardwell's Law* (Cardwell, 1972; Mokyr, 1990): the group that plays the leading role in the advance of one period is unlikely to play a similar role in the next period.

Our aim is to investigate the origin of such a cyclical behavior. More precisely, we focus on the specific question why, when a new technology appears, the economy to which it is proposed some times adopts it while other times it fails to do so even though the new technology is freely available. This would be a trivial question to ask if economic forces were all that mattered for technological choices: if a new technique increases profits it will be adopted by individualistic profit maximizing firms, otherwise it will be discarded. From the point of view of economic history, however, as reported by Bauer (1995), such a decentralized market outcome seems to be a poor description of many technological breakthroughs. This is not to say that economic convenience is irrelevant, but rather, as argued by Mokyr (1998), that: "There usually is, at some level, a non-market institution that has to approve, license or provide some other imprimatur without which firms cannot change their production methods. The market test by itself is not always enough. In the past, it almost never was" (p.1). The reason is the very nature of technological change that leads almost inevitably to an improvement in the welfare of some and a deterioration in that of others. Thus, as envisaged by Olson (1982), the decision whether to adopt a new technology is likely to be resisted by losers through some kind of activism aimed at influencing the decision by the aforementioned institution.

Accordingly, we model a situation in which, for exogenous reasons, technology adoption is delegated to a regulatory authority. Its decisions are binding for all individuals in the economy but can be affected by interest groups. Based on historical evidence, the central authority can be thought of as a licensing system that has some agency approve new technology *before* it is brought to the market.[1] As to interest groups, along history they have ranged from labor unions to business associations, from giant corporations to environmental lobbies.[2]

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[1] As pointed out by Mokyr (1998, p.38), "almost everywhere some kind on non-marketing control and licensing system has been introduced". For instance, this role has often been played by the Crown (Heller, 1996). A more recent example is the creation of standard-setting agencies such as the International Organization for Standardization (ISO).

[2] See, for example, Lorenz (1991) on labor unions as well as Coleman and MacLeod (1986) on business associations.

To capture in a simple way the evolving clash between conservative and progressive interests, the economics of our model follows Krusell and Ríos-Rull (1996) as well as Aghion and Howitt (1998). In particular, we consider an economy that, at any point in time, is populated by two overlapping groups of individuals differing in terms of their life horizons. Productivity growth comes from two alternative sources: process innovation and learning-by-doing. At each point in time there is an incumbent vintage of an aggregate technology. Such vintage can either be still improvable or obsolete. In the former case, learning-by-doing can enhance its productivity, in the latter the scope for learning is exhausted. Also, at each point in time, there is a new vintage, which is freely available and, if adopted, becomes more productive than the old one only after some running in. This initial productivity gap is the more severe the less learning has taken place on the previous vintage. Therefore, there is a trade-off between innovation and learning-by-doing, which creates a potential conflict of interests between the long-lived ('young') and the short-lived ('old') individuals who, due to their different life horizons, tend to favor innovation and learning-by-doing respectively.

A more significant departure from the existing literature is made on the political side of the model. Krusell and Ríos-Rull (1996) as well as Aghion and Howitt (1998) assume that the intergenerational conflict is handled by democratic voting so that the interests of the larger generation prevail. While an enlightening first step, this approach is unsatisfactory for two main reasons. First, when technological change is involved, public intervention usually takes the form of regulation in areas such as product and security standards, environmental policy, restrictions on entry, and trade barriers, which are the realm of organized interest group action rather than of democratic voting (see, e.g., Viscusi, Vernon and Harrington, 2000). Second, by attributing an overwhelming role to demographic factors, democracy somehow obscures the underlying economic stances and the relevance of market considerations, which may make it possible for a sufficiently advanced technology to break through despite reactionary institutions. This is stressed, for example, by Mokyr (1990).

For these reasons, we model an alternative political mechanism, based on the action of organized interest groups, that will be shown to yield a resolution of the intergenerational conflict in which also economic factors play a relevant role. We build on the ideas of Olson (1965) who argues that what matters for the success of special interest groups are the relative surpluses that they are able to generate for their members, rather than their relative demographic sizes. His insights have been recently formalized in terms of a *common agency* set-up in which, in the wake of Bernheim and Whinston (1986), competing interest groups (*principals*) lobby an incumbent policy maker (*agent*) in order to influence her decisions (see, e.g., Grossman and Helpman, 1994; Dixit, Grossman and Helpman, 1997). In our framework, this means that competing generations invest a certain amount of resources in supporting either the maintenance of the current vintage technology or the adoption of the new one. In so doing, they expect the policy maker to implement the alternative whose support absorbs the larger amount of resources. This leads to the characterization of the mechanics of interest intermediation in each period as a menu auction game between two overlapping generations of principals and an agent who is also assumed to be short-lived (specifically, one-period-lived).

We are not aware of any study of such a game and even related results are scarce. Bergemann and Välimäki (2003) investigate a dynamic common agency game with infinitely-lived players and propose the Truthful Markov Equilibrium concept that we also adopt. Grossman and Helpman (1998) characterize the Markov Perfect Equilibrium of a common agency game of intergenerational distribution in which there are overlapping generations but only the older is exogenously assumed to act as an active principal. Moreover, while their policy space is continuous, our technology adoption choice is inherently binary. This discrete feature will be shown to give rise to endogenous lobbying activity.[3]

Under the assumption that players are perfectly informed, that regulators maximize total contributions by the pressure groups over their period in office, and that there a no credit markets, we are able to show the following results. First, the identity of the winning interest group depends on the relative surpluses of the two generations (hence, on the underlying economic parameters) and their relative abilities to implement effective collective actions. Second, due to perfect information, only the prospective winning generation implements some collective action and ends up contributing an amount of resources that is equal to the highest offer the losing group could afford (*second-price*). Third, as the relative surpluses of overlapping generations vary from period to period depending on the current technological status quo, a Cardwellian cycle involving periods of stagnation being followed by periods of technological change may arise endogenously from the competing actions of organized interest groups. Such an *economic cycle* is caused by an endogenous *political cycle* of lobbies spending. Specifically, the cycle is likely to occur in equilibrium when generations care little about the future, when new vintages are not

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[3] As all cited contributions, we abstract from the crucial issue of endogenous lobby formation, that is, how and why the relevant groups organize for collective action. As pointed out by Grossman and Helpman (2001), theorizing about coalition formation has proved very difficult even in static common agency games. Thus, in extending the static model to an overlapping generations framework, we prefer to restrain from addressing that issue.

much more productive than old ones, when the initial costs of running in a new technology are large, when positive learning spillovers from old to new vintages are strong, and when population growth is slow.

Finally, since current policymakers and interest groups do not take into account the impact of their choices on future generations and credit markets are absent, in general the political outcome is dynamically inefficient from the point of view of a social planner with infinite horizon. In particular, the equilibrium Cardwellian cycle turns out to be inefficient with respect to restless technological change whenever the introduction of new technologies entails initial costs of running in that cannot be significantly reduced by human capital accumulated while working on old technologies.

The remainder of the paper is organized as follows. Section 2 presents the mechanics of the model. After presenting the political equilibrium concept, Section 3 solves the model and analyzes its comparative statics implications. In particular, it studies the emergence of endogenous cycles in relation to the underlying parameters. Welfare analysis is performed in Section 4. Section 5 concludes.

2 The model

2.1 Economics

Consider an overlapping generations framework consisting of individuals who live for two periods only. Calendar time t is discrete and runs from 0 to infinity. At any time $t = 0, 1, .., \infty$ two generations are alive: the old O and the young Y with lifetime horizons of one and two periods respectively. Population grows at a constant rate n starting from an initial level $L_0 = (2 + n)$ consisting of masses 1 and $1 + n$ of old and young individuals respectively. Therefore, at time t $L_t = L_0(1 + n)$ individuals are alive.

Each generation is made of homogeneous individuals. At birth the lifetime preferences of the representative individual born at time t are represented by the following intertemporal utility function:

$$u^t = c_t^t + \rho c_{t+1}^t \tag{1}$$

where c_s^t is consumption at time s of an individual born at t and $\rho \in (0, 1)$ is the discount factor.

Independently from their generation, all individuals supply inelastically one unit of the sole factor of production, say labor L, which is employed to produce a unique consumption good X under constant returns to scale. At any time t per-capita output is given by:

$$x_t = \lambda A^{\alpha_{t+1}} \tag{2}$$

where x_t is per-capita output, $\lambda A^{\alpha_{t+1}}$ is labor productivity, and α_{t+1} is the vintage of the technology adopted for production at time t. The final good cannot be stored and there are no credit markets. Thus, in each period and for each generation, consumption equals disposable income.

Labor productivity improves in time due to process innovation. Progress comes in the form of new vintages of technology with each new vintage inducing an improvement of size $A \in (1, \infty)$. A new vintage becomes available only one period after the previous one has been adopted. However, the full exploitation of a new vintage technology requires learning-by-doing. In particular, we assume that learning takes one period so that $\lambda \in (0, 1)$ when the new vintage is introduced and $\lambda = 1$ after one period. Moreover, part of the learning obtained on the old vintage spills over to the new vintage: $\lambda = \underline{\lambda}$ if learning-by-doing did not occur on the old vintage, and $\lambda = \overline{\lambda} > \underline{\lambda}$ if it occurred. The idea is that learning on an old technology generates human capital that is partly useful to run the new technology.

Accordingly, when deciding whether to substitute the existing vintage with the new vintage, individuals may face a trade-off between the productivity gains of learning-by-doing and those of process innovation. In particular, for this to be the case we need to impose:

$$\underline{\lambda} A < 1 < \overline{\lambda} A \tag{3}$$

The first inequality in (3) states that, when some scope for learning still exists on an incumbent vintage, there is a short-run opportunity cost of innovating. The second inequality requires that, when the scope for learning is exhausted, there is a short-run cost in keeping the incumbent vintage.

The existence of a trade-off between innovation and learning-by-doing creates a potential intergenerational conflict. The old, who will not be there next period, may prefer the current productivity gains arising from learning on the existing vintage. On the contrary, the young, who will be alive next period, may like to trade such gains for future productivity improvements stemming from current innovation.

2.2 Politics

Innovation policy is the outcome of a process of interest intermediation by public regulators, who do not participate to production and consume out of the contributions made by interest groups to support alternative policy decisions.[4] Regulators are assumed to live for one period and have linear preferences over the consumption of good X.

Against this background, we model the mechanism of interest intermediation as a common agency game. Each generation is exogenously organized as a pressure group that has the opportunity of influencing the regulator's decision through direct payments. The specific mechanism we consider is a first-price menu-auction game *à la* Bernheim and Whinston (1986). In each period t the regulator selects an action and each lobby of the living cohorts offers a menu of contributions contingent on the action chosen. The lobbies pay their announced contributions for the allocation ultimately chosen by the regulator and this choice is made to maximize the regulator's payoff, given the menus of offers announced. A complication with respect to the original set-up by Bernheim and Whinston (1986) comes from the fact that, in choosing their contributions at time t, the current young must look ahead to period $t+1$. This is because they will still be around and their future consumption will be affected by both the policy adopted and the contributions paid at that time.

Specifically, we extend the common agency model of Bernheim and Whinston (1986) to a dynamic setting. In each period there are three players: an agent (the incumbent *regulator*) and two principals (the *lobbies* of the current young and old). Players are short-lived. The lobby of the current young live two periods while the regulator as well as the lobby of the current old live for one period only. The lobby of the current young becomes next period old lobby. Therefore, we have a dynamic common agency set-up with one-period-lived agents and overlapping generations of principals.[5]

Each period t starts with an incumbent vintage technology α_t inherited from period $t-1$ and a generation (the old) survived from the same period. The timing of events is the following. First, at the beginning of period t the young generation is born and a new regulator is appointed to decide on the vintage technology α_{t+1} to be used for production in that period. She can innovate (hence, $\alpha_{t+1} = \alpha_t + 1$) or not (hence, $\alpha_{t+1} = \alpha_t$). Second, the young and old generations announce their contributions to the regulator contingent on her technological choice. Third, the regulator makes her decision. Fourth, production takes place according to the chosen vintage, consumption takes place and the announced contributions are paid. Fourth, the old generation dies and the regulator expires. As to

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[4] Differently from the common agency in Grossman and Helpman (1994) but closer in spirit to the menu auction in Bernheim and Whinston (1986), the regulator does not weigh public utility per se. See, also, Footnote 11.

[5] Short-lived agents and overlapping generations of principals differentiate our extension from the dynamic common agency game with infinitely lived players studied by Bergemann and Välimäki (1998b).

period 0, we assume an initial vintage technology $\alpha_0 = 0$ that has still to be learned: $x_0 = 1$ if the first regulator does not innovate and selects $\alpha_1 = \alpha_0 = 0$; $x_0 = \underline{\lambda} A$ if she innovates and selects $\alpha_1 = \alpha_0 + 1 = 1$.

Formally, the lobbies are indexed by $i \in \mathcal{I} = \{Y, O\}$. In each period the regulator can select an action (*policy*) $p_t \in \mathcal{P} \in \{I, N\}$ where I and N stand respectively for 'innovation' and 'no innovation'. Each lobby offers a reward scheme (*contribution*) $(r_i(z_t, I), r_i(z_t, N)) \in \mathbb{R}_+^2$ which depends on the history z_t and the action p_t chosen by the regulator in period t. Let $r_t \equiv (r_O(z_t, I), r_O(z_t, N), r_Y(z_t, I), r_Y(z_t, N))$ be the list of lobbies' contributions in period t, $\mathrm{p} \equiv (p_0, ..., p_t, ...)$ be the list of policies chosen in each period and $\mathrm{r} \equiv (r_0, ..., r_t, ...)$ be the list of the lists of lobbies' contributions in each period.

The history of the game in period t is $z_t \equiv (t, \alpha_1, ...\alpha_t, r_0, ..., r_{t-1}, p_0, ..., p_{t-1})$ for $t \geq 1$ where $\alpha_t = \sum_{s=1}^{t} F_s$ with $F_s = 1$ for $p_{s-1} = I$ and $F_s = 0$ for $p_{s-1} = N$. For the initial period, history is $z_0 \equiv (0, 0, \varnothing, \varnothing)$. The set of all possible t period histories is denoted by Z_t. The future in period t is the sequence of future actions and states $(t+1, ..., \alpha_{t+1}, ..., r^t, p^t) = (t+1, ..., \alpha_{t+1}, ..., r_{t+1}, ..., p_{t+1}, ...)$. We denote by $Z(z_t)$ the set of all possible histories z_{t+1} which are accessible from history z_t, and analogously $Z(z_t, p_t)$ the set of all possible histories z_{t+1} generated by z_t and p_t.

Both actions I and N can be implemented by the regulator with no inherent personal benefit. On the contrary, they are not indifferent to the lobbies. The instantaneous flow benefit of regulator's action p_t to lobby i is $v_i(z_t, p_t)$. A reward strategy for lobby i is a sequence of mappings $r_i : Z_t \times \mathcal{P} \rightarrow \mathbb{R}_+^2$ which assigns to every possible action $p_t \in \mathcal{P}$ of the regulator a nonnegative reward contingent on the past history of the game. A strategy for the regulator is a sequence of actions $p : Z_t \times \mathbb{R}_+^2 \rightarrow \mathcal{P}$ which depends on the aggregate reward and history in period t.

With history z_t the expected payoff for the regulator of an action p_t is the total reward raised which consists of the current reward if in period t the action was p_t and history was z_t:

$$m(z_t, p_t) \equiv r_O(z_t, p_t) + r_Y(z_t, p_t)$$

The expected payoff for the old lobby is the current flow benefit net of the regulator's reward:

$$h_O(z_t, p_t) \equiv v_O(z_t, p_t) - r_O(z_t, p_t)$$

while the expected payoff of the young lobby also includes the expected next-period flow benefit $V(z_t, p_t)$ if in period t the action was p_t and history was z_t:

$$h_Y(z_t, p_t) \equiv v_Y(z_t, p_t) - r_Y(z_t, p_t) + \rho V(z_t, p_t)$$

In principle, this game has a potentially large set of Nash equilibria. To limit their number, we follow Bergemann and Välimäki (2003) and restrict our attention to *truthful Markov Perfect Equilibria*, that is, Nash equilibria that are both 'truthful', in that the corresponding contributions correctly reflect relative preferences for the various alternatives (as in Bernheim and Whinston, 1986) and 'Markov perfect' in that, in a stationary environment, expected policies are not only self-fulfilling but also depend only on the values of the state variable expected at that time (as in Maskin and Tirole, 2001). In so doing, we disregard the purely strategic effects of changes in states that are not relevant to payoffs.

Specifically, a strategy is said to be a *Markov strategy* if in any period t it depends only on the calendar time t, on the initial vintage α_t and on the previous period regulator's action p_{t-1}. Consequently, a Markov strategy for lobby i in period t assigns to every possible action $p_t \in \mathcal{P}$ of the regulator a non-negative reward contingent on t, α_t and p_{t-1}. Notice that, given the economics of the model, the previous period regulator's action is a 'natural' state variable of the economy as current payoffs (and therefore current actions) depend crucially on whether in the previous period there was a technological change or not. Calendar time and vintage are relevant insofar as they determine the size of the population as well as the level of income of the economy and, therefore, they affect the amount of contributions.

Definition 1 ***(Truthful Markov Strategy)*** *A Markov strategy $r_i(t, \alpha_t, p_{t-1}, p_t)$ for lobby i is said to be* truthful *with respect to $(t, \alpha_t, p_{t-1}, \widetilde{p})$ if and only if for all $p_t \in \mathcal{P}$, either*

(i) $h_i(t, \alpha_t, p_{t-1}, p_t) = h_i(t, \alpha_t, p_{t-1}, \widetilde{p})$

or

(ii) $h_i(t, \alpha_t, p_{t-1}, p_t) < h_i(\widetilde{p}, p_{t-1}, t, \alpha_t)$, and $r_i(t, \alpha_t, p_{t-1}, p_t) = 0$.

In words, a lobby's reward strategy that is truthful with respect to a certain action assigns zero reward to any other action that yields a lower expected payoff to the lobby. That is, a truthful reward strategy always reflects the relative values for the lobby of any two actions unless the implied reward were negative, in which case, due to the nonnegativity constraint, the actual reward is set to zero.

Accordingly:

Definition 2 ***(Truthful Markov Perfect Equilibrium)*** *The Markov strategies $r^*_O(t, \alpha_t, p_{t-1}, p_t)$,*

$r_Y^*(t, \alpha_t, p_{t-1}, p_t)$ *and* $p^*(t, \alpha_t, p_{t-1}, r(\cdot))$ *form a* Markov Perfect Equilibrium *(MPE) in truthful strategies if and only if:*

(i) for all t*,* α_t, p_{t-1} *and all* $r(\cdot)$*,* $p^*(t, \alpha_t, p_{t-1}, r(\cdot))$ *is a solution to*

$$\max_{p_t \in \mathcal{P}} \{m(t, \alpha_t, p_{t-1}, p_t)\}$$

(ii) for all t*,* α_t, p_{t-1} *there is no other reward function* $\widehat{r}_O(t, \alpha_t, p_{t-1}, p_t)$ *such that*

$$h_O(t, \alpha_t, p_{t-1}, \widehat{p}_t) > h_O(t, \alpha_t, p_{t-1}, p_t^*)$$

where $p^* = p^*(r_O^*(\cdot), r_Y^*(\cdot))$ *and* $\widehat{p} = \widehat{p}(\widehat{r}_O(\cdot), r_Y^*(\cdot))$ *are best response actions to* $(r_O^*(\cdot), r_Y^*(\cdot))$ *and* $(\widehat{r}_O(\cdot), r_Y^*(\cdot))$ *respectively.*

(iii) for all t*,* α_t, p_{t-1} *there is no other reward function* $\overline{r}_Y(t, \alpha_t, p_{t-1}, p_t)$ *such that*

$$h_Y(t, \alpha_t, p_{t-1}, \overline{p}_t) > h_Y(t, \alpha_t, p_{t-1}, p_t^*)$$

where $p^* = p^*(r_O^*(\cdot), r_Y^*(\cdot))$ *and* $\overline{p} = \overline{p}(r_O^*(\cdot), \overline{r}_Y(\cdot))$ *are best response actions to* $(r_O^*(\cdot), r_Y^*(\cdot))$ *and* $(r_O^*(\cdot), \overline{r}_Y(\cdot))$ *respectively.*

(iv) $r_O^*(\cdot)$ *and* $r_Y^*(\cdot)$ *are truthful strategies with respect to* $p^*(\cdot)$*.*

3 The political equilibrium

Since the rate of population growth is constant and the technological gain due to innovation is also constant (and equal to A) what is really crucial for the characterization of the equilibrium of the game at any point in time is the previous period action of the regulator, p_{t-1}. In fact, information on p_{t-1} is sufficient to know which lobby is going to win the auction in the current period t and consequently whether there will be innovation or not.

More specifically, we can show that contributions depend on calendar time t but regulators' equilibrium decisions are a Markov process for an appropriate state variable, that is, the previous period regulatory decision. For the formal statement, we need to define two threshold levels of λ, namely:

$$\lambda_1 \equiv \frac{1 + (1+n)(1+\rho\overline{\lambda}A)}{A[1 + (1+n)(1+\rho A)]} \tag{4}$$

$$\lambda_2 \equiv \frac{1}{A(2+n)} \tag{5}$$

Then, the following result applies.

Proposition 1 ***Restless technological upgrading***

Given vintage α_t *and calendar time* t, *the strategies*

$(r_O^*, r_Y^*, p^*) = (0, (1-\underline{\lambda}A)\, A^{\alpha_t}(1+n)^t, I)$ when $p_{t-1} = I$ *or* $t = 0$

$(r_O^*, r_Y^*, p^*) = (0, 0, I)$ when $p_{t-1} = N$

form the only MPE in truthful strategies if and only if

$$\max[\lambda_1, \lambda_2] < \underline{\lambda} < \overline{\lambda} < 1 \tag{6}$$

Proof. *See Appendix.* ■

When condition (6) is satisfied, restless technological updating sustained by the organized collective action of the young takes place at every point in time and learning-by-doing never happens. To understand when this is the case, we have to study the comparative statics of λ_1 and λ_2: whatever decreases the value of the maximum among λ_1 and λ_2 also enlarges the set of values $\underline{\lambda}$ supporting restless technological updating.

Some parameters relate to the static common agency models with lobbying, as first explored in Grossman and Helpman (1994). Among these are the technological parameters, which mainly concern surplus issues. Restless innovation is less likely to occur when the relative benefit of the new vintage is weaker. In particular, ongoing technological upgrading is less likely to emerge when the productivity gains implied by the new vintage are smaller (smaller A), when the initial costs of running in are larger (smaller $\underline{\lambda}$), and when the positive spillover from learning on the old vintage to running in the new vintage is stronger (larger $\overline{\lambda}$). In all three cases the willingness of the young to pay for technological upgrade is reduced.

Other parameters are inherently dynamic. These are the rates of time preference and population growth. As it is intuitive, when the intertemporal discount factor ρ decreases (increases), restless innovation is less (more) likely to occur. This is due to the fact that, as ρ falls, the young care less about the future and are less likely to sacrifice current consumption in order to adopt the new vintage technology. Smaller n makes innovation less likely. This happens because the relative sizes of generations determine the intergenerational distribution of output. In particular, as n is reduced, a smaller share of output goes to the young, thus decreasing their relative ability to pay. Thus, as in 'democratic' models *à la* Krusell and Ríos-Rull (1996), demography plays a role in our context too.

When (6) is violated a Cardwellian cycle arises. A period of technological upgrade is followed by a period of stagnation and viceversa. Growth alternatively relies on innovation and learning-by-doing. This happens in three alternative scenarios. For the formal statement, we need to define a third threshold level of λ, namely:

$$\lambda_3 \equiv \frac{1+\rho\overline{\lambda}A}{A(1+\rho A)} \tag{7}$$

Then, we can write:

Proposition 2 ***Cardwellian cycle***

Given vintage α_t and calendar time t, the strategies

$(r_O^*, r_Y^*, p^*) = (\underline{\lambda}(1+n)^{t+1}A^{\alpha_t+1}, 0, N)$ when $p_{t-1} = I$ *or* $t = 0$

$(r_O^*, r_Y^*, p^*) = (0, 0, I)$ when $p_{t-1} = N$

form the only MPE in truthful strategies if and only if

$$\lambda_1 < \underline{\lambda} < \lambda_2 \tag{8}$$

The strategies

$(r_O^*, r_Y^*, p^*) = ([\underline{\lambda}A - 1 + \rho A(\underline{\lambda}A - \overline{\lambda})]A^{\alpha_t}(1+n)^{t+1}, 0, N)$ when $p_{t-1} = I$ *or* $t = 0$

$(r_O^*, r_Y^*, p^*) = (0, 0, I)$ when $p_{t-1} = N$

form the only MPE in truthful strategies if and only if:

$$\lambda_3 < \underline{\lambda} < \lambda_1 \tag{9}$$

The strategies

$(r_O^*, r_Y^*, p^*) = (0, 0, N)$ when $p_{t-1} = I$ *or* $t = 0$

$(r_O^*, r_Y^*, p^*) = (0, 0, I)$ when $p_{t-1} = N$

form the only MPE in truthful strategies if and only if:

$$0 < \underline{\lambda} < \lambda_3 \tag{10}$$

Proof. See Appendix. ■

When (8) holds, the Cardwellian cycle stems from the liquidity constraint of the young due to the absence of credit markets. As under (6), the young's relative surplus from restless innovation is larger than the old's relative surplus from the cycle. However, now the young's current income is not enough to outbid the old. Differently, when condition (9) is satisfied, the cycle arises because the relative surplus of the old dominates the relative surplus of the young. In both cases, however, technological change is accompanied by an endogenous cycle of lobbies spending.[6] Finally, under (10), there is no intergenerational conflict and technological change takes place every second period.

In terms of comparative statics, condition (8) is more likely to hold than condition (9), and this is more likely to hold than condition (10), the more generations care about the future, the higher the productivity advantage of new vintages with respect to old ones, the smaller the initial costs of running in a new technology, the weaker the learning spillovers from old to new vintages, and the faster population growth.

Moreover, notice that $\lambda_1 > \lambda_2$ if and only if

$$\overline{\lambda} > \frac{1}{2+n} - \frac{1}{\rho A} \tag{11}$$

in which case the liquidity constraint of the young is not binding so that (8) is never met. Condition (11) holds when population growth is fast (large n), because in that case a large fraction of output goes to the young. It also holds when the young care little about the future (small ρ) and the productivity gain from innovation is tiny (small A), because in that case the contribution of future production to their discounted surplus is small, which implies little need of borrowing.

4 Welfare analysis

It is worthwhile noticing that, as long as the current young are not liquidity constrained (i.e. (11) holds), since strategies are truthful the MPE entails the step-wise maximization of lobbies aggregate welfare.[7] However, even in this case, the MPE will be generally inefficient from a dynamic point of view because incumbent regulators and living generations do not take into account the effects of current technological choices on future generations' welfare. In other words, as shown by Bergemann and Välimäki (2003), dynamic efficiency

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[6] It is sometimes argued that the main function of a firm is to provide a way around the short planning horizons of individuals. Accordingly, if the old could sell the firm to the young, it would be in the interest of the former to innovate when this is good for the latter. This is not the case here. Indeed, to convince the old to innovate, the young would have to make the old indifferent between innovating or not. This would imply a price of the firm that is equivalent to the second price of the menu auction. Thus, for innovation to take place, the young would have to pay the old exactly what they pay the regulator for the same outcome: technological choices are unaffected.

[7] The MPE is also Pareto efficient. It does not exhaust, however, the set of Pareto efficient sequences as these include all sequences that do not feature $(p_{t-1}, p_t) = (N, N)$ at any t: since learning to use a new vintage technology takes one period only and, once acquired, such learning spills over to the next vintage, no lobby would benefit from resisting innovation at t when no innovation has taken place at $t-1$.

of dynamic common agency games requires infinite planning horizons.[8]

More specifically, we can rank in welfare terms the two alternative technological trajectories associated with restless technological updating and the Cardwellian cycle respectively. In so doing, we consider the point of view of an infinite-horizon benevolent planner who compares the corresponding discounted sums of aggregate output from time 0 to infinity. With restless upgrading, the discounted sum of future incomes is:

$$E_{II} \equiv L_0 \underline{\lambda} A \sum_{t=0}^{\infty} [\rho(1+n)]^t A^t \tag{12}$$

while along the Cardwellian cycle it is:

$$E_{NI} \equiv L_0 [1 + (1+n)\rho \overline{\lambda} A] \sum_{t=0}^{\infty} \{[\rho(1+n)]^2 A\}^t \tag{13}$$

where $L_0 = 2 + n$ and $p_0 = N$.

Assuming convergence of the two series in (12) and (13),[9] we get:

$$E_{II} = \frac{L_0 \underline{\lambda} A}{1 - (1+n)\rho A}$$

and

$$E_{NI} = \frac{L_0 [1 + (1+n)\rho \overline{\lambda} A]}{1 - [(1+n)\rho]^2 A}$$

Simple inspection reveals the intuitive result according to which restless upgrading tends to be superior to the cycle when the short run drop in productivity due to the adoption of a new vintage is small ($\underline{\lambda}$ large) and the learning spillover from the old to the new vintage is unimportant ($\overline{\lambda}$ small). More precisely, E_{II} is larger than E_{NI} whenever $\underline{\lambda}$ is larger than:

$$\lambda_o \equiv \frac{[1 + (1+n)\rho \overline{\lambda} A][1 - (1+n)\rho A]}{A[1 - (1+n)^2 \rho^2 A]} \tag{14}$$

This expression defines the threshold value of $\underline{\lambda}$ above which the planner would deliver restless technological upgrading.[10] It is interesting to compare λ_o with the threshold value

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[8] See the Appendix for a discussion of the case of an infinitely-lived regulator facing overlapping generations of lobbies.

[9] This requires assuming $\rho(1+n)A < 1$ and $[\rho(1+n)]^2 A < 1$.

[10] Indeed, it can be shown that the surplus maximizing sequence of innovations is either restless innovation or the Cardwellian cycle depending on whether $\underline{\lambda}$ is larger or smaller than λ_o respectively.

λ_1 above which restless innovation is the decentralized outcome when the current young are not liquidity constraint. However, since, due to the many parameters and restrictions, a general comparison turns out to be unwieldy, we prefer to restrict our attention to a specific though suggestive case. In particular, assume that $\overline{\lambda}$ is 1, that is the spillover from old to new vintages is at its maximum. In that case, it is easy to show that λ_1 is larger than λ_o so that, when $\underline{\lambda}$ falls in between those two values, decentralization yields a Cardwellian cycle while the planner would rather have ongoing innovation. This is due to the fact that, when the spillover is strong, in the period after a new vintage has been introduced the young may want to postpone its upgrade in order to draw from the existing technology some experience that will lower the initial costs of running in the next vintage. In particular, we have:

$$|\lambda_1 - \lambda_o|_{\overline{\lambda}=1} = \frac{(1+n)^2\rho^2(A-1)}{[1-(1+n)^2\rho^2 A]} \tag{15}$$

which shows that the range of values of $\underline{\lambda}$ for which the Cardwellian cycle is inefficient expands as ρ, n, and A grow.

Though specific, these results single out the source of inefficiency, namely the shorter planning horizon of the individuals with respect to the planner. When deciding in a decentralized fashion, existing individuals do not take into account the benefit of technological upgrading for the future generations' productivity. This benefit increases with the size of the technological step A and its importance for the planner increases with the economy discount factor ρ and with population growth n.

More precisely, inefficiency stems from the lobbies' rather than the regulator's shortsightedness. To see this, consider the point of view of an infinitely lived regulator who has to choose between restless technological upgrading and the Cardwellian cycle. For simplicity, assume that $\overline{\lambda} = 1$ and liquidity constraints do not bind. Being infinitely lived, the regulator takes into account the bids of all current and future generations. Therefore, for her to favor perpetual innovation over Cardwellian cycle it must be the case that her valuation of the *joint* highest bids of all young generations is larger than her valuation of the *joint* highest bids of all old generations. Straightforward calculations show that:

$$\lambda_o < \lambda_1 = \lambda_r = 1/A \text{ when } \overline{\lambda} = 1 \tag{16}$$

where λ_r is the threshold value for $\underline{\lambda}$ above which the regulator prefers restless innovation to cycle. Accordingly, the infinitely lived regulator behaves as the regulator who lives for one period. This is due to the nature of the menu auction, in which the auctioneer is a passive executor of the policy supported by the winning bid. Thus, it is the short planning horizon of the lobbies that generates inefficient outcomes.[11]

5 Conclusion

This paper has constructed a model where the interaction between organized special interests and policy makers generates political equilibria that involve either restless innovation or alternating periods of technological change and stagnation (*Cardwellian cycle*). With respect to existing 'democratic' models *à la* Krusell and Ríos-Rull (1996), the prevailing equilibrium has been shown to depend not only on the demographic structure of the population but also on technological and preference parameters. In particular, cycles arise in equilibrium when special interests and policy makers put little weight on future consumption and when the introduction of new vintage technologies is hampered by initial learning costs that are reduced if some experience has been gained on previous vintages. In any case, technological change is accompanied by endogenous political cycles of lobbies' spending and, since current decisions do not take into account the well-being of future generations, its pattern will be generally inefficient from a dynamic point of view. The more so the larger the short-run learning costs of innovation with respect to its long-run productivity gains.

The model can be used to link international income differences to the national propensities to adopt new technologies (see, e.g., Prescott, 1998). When facing similar technological opportunities (same A), better performing countries should be characterized by more patience (larger ρ), more abundant and more flexible human capital (larger λ's), more efficient credit markets (softer liquidity constraints on project with delayed payoffs), and younger demographic composition (larger n). Another qualification provides additional insights. As pointed out by Olson (1965), it is not members' relative numerosity per se that drive a lobbies' success but rather their relative efficacies in the process of interest intermediation. Under this respect, we can conclude that better performing countries should be those who are able to grant fairer political access to all interests.

From a technical point of view, the main contribution of the paper is the analysis of common agency in a dynamic setting with overlapping generations of principals. Its main limitation is its abstraction from the issue of how and why interest groups organize for

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[11] The results would differ if the regulator cared not only about contributions but also about public utility per se (see, e.g. Grossman and Helpman, 1994). In particular, as long as the objective of the regulator attached some weight to future aggregate welfare, the inefficiency of her decisions would be mitigated.

collective action. Indeed, as argued by Olson (1965), some interests are more diffuse in the society than others and thus their organization faces more severe free riding problems. This is because those who share a lobby's objective can benefit from its activism even without supporting its contributions. The relevance of this problem grows with the number of people sharing the common objective, because opportunistic behavior is more difficult to control within large groups. Specifically, in our setting population growth implies that the young exceed the old so that their collective action would be more difficult to organize. By reducing the relative effectiveness of young interests, this would further increase the inefficiency of the lobbying outcome and reinforce suboptimal cycles against restless technological progress.

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APPENDIX

Lemma 1 *In a truthful MPE* $p_{t-1} = N$ *it never follows* $p_t = N$.

Proof. Whenever in the previous period the regulator did not innovate, that is $p_{t-1} = N$, (3) implies that in the current period both groups benefit from innovation. ■

Thus, in equilibrium, whenever $p_{t-1} = N$, it must be that $p_t = I$.

Proof of Proposition 1

Proof. The game is a first-price menu auction where the winner pays the highest bid that makes the loser indifferent between winning and losing (see Bernheim and Whinston, 1986). Accordingly, we need to find the conditions under which, given $p_{t-1} = I$, the regulator, notwithstanding the opposition by the old, implements the policy that is sponsored by the young, namely $p_t = I$. This happens when the regulator prefers $(p_{t-1}, p_t) = (I, I)$ to $(p_{t-1}, p_t) = (I, N)$, which is the case if and only if at time t the highest bid the current young are *willing and able* to pay is larger than the highest offer the current old are willing to make. The liquidity constraint is relevant only for the young, because, differently from the old, their current incomes may not be enough to signal their life-long interests to the one-period regulator.

Consider what would be true were the current young able to pay any desired contribution. When deciding at time t, the regulator takes into account the bids of those who are young at time t. Therefore, for her to favor $(p_{t-1}, p_t) = (I, I)$ over $(p_{t-1}, p_t) = (I, N)$ it must be that her valuation of the highest bid of the current young $[\underline{\lambda} A^{\alpha_t+1} + \rho \underline{\lambda} A^{\alpha_t+2} - (A^{\alpha_t} + \rho \overline{\lambda} A^{\alpha_t+1})](1+n)^{t+1}$ is larger than her valuation of the highest bid of the current old generation $(A^{\alpha_t} - \underline{\lambda} A^{\alpha_t+1})(1+n)^t$. Simple manipulations show that this happens whenever $\underline{\lambda} > \lambda_1$, in which case the young generation ends up contributing the highest bid that the old would be willing to pay $(A^{\alpha_t} - \underline{\lambda} A^{\alpha_t+1})(1+n)^t$.

Consider now what the current young are indeed able to pay. In the absence of capital markets, they have to cover their current bids in favor of innovation by current incomes. Therefore, they will be able to pay what is necessary to outbid the old if and only if $\underline{\lambda} A^{\alpha_t+1}(1+n)^{t+1}$ is larger than $(A^{\alpha_t} - \underline{\lambda} A^{\alpha_t+1})(1+n)^t$. Straightforward manipulations reveal that this is true insofar as $\underline{\lambda} > \lambda_2$.

So, whenever $\underline{\lambda} > \max[\lambda_1, \lambda_2]$, the current young are *willing and able* to convince the regulator to implement $(p_{t-1}, p_t) = (I, I)$ by offering the contribution $r_Y^* = (1+n)^t (A^{\alpha_t} - \underline{\lambda} A^{\alpha_t+1})$.

Finally, when $p_{t-1} = N$, both lobbies benefit from innovation. In this case, the only truthful Markov perfect equilibrium is for both lobbies not to contribute and for the regulator to innovate.

As to the initial period $t = 0$, the assumption of an initial vintage technology $\alpha_0 = 0$ that has still to be learned imply that period 0 is analogous to any period t such that $p_{t-1} = I$.

■

Proof of Proposition 2

Proof. Whenever $\lambda_1 < \underline{\lambda} < \lambda_2$, the current young are *willing but unable* to convince the regulator who ends up delivering $(p_{t-1}, p_t) = (I, N)$ after accepting a contribution by the old equal to the maximum that the current young can afford, namely $r_O^* = \underline{\lambda} A^{\alpha_t+1}(1+n)^{t+1}$.

Irrespective of liquidity constraints, whenever $\underline{\lambda} < \lambda_1$ the regulator's valuation of the bid of the current young generation is smaller than the value of the highest bid of the current old generation. In this case, she implements the policy sponsored by the old who contribute the highest bid of the young $r_O^* = [\underline{\lambda} A^{\alpha_t+1} + \rho \underline{\lambda} A^{\alpha_t+2} - (A^{\alpha_t} + \rho \overline{\lambda} A^{\alpha_t+1})](1+n)^{t+1}$.

Moreover, also the young support $(p_{t-1}, p_t) = (I, N)$ against $(p_{t-1}, p_t) = (I, I)$ whenever the latter makes them worse off than the former. This happens insofar as $[\underline{\lambda} A^{\alpha_t+1} + \rho \underline{\lambda} A^{\alpha_t+2} - (A^{\alpha_t} + \rho \overline{\lambda} A^{\alpha_t+1})] < 0$, that is, $\underline{\lambda} < \lambda_3$. In this case, the only Nash equilibrium is for the lobbies not to contribute and for the regulator not to innovate.

■

The infinitely lived regulator

In the main text we have investigated the inefficiency of the choices made by one-period-lived regulators. Here we show that the inefficiency is not removed but only mitigated by considering the case of an infinitely-lived regulator. The reason is the short planning horizon of lobbies.

Consider the point of view of an infinite-horizon regulator who has to choose between restless technological upgrading and the Cardwellian cycle. In so doing, she compares the corresponding discounted sums of contributions from time 0 to infinity. For simplicity, we abstract from liquidity constraints.

Since she is infinitely lived, the regulator takes into account the bids of all current and future generations. Therefore, for her to favor restless upgrading over the cycle, it must be that her valuation W_{II} of the *joint* highest bids of all young generations is larger than her valuation W_{NI} of the *joint* highest bids of all old generations. As to the former valuation, we have:

$$W_{II} = [\underline{\lambda} A + \rho \underline{\lambda} A^2 - (1 + \rho \overline{\lambda} A)](1+n) \sum_{t=0}^{\infty} [\delta(1+n)A]^t$$

As to the latter valuation, we have instead:

$$W_{NI} = (1 - \underline{\lambda} A) \sum_{t=0}^{\infty} [\delta^2 (1+n)^2 A]^t$$

The regulator favors $(p_{t-1}, p_t) = (I, I)$ over $(p_{t-1}, p_t) = (I, N)$ if and only if $W_{II} > W_{NI}$. Assuming the two series converge (i.e., $\delta(1+n)A < 1$ and $\delta^2(1+n)^2 A < 1$ respectively), then she will opt for restless technological upgrading if and only if $\underline{\lambda}$ is larger than:

$$\lambda_1' \equiv \frac{[1 - \delta(1+n)A] + (1 + \rho\overline{\lambda}A)(1+n)[1 - \delta^2(1+n)^2 A]}{A\{(1+\rho A)(1+n)[1 - \delta^2(1+n)^2 A] + [1 - \delta(1+n)A]\}}$$

This can be compared with the planner's threshold (14) and the threshold of the one-period-lived regulator (4) after setting $\delta = \rho$ to abstract from the implications of an infinitely-lived regulator's idiosyncratic time preference. Such comparisons yield:

$$\lambda_o < \lambda_1' \leq \lambda_1$$

with equality in the special case of $\overline{\lambda} = 1$. Being less conservative, the infinitely lived regulator makes more efficient decisions than the one-period lived one (unless $\overline{\lambda} = 1$). Nonetheless, she does not reach full efficiency because the planning horizon of the lobbies is still too short.

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