Essays on Economic Growth and Political Economy

by

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PREFACE

The common element to the three chapters in this dissertation is the interaction between the political and economic spheres. The first two chapters are closely related in subject matter and address the incentives that political elites face when choosing policies that affect economic growth. The final chapter investigates the determinants of local voting equipment in light of the controversy surrounding the 2000 Presidential election in the United States.

The second chapter, *Do Governments Suppress Growth?*, was written with Azam Chaudhry, a fellow graduate student in the Department of Economics at Brown. The third chapter, *Why Chads?*, was written with Enrico Spolaore, assistant professor in the Department of Economics at Brown.

I would like to thank my advisors, Peter Howitt, Oded Galor, and Enrico Spolaore. Their insightful and critical comments helped me to question the assumptions and conclusions of the papers and in the end produce better research. In particular, I appreciate their willingness to take the time to meet with me regularly and to read my drafts in great detail. I would also like to thank David Weil for his comments on my work and his general advice and help with completing my graduate studies here at Brown. My fellow graduate students have been a source of encouragement and helpful criticism. The Macro lunches with both graduate students and faculty were the source of some of the best suggestions and comments that I received. Most of all, I would like to express my gratitude to my wife, Rebecca. Her support and patience through the seemingly endless years of schooling made all of this possible.

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Introduction

It has been argued, beginning with Hume and perhaps most strongly by Jones in *The European Miracle*, that the political fragmentation of Europe was an important factor in the economic rise of the West. In contrast, the political unity and relative isolation from other major states of pre-modern China has been viewed as an impediment to China's economic progress, in spite of its relatively advanced technology. In the words of Diamond (1997), "the real problem in understanding China's loss of political and technological preeminence to Europe is to understand China's chronic unity and Europe's chronic disunity". Why would unity or disunity matter? Because the political threat of competition from neighboring countries can reduce the incentives that political elites may have to block innovation and change. In the case of China, "it lacked the competition or threat of invasion that was critical to western Europe's development" (Parente and Prescott 2000). As a result "China's connectedness eventually became a disadvantage because a decision by one despot could and repeatedly did halt innovation. In contrast, Europe's geographic balkanization resulted in dozens or hundreds of independent, competing statelets and centers of innovation. If one state did not pursue some particular innovation, another did, forcing neighboring states to do likewise or else be conquered or left behind economically" (Diamond 1997).

China's failure to industrialize, then, was caused in part by being too successful politically, in terms of unification. On the other hand, "Europe's great good fortune lay in the fall of Rome and the weakness and division that ensued" (Landes 1998). How can we incorporate this idea of competition between countries into a model of economic growth? First, we need some reason why a country in isolation would not choose to innovate and grow as much as possible. We believe that the most reasonable explanation is that the stability of a government may be threatened by innovation and economic change. Motivation for this is provided below.

The essence of the model presented in this paper is nicely summarized by North (1981): "In short, the process of growth is inherently destabilizing to a state. ... If, however, growth is destabilizing, so is no growth, when a political-economic unit exists in a world of competing political-economic units". We are unaware of any other formal model that combines 'political losers' from innovation with 'political competition' between countries.

Does this paper help us understand the history of economic growth across the world? We argue that it does. First, as discussed below, political losers from innovation are an important part of the reason why some countries adopt policies that are bad for growth. Second, the most plausible reason why governments whose stability may be threatened by innovation would nevertheless, at some point in time, stop blocking innovation is that they are threatened by competition from countries that are innovating. The contrasting cases of China and Europe were discussed above. History provides many other examples of political competition between countries motivating economic change. Why did Peter the Great bring in foreign workers and engineers into Russia if not in an attempt to keep up with the West? Without the threat of the innovating West, it seems unlikely that Russia would have promoted innovation on its own.

Consider the case of Japan in the 19th century. It is reasonable to suppose that the political elites felt threatened by innovation because they more or less sealed off the country from the rest of the world. Only when U.S. warships appeared on the coast did the political elites decide to encourage, rather than block innovation. It was the direct threat of future conflict with innovating countries that motivated Japan to promote economic change.

Consider also the case of the fall of the Soviet empire. Since WWII the Soviet Union and NATO were engaged in the Cold War. Failure to keep up technologically and economically with your rival increased the likelihood of losing any potential conflict. Despite early predictions of "burying capitalism", it became increasingly clear to Soviet leaders that the Communist block was falling further and further behind the West. The threat of future conflict with an innovating West eventually led to attempts to change the Soviet system. As we know, the system was too brittle to admit any substantial change and the Soviet empire collapsed in a remarkably short period of time. Without the threat of political competition from the West, it is doubtful that such drastic attempts would have been made to overhaul the stagnant Soviet system. For Russia, unfortunately, the threat of outside political competition has not yet led to increases in the growth rate of its economy. The predictions of the model presented in this paper should be seen as long run results. Hopefully, once the former Soviet countries have adopted the appropriate institutional structure, their economies will experience sustained growth. Note also that with the implosion of the Soviet empire, much of the threat of direct conflict with the West also disappeared, reducing the role for political competition on growth. Similar arguments could be made for more contemporary examples, including economic reforms in China and India.

Acemoglu and Robinson (2000) and Chaudhry and Garner (2001) present models of innovation threatening the political power of the government. A government may then try to block innovation in order to remain in power. This would result in a reduced rate of economic growth. Acemoglu and Robinson (2000) argue that, "Despite the intuitive appeal of the idea, there are relatively few instances where major economic change was blocked by economic losers...A more important reason, however, may be that the introduction of new technology, and economic change more generally, may simultaneously affect the distribution of political power." Any sustained attempts to suppress economic change within a country must have the support of the country's political elites.

In general we can think of three ways in which innovation can politically threaten the current government. First, the nature of the innovation itself could be threatening. Information technologies like printing, satellite dishes, and the Internet could spread information that could induce political instability, especially in repressive regimes that attempt to control the population through ideology, etc. Second, innovations in the private sector could also shift economic power to groups that are unfavorable to the current regime. These groups could use their new economic strength to undermine the government and replace it with one that is more preferable. Third. there may be vested interests that oppose the adoption of a new innovation. These interests could threaten the stability of the current government if new innovations are adopted. See the papers cited above for a more detailed discussion.[1] The historical record contains many examples of governments suppressing innovations when they feel politically threatened by these innovations. Acemoglu and Robinson (2000) cite the reaction of landed elites in England and Germany with those of Russia and Austria-Hungary in response to industrialization. They note that in England and Germany these landed elites felt more or less secure in their political power and hence did not attempt to block industrialization (i.e. innovation). In Russia and Austria-Hungary, however, the political elites did try to block industrialization as they saw in it a threat to their political power.

One of the most dramatic examples of innovation blocking activity by a government occurred in 1433 C.E. when, after a series of voyages that brought the Chinese navy to the eastern coast of Africa, the Chinese emperor forbade further voyages, ordered the destruc-

[1]Barro (1996) argues that economic development is correlated with democracy. If economic growth, at some stage, encourages the emergence of democracy then this could be another reason why innovation can be threatening to authoritarian regimes.

tion of ocean-going vessels, and prohibited his subjects from traveling abroad. The primary consideration for this seems to have been that an expansion in maritime activity could have resulted in a shift in political power inside China.

The case of the New Economic Policy (NEP) in Russia in the 1920's is another example of a government suppressing economic change. Initially, the economic liberalizations of the NEP were introduced to try to salvage the collapsing Soviet economy. In a sense, the NEP was too successful, permitting an increasingly important part of the Russian economy and society to move beyond the state's control. So Stalin launched the so called "second Bolshevik revolution" with the first of his five-year plans and brought a halt to the NEP. According to Cameron (1997) this "from Stalin's view had the further advantage of increasing the state's control over the lives of its subjects and thus preventing attempts to overthrow the regime." See Chaudhry and Garner (2001) for other examples of innovation blocking by governments.

One of Easterly and Levine's (2001) four stylized facts about economic growth is that economic activity is highly concentrated. On the country level, we observe the clustering of rich and poor nations. Moreno and Trehan (1997) examine the linkage between a country's location and its growth rate. They find that a country's growth rate is closely related to that of neighboring countries and show that this correlation reflects more than the existence of common shocks or trade. Although in discussing their results, the authors listed above did not have in mind the political competition between countries that is the subject of this paper, their findings are consistent with the model presented here. A government in a country whose neighbors (and potential competitors) are experiencing economic growth will have less incentive to block innovation than would one whose neighbors are not growing. Location would thus matter for economic growth and we would expect to see some level of clustering with respect to income per capita on the country level.

The model presented in this paper works as follows: There are two countries, country 1 and country 2. The rent-seeking government in each country faces some probability of losing power if an innovation occurs in their country, and on average innovation decreases the expected wealth of the government. Hence, in isolation, each government would have an incentive to block as much innovation as possible in order to stay in power. However both countries face the possibility of 'conflict' with the other country in the future. The larger country, in terms of economic strength (where economic strength is thought of as GDP in order to take into account both population size and per capita income), will be able to expropriate part of the income of the smaller country. This competition will provide an incentive (in most cases, though somewhat surprisingly, not all) for the countries to block less innovation and as a result there will be higher growth. Competition will also be the mechanism through which institutions in one country will affect the growth rate in the other country.

The setup of the paper is as follows: Section 2 presents a simplified version of the Chaudhry and Garner (2001) one country model of growth and innovation with innovation blocking activity[2]. Section 3 sets-up the model of political competition between countries and examines the case of two equal countries. Section 4 examines the case of unequal countries competing. Section 5 introduces a scale effect in innovation and examines the implications of this on political fragmentation and growth. Section 6 discusses alternative mechanisms for competition between countries and extensions of the model. Section 7 con-

[2]In Chaudhry and Garner (2001), a general equilibrium model of innovation based growth with a rent-seeking government and innovation blocking is presented. Extending that model to the case of two governments that are political competitors proves to be not particularly tractable. For this reason, and for expositional simplicity, in the present paper we present a simple, 2 period model that is still sufficient for our purposes

cludes.

The One Country Model

Consider the case of one country in isolation. For presentation and algebraic simplicity there are 2 periods[3]. The government of this country captures a certain fraction, $0 < f < 1$, of the country's output as rent in period 2. This government faces the possibility of an innovation occurring in the period 2. If an innovation occurs, then the economy becomes more productive and the country's aggregate income rises. In period 1, the government can influence the probability of an innovation occurring by accessing a costly innovation blocking technology. How could the government make innovation more difficult? The government could introduce a complicated and protracted approval process for any new innovation. These could be concrete obstacles such as the need for government licenses and/or permits, or obstacles such as bureaucratic delays and red-tape. The government could also use legal mechanisms to protect the current monopolist in the sense of patent rights that are too broadly interpreted; any innovation that even closely resembles the technology of the incumbent monopolist could be blocked. Another interpretation of the government affecting the flow rate of innovation is that it can limit the set of innovations that if discovered can be implemented. For example, the government could prohibit all innovations that use Internet technology. Then the flow rate of innovation would tend to be smaller simply because there are less potential 'usable' innovations that researchers could discover.

The probability of an innovation occurring is given by $\lambda(\psi)$ where $\psi \geq 0$ is the level of innovation blocking activity (IBA) chosen by the government and λ is a function of ψ such

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[3]Two periods are all that we require to demonstrate the main results of the paper. Adding additional periods would provide a somewhat richer model, but would involve cumbersome algebraic manipulations.

that $0 \leq \lambda(\psi) \leq 1$, $\lambda(0) > 0$, and $\lambda'(\psi) < 0$, $\lim_{\psi \to \infty} \lambda'(\psi) = 0$, $\lambda''(\psi) > 0$. The cost of implementing IBA level ψ is given by the cost function $\beta c(\psi)$ with $c(0) = 0$, $c'(0) = 0$, and $c' \geq 0$, $c'' > 0$. This cost is realized in period 2 [4]. The quality of a country's institutions is reflected in the cost of innovation blocking. In a country with well protected property rights and constraints on the arbitrary exercise of government power, it is more difficult and costly for a government to try to suppress economic activity and change. Hence, a country with a strong tradition of rule of law would have a relatively high value of β and a country without such a tradition would have a relatively low value of β. Let y denote the income of the country if no innovation takes place and let $\gamma > 1$ denote the size of the innovation so that the income of the country if the innovation occurs is given by γy. When an innovation occurs, the government may be threatened politically and thus faces probability μ of retaining power, so with probability $1 - \mu$ the government loses power and collects no rents in period 2. The expected wealth of the government in period 2 is given by:

$$EW(\psi) = f[(1 - \lambda(\psi))y + \lambda(\psi)\mu\gamma y] - \beta c(\psi) \tag{1}$$

The government's problem is to maximize expected wealth with respect to IBA level ψ. It is assumed that $\mu\gamma < 1$ so that the government is ex-ante on average hurt by innovation. Given that $c'(0) = 0$ and $\lambda'(\psi) < 0$ the unique solution to the government's problem exists and will be an interior solution. The first order condition is:

$$\lambda'(\psi) f y(\mu\gamma - 1) - \beta c'(\psi) = 0 \tag{2}$$

The first term of the first order condition represents the marginal benefit of blocking innova-

[4] We could have this cost realized in this first period. This would require us to be more explicit about government income in the first period and in general would complicate the presentation of the model with no qualitative changes.

tion and the second term the marginal cost. Note that $\frac{\partial^2 EW}{\partial \psi^2} = \lambda''(\psi) fy(\mu\gamma - 1) - \beta c''(\psi) < 0$, so that the second order condition for a maximum is satisfied.

This model, then, is applicable to countries in which the government is threatened politically by innovation and that has poor enough institutions so that blocking is not prohibitively expensive. We believe that historically the set of countries that satisfied the two above criteria was quite large and still may be so for many developing countries.

Letting $\psi^*(\mu, \gamma, f, \beta)$ represent the level of IBA that satisfies the above equation, and with an interior solution so that $\psi^* > 0$, the following holds: $\frac{\partial \psi^*}{\partial \mu} < 0$, $\frac{\partial \psi^*}{\partial \gamma} < 0$, $\frac{\partial \psi^*}{\partial f} > 0$, $\frac{\partial \psi^*}{\partial \beta} < 0$ A more stable government will block less innovation. The larger the size of the innovation, the less innovation will be blocked. The more the government can extract as rent, the more innovation will be blocked. The more costly innovation blocking is the less innovation will be blocked.

The expected growth rate in this economy is: $\lambda(\gamma - 1)$.

The Two Country Model

There are two countries, country 1 and country 2 with aggregate incomes (without innovation) given by y_1 and y_2 respectively and 2 periods in the model. Denote also the fraction of rent collected by the government, the probability of retaining power following innovation, and the cost of innovation blocking in the two countries as f_1, f_2, μ_1, μ_2, β_1, β_2. For simplicity we abstract from direct technology spillovers between the two countries so that the probability of innovation in a country will depend only on the amount of innovation blocking occurring in that country. Adding spillovers in innovation complicates the analysis significantly, but the result that political competition between countries can be growth enhancing remains. In period 1 both countries choose the level of IBA to be implemented in their respective countries, ψ_1 and ψ_2. The function λ and the size of the innovation γ is the same for both countries[5]. In period 2 they engage in 'conflict' (broadly defined). The conflict consists of the larger country, in terms of income, expropriating a fraction of the income of the smaller country[6]. We use this formulation because in the long run it is economic strength that largely determines military potential. Also, we could have this conflict occurring only with some probability p. This would complicate the presentation of the results but add no essential insights. It is the *threat* of future conflict, not the conflict itself, that can encourage innovation in this model. Other forms of competition between countries are discussed in section 6. Denoting the post innovation income of country i as y_i^P and of country j as y_j^P, so that $y_i^P = y$ if no innovation occurs and $y_i^P = \gamma y$ if innovation occurs, the post innovation/post conflict income of country i is:

$$y_i^P + \phi\Pi(y_i^P, y_j^P)\min[y_i^P, y_j^P]$$

where $0 \leq \phi \leq 1$ is a parameter that measures the degree of conflict or competition between the 2 countries with $\phi = 0$ representing no conflict and $\phi = 1$ representing the maximum level of conflict. $\Pi(.,.)$ is the conflict redistribution function which determines the fraction of the smaller country's income that is expropriated and has the following properties:

1) $\Pi(y_i^P, y_j^P) = -\Pi(y_j^P, y_i^P)$

2) $y_i^P > y_j^P \implies 0 < \Pi(y_i^P, y_j^P) < 1$

3) $\frac{\partial\Pi(y_i^P, y_j^P)}{\partial y_i^P} > 0$

[5] If we allow these to differ across countries we would still have similiar qualitative results.

[6] Alternatively, we could have the winner of the conflict (the government of the larger country) experience an increase in the probability of remaining in power and the loser (the government of the smaller country) experience a reduction in the probability of remaining in power. This would produce qualitatively similar results to those presented below.

4) $\Pi(ay_i^P, ay_j^P) = \Pi(y_i^P, y_j^P)$ where $a > 0$

Property 1 states that one country's loss is the other's gain: there is no deadweight loss in conflict. We make this assumption in order to focus more clearly on how the mechanism of political competition can be growth enhancing. Thus in the remainder of the paper it is useful to keep in mind that the destructiveness of the conflict can reduce the growth benefits of political competition between countries.

Property 2 simply states that the larger country expropriates a fraction of the income of the smaller country, and that this fraction is bounded between zero and one.

Property 3 states that an increase in the economic size of the country increases the fraction expropriated. Note that if this fraction is negative, then the absolute value of the fraction would decrease.

Property 4 states that if the economic size of both countries increases by the same proportion, this does not change the fraction expropriated. This assumption seems reasonable and is largely made for analytical convenience.

Note that property 1 implies that $\Pi(y, y) = 0$ and that properties 1 and 3 together imply that $\frac{\partial \Pi(y_i^P, y_j^P)}{\partial y_j^P} < 0$.

The expected wealth of the government in country 1 can therefore be written as:

$$\begin{aligned} EW_1 &= f_1[(1-\lambda_1)((1-\lambda_2)(y_1 + \phi\Pi(y_1, y_2)\min[y_1, y_2]) + \lambda_2((y_1 \\ &+ \phi\Pi(y_1, \gamma y_2)\min[y_1, \gamma y_2])) + \lambda_1\mu_1((1-\lambda_2)(\gamma y_1 + \phi\Pi(\gamma y_1, y_2)\min[\gamma y_1, y_2]) \\ &+ \lambda_2((\gamma y_1 + \phi\Pi(y_1, \gamma y_2)\min[\gamma y_1, \gamma y_2]))] - \beta_1 c(\psi_1) \end{aligned}$$

where $\lambda_1 = \lambda(\psi_1)$ and $\lambda_2 = \lambda(\psi_2)$. This is a two player, single shot game. A Nash equilibrium will be a pair (ψ_1^*, ψ_2^*) that satisfies simultaneously the following first order conditions:

$$\frac{\partial EW_1(\psi_1^*, \psi_2^*)}{\partial \psi_1} = 0 \qquad (3)$$

$$\frac{\partial EW_2(\psi_1^*, \psi_2^*)}{\partial \psi_2} = 0 \tag{4}$$

To compare the case of one country in isolation with two countries who are political competitors we will compare the value of ψ^* that satisfies the respective first-order conditions. For country 1, equation 3 can be written as:

$$\begin{aligned}\frac{\partial EW_1}{\partial \psi_1} &= f_1\lambda_1'[(\mu_1\gamma - 1)y_1 + \phi((1-\lambda_2)(\mu_1\Pi(\gamma y_1, y_2)\min[\gamma y_1, y_2] \\ &- \Pi(y_1, y_2)\min[y_1, y_2]) + \lambda_2(\mu_1\gamma\Pi(y_1, y_2)\min[y_1, y_2] - \Pi(y_1, \gamma y_2)\min[y_1, \gamma y_2]))] \\ &- \beta_1 c'(\psi_1) = 0\end{aligned}$$

There exist five possible cases:

I) $y_1 = y_2$, the case where the incomes of both countries are the same.

II) $y_1 < y_2$, $\gamma y_1 < y_2$, the case where the income of country 1 is less than the income of country 2, and would remain smaller even after it innovates.

III) $y_1 < y_2$, $\gamma y_1 > y_2$, the case where the income of country 1 before it innovates is less than the income of country 2, though the income of country 1 after innovation is larger than that of country 2 if country 2 does not innovate

IV) $y_1 > y_2$, $y_1 > \gamma y_2$, the case where the income of country 1 is greater than the income of country 2, and would remain greater even after country 2 innovates.

V) $y_1 > y_2$, $y_1 < \gamma y_2$, the case where the income of country 1 is greater than the income of country 2, though the income of country 1 is smaller than the income of country 2 if country 2 innovates.

The remainder of this section will examine the first and most simple case, countries of equal size.

Case I: $y_1 = y_2$

With equal initial incomes the first order condition for country 1 can be written as:

$\frac{\partial EW_1}{\partial \psi_1} = f_1\lambda_1'[(\mu_1\gamma - 1)y_1 + \phi((1-\lambda_2)(\mu_1\Pi(\gamma y_1, y_2)y_2) - \lambda_2\Pi(y_1, \gamma y_2)y_1)]$

$-\beta_1 c'(\psi_1) = 0$

This condition is the same as the first order condition obtained in the single country case (discussed above), with the addition of the term:

$$\phi((1-\lambda_2)(\mu_1\Pi(\gamma y_1, y_2)y_2) - \lambda_2\Pi(y_1, \gamma y_2)y_1)$$

which is positive. This means that the marginal benefit from blocking innovation is lower than in isolation, so ψ_1^*, will be less in the two country case. In fact, if this term is larger than $(\mu_1\gamma - 1)y_1$ then innovation is on average beneficial to the government and no innovation will be blocked. Thus we have the following:

Proposition 1: *If initial income is the same in both countries then competition between the two countries results in less innovation being blocked in country 1. and thus higher growth in country 1.*

Note that the degree to which competition increases growth in country 1 depends positively on ϕ, the degree of conflict between the two countries. If $\phi = 0$, so that there is no conflict in period 2, then country 1 will be unaffected by growth in country 2.

If we assume that λ_2 does not depend on ψ_1 then it is easy to see that $\frac{\partial \psi_1^*}{\partial \lambda_2} < 0$. Thus an increase in the probability of innovation in country 2 will reduce innovation blocking in country 1 and increase growth in country 1. An increase in the probability of innovation in country 2 could occur if μ_2 increases; the government in country 2 would be more stable and block less innovation. Likewise, an increase in β_2 or a decrease in f_2 would raise growth in country 1. This type of spillover from country 2 to country 1 is discussed in more detail below.

More generally, in the context of a Nash equilibrium, the following comparative statics can be shown:

Proposition 2: *If initial income is the same in both countries and if innovation on average harms the government of country 1 then the level of innovation blocking in country 1 will be reduced and growth in country 1 will be increased by:*

(i) An increase in the stability of country 1

(ii) A decrease in the degree of rent-seeking in country 1

(iii) An increase in the degree of political competition between the two countries

(iv) A decrease in the level of rent-seeking in country 2

(v) An increase in the stability of country 2

(vi) An increase in the cost of innovation blocking in country 1

(vii) An increase in the cost of innovation blocking in country 2

Proof : We will illustrate the proof of result (v). The other results follow in a similar fashion and are proved in the Appendix.

To determine the effect of an increase in the stability of the government in country 2 on growth in country 1 we need to determine the sign of $\frac{\partial \psi_1^*}{\partial \mu_2}$. If the sign is negative then an increase in the stability of the government in country 2 will result in the government in country 1 blocking less innovation and thus growth will be greater in country 1. To find this sign we will use the implicit function theorem (assuming the appropriate regularity conditions). Write equations 3 and 4 as follows:

$$G_1(\psi_1^*, \psi_2^*) = 0 \tag{5}$$

$$G_2(\psi_1^*, \psi_2^*, \mu_2) = 0 \tag{6}$$

Note that equation 6 implicitly defines ψ_2^* as a function of ψ_1^* and μ_2. Abusing notation somewhat we could, from equation 6, define the function $\psi_2^*(\psi_1^*, \mu_2)$ and combine this with equation 5 to get $G_1(\psi_1^*, \psi_2^*(\psi_1^*, \mu_2)) = 0$.

Then by the implicit function theorem:

$$\frac{\partial \psi_1^*}{\partial \mu_2} = \frac{-\frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \mu_2}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)}{\frac{\partial G_1}{\partial \psi_1^*} + \frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \psi_1^*}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)} \tag{7}$$

where $\frac{\partial G_1}{\partial \psi_1^*} < 0$, $\frac{\partial G_2}{\partial \psi_2^*} < 0$, $\frac{\partial G_1}{\partial \psi_2^*} > 0$, $\frac{\partial G_2}{\partial \psi_1^*} > 0$, $\frac{\partial G_2}{\partial \mu_2} < 0$.

The numerator of the above expression is positive. the first term of the denominator is negative and the second term of the denominator is positive. The sign of the denominator will be negative if:

$$-\frac{\frac{\partial G_1}{\partial \psi_1^*}}{\frac{\partial G_1}{\partial \psi_2^*}} > -\frac{\frac{\partial G_2}{\partial \psi_1^*}}{\frac{\partial G_2}{\partial \psi_2^*}} \tag{8}$$

In words. the slope of country 1's reaction function must be greater than the slope of country 2's reaction function at the Nash Equilibrium. Furthermore, given that $\lambda'' > 0$ and $c'' > 0$, country 1's reaction function is convex and country 2's reaction function is concave [see Figure 1]. This, together with the assumption that innovation is on average harmful to the government even with political competition, implies that the reaction functions will cross and an interior Nash equilibrium will exist. Therefore. at the Nash equilibrium it must be the case that condition (8) is satisfied and so $\frac{\partial \psi_1^*}{\partial \mu_2} < 0$.

Thus we have shown that $\frac{\partial \psi_1^*}{\partial \mu_2} < 0$. If country 2's regime becomes more stable (in the sense of being threatened less by innovation), then country 1 in equilibrium will block less innovation than before. This is an example of an **"institutional spillover"**. Instability in one country will reduce the growth rate of the other country. Ades and Chua (1997) find that even after controlling for domestic instability, regional instability has strong negative effects on a country's growth rate. This empirical result is consistent with our model.

Take (*iv*) above as another example. An increase in the degree of rent-seeking in country 2 lowers the growth rate of country 1 by encouraging more IBA in country 1 [see Figure 2]. Also, (*vii*) states that an increase in the cost of innovation blocking in country 2 increases the growth rate in country 1 by encouraging less IBA in country 1. We can interpret (*iv*) and (*vii*) as an improvement in the institutions in one country will have a spillover effect on growth in the other country through the mechanism of political competition.

Note that it may be in the interests of the governments in both countries to collude in order to reduce the competition between them so that they may both block more innovation and remain in power.[7] Collusion in this case suffers from the same incentive problem that faces cartels: one government may be tempted to 'cheat' if it knows that the other government is sticking to the agreement. One possible way to avoid this problem is to enter into binding treaties that lower φ, the degree of conflict between the two countries. Once the threat of competition from the other country is removed, the governments in both countries can focus on internal stability and innovation blocking.

Unequal Countries

There are four cases to consider if the two countries are not of the same size in terms of economic strength prior to any potential conflict. The effects of political competition compared to no political competition (i.e. isolation) are summarized below

Proposition 3: *If the initial income is smaller in country 1 than in country 2 then*

[7]Whether it would be in the interests of a government to collude with its competitor in order to increase its level of IBA depends on the exact specifications of the parameters in the model. In general, the more threatened by innovation the government is and the more likely its competitor is to innovate, the more incentitive it has to collude.

competition between the two countries results in less innovation being blocked in country 1, and thus higher growth in country 1.

Proof :

Case II: $y_1 < y_2$, $\gamma y_1 < y_2$

$\frac{\partial EW_1}{\partial \psi_1} = f_1\lambda_1'[(\mu_1\gamma - 1)y_1 + \phi((1-\lambda_2)(\mu_1\Pi(\gamma y_1, y_2)\gamma y_1 - \Pi(y_1, y_2)y_1) + \lambda_2(\mu_1\gamma\Pi(y_1, y_2)y_1 - \Pi(y_1, \gamma y_2)y_1))] - \beta_1 c'(\psi_1) = 0$

This condition is the same as the first order condition obtained in the single country case, with the addition of the term

$$\phi((1-\lambda_2)(\mu_1\Pi(\gamma y_1, y_2)\gamma y_1 - \Pi(y_1, y_2)y_1) + \lambda_2(\mu_1\gamma\Pi(y_1, y_2)y_1 - \Pi(y_1, \gamma y_2)y_1))$$

We need to show that this term is positive. To do so note that $\mu_1\Pi(\gamma y_1, y_2)\gamma y_1 - \Pi(y_1, y_2)y_1 > 0$ since $\mu_1\gamma\Pi(\gamma y_1, y_2) > \Pi(\gamma y_1, y_2) > \Pi(y_1, y_2)$. Also note that $\mu_1\gamma\Pi(y_1, y_2)y_1 - \Pi(y_1, \gamma y_2)y_1 > 0$ since $\mu_1\gamma\Pi(y_1, y_2) > \Pi(y_1, y_2) > \Pi(y_1, \gamma y_2)$.

This means that the marginal benefit from blocking innovation is lower than in isolation, so ψ_1^*, will be less in the two country case. So competition between the two countries results in less innovation being blocked in country 1, and thus a higher growth rate in country 1.

Case III: $y_1 < y_2$, $\gamma y_1 > y_2$

The first order condition is:

$$\frac{\partial EW_1}{\partial \psi_1} = f_1\lambda_1'[(\mu_1\gamma - 1)y_1 + \phi((1-\lambda_2)(\mu_1\Pi(\gamma y_1, y_2)y_2 - \Pi(y_1, y_2)y_1)$$
$$+\lambda_2(\mu_1\gamma\Pi(y_1, y_2)y_1 - \Pi(y_1, \gamma y_2)y_1))] - \beta_1 c'(\psi_1) = 0$$

This condition is the same as the first order condition obtained in the single country case, with the addition of the term:

$$\phi((1-\lambda_2)(\mu_1\Pi(\gamma y_1, y_2)y_2 - \Pi(y_1, y_2)y_1) + \lambda_2(\mu_1\gamma\Pi(y_1, y_2)y_1 - \Pi(y_1, \gamma y_2)y_1))$$

We need to show that this term is positive. To do so note that $\Pi(\gamma y_1, y_2) > 0$ so $\mu_1\Pi(\gamma y_1, y_2)y_2 - \Pi(y_1, y_2)y_1 > 0$ and that $\mu_1\gamma\Pi(y_1, y_2)y_1 - \Pi(y_1, \gamma y_2)y_1 > 0$ by the same reasoning as in Case II.

This means that the marginal benefit from blocking innovation is lower than in isolation, so ψ_1^*, will be less in the two country case. So competition between the two countries results in less innovation being blocked in country 1, and thus a higher growth rate in country 1.

If initial income in country 1 is higher than in country 2, political competition may result in *more* innovation being blocked in country 1. Just as a higher level of rent-seeking results in more innovation being blocked, the additional rent that may go to country 1 following a conflict can result in more innovation being blocked by the government in country 1. More specifically we have:

Case IV : $y_1 > y_2$, $y_1 > \gamma y_2$. *If μ_1 is sufficiently large then competition between the two countries results in less innovation being blocked in country 1. and thus higher growth in country 1. For small μ_1, we have that competition between the two countries results in more innovation being blocked in country 1, and thus lower growth in country 1.*

Case V : $y_1 > y_2$,$y_1 < \gamma y_2$. *If $\lambda_2$or $\mu_1$is sufficiently large then competition between the two countries results in less innovation being blocked in country 1, and thus higher growth in country 1. For small $\lambda_2$and $\mu_1$we have that competition between the two countries results in more innovation being blocked in country 1, and thus lower growth in country 1.*

Note that the less threatened politically by innovation the government in country 1 is, the more likely that competition with country 2 will result in higher growth in country 1. It is also not difficult to show that an increase in initial income in country 1 results in more innovation being blocked in country 1.

In general, the smaller country has less incentive to block innovation in the presence of political competition than the larger country. [8]

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[8]Which case, I, II, or III, results in the highest growth in country 1 depends on, among other things,

We have seen that in the case of equal initial economic size, the introduction of political competition results in higher growth in country 1. The model as presented so far suggests that as more potential competing countries are introduced, this should encourage less innovation blocking and higher growth in country 1. Taking this to extreme, we would conclude that for any given region of the world, the optimal size of countries for growth would be infinitesimally small.

To avoid this we need some mechanism that tends to reduce the probability of innovation as a country's size diminishes. We believe that the most plausible is the existence of economies of scale in innovation with respect to population size. Jones (1987) argues that, "against the benefits of decentralization within systems of states, the case in favor of a land empire would presumably rest on economies of scale." As country size diminishes, and with it the country's population, there are less individuals who may potentially innovate and so the domestic rate of innovation falls. If the transfer of innovation across countries is not perfect, then a scale effect will be present[9].

Consider a region with population N and per-capita income y. Thus the total income of the region is yN. It is reasonable to suppose that the cost of innovation blocking is increasing in population size. The larger the population is the greater the resources that are needed to police the population and enforce the will of the government. For simplicity we will assume that the cost of IBA is proportional to the population size, that is the cost of innovation blocking is $\beta c(\psi)N$.

We also assume that the probability of an innovation occurring in the economy is in-

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whether $\mu_1\gamma^2$ is greater than or less than 1. These three cases cannot, in general, be ranked in terms of the amount of innovation blocked.

[9]See Kremer (1993) for a discussion of the long run implications of population size on technological progress.

creasing in the population size. The more people there are, the more potential for new ideas. The probability of innovation can be written as $\lambda(\psi, N)$ with $\frac{\partial\lambda(\psi,N)}{\partial N} > 0$ and, for simplicity and ease of comparison, with $\frac{\partial^2\lambda}{\partial N\partial\psi} = 0$.

If this region is a single political unit with no potential competitors then, following section 2, we can write the government's expected wealth as:

$$EW(\psi) = f[(1 - \lambda(\psi, N))yN + \lambda(\psi)\mu\gamma yN] - \beta c(\psi)N \tag{9}$$

and the first order condition becomes

$$f\lambda'(\psi, N)(\mu\gamma - 1)y - \beta c'(\psi) = 0 \tag{10}$$

Denote the value of ψ that satisfies the above equation by ψ^*_{single}.

Consider now the case when the region is divided into two political units which are political competitors. For simplicity assume that the population of each country is equal and that μ, f, and β are the same in each country and are the same as they were in the single country case. If ideas are completely free to flow across borders then the probability of an innovation occurring in a country (either indigenously developed or imported from the other country) will be the same as in the case of a single political entity. If not, then the probability of innovation will depend on the population size of the country and a scale effect will be present. The greater the degree of idea and technological spillovers between the two countries, the less the scale effect is present.

With the above assumptions we can write the expected wealth of country 1 as:

$EW_1 = f[(1-\lambda(\psi_1, \frac{N}{2})((1-\lambda(\psi_2, \frac{N}{2})y\frac{N}{2}+\lambda(\psi_2, \frac{N}{2})(y\frac{N}{2}+\phi\Pi(y, \gamma y)y\frac{N}{2}) +\lambda(\psi_1, \frac{N}{2})\mu((1-\lambda(\psi_2, \frac{N}{2}))(\gamma y\frac{N}{2} + \phi\Pi(\gamma y, y)y\frac{N}{2}) + \lambda(\psi_2, \frac{N}{2})\gamma y\frac{N}{2})] -\beta c(\psi_1)\frac{N}{2}$

The first order condition is:

$\frac{\partial EW_1}{\partial\psi_1} = f\lambda_\psi(\psi_1, \frac{N}{2})[(\mu\gamma - 1)y + \phi((1 - \lambda(\psi_2, \frac{N}{2}))\mu\Pi(\gamma y, y)y$

$-\lambda(\psi_2, \frac{N}{2})\Pi(y, \gamma y)y)] - \beta c'(\psi_1) = 0$

Denote the value of ψ that satisfies the above equation by ψ^*_{multi}. Note that in Nash equilibrium this will be the same value for both countries since they share the same parameters.

Since by assumption $\lambda_\psi(\psi, \frac{N}{2}) = \lambda_\psi(\psi, N)$ we have, by the same reasoning used to prove Proposition 1, that $\psi^*_{\text{multi}} < \psi^*_{\text{single}}$. Thus dividing the region into two political entities results in less innovation blocking. Whether or not the probability of innovation occurring is greater depends on the degree to which the scale effect is present.

If there is no scale effect, that is, if $\lambda(\psi, N) = \lambda(\psi, \frac{N}{2})$ then obviously $\lambda(\psi_{\text{single}}, N) < \lambda(\psi_{\text{multi}}, \frac{N}{2})$ and political fragmentation results in a greater probability of innovation. If the scale effect dominates the competition effect then $\lambda(\psi_{\text{single}}, N) > \lambda(\psi_{\text{multi}}, \frac{N}{2})$ and political fragmentation results in a smaller probability of innovation.

In terms of expected growth we have the following:

$\textit{Expected Growth}_{\text{single}} = \lambda(\psi_{\text{single}}, N)(\gamma - 1)$

$\textit{Expected Growth}_{\text{multi}} = \lambda(\psi_{\text{multi}}, \frac{N}{2})(\gamma - 1)$

Which is larger depends on the degree of political competition, with larger ϕ increasing $\textit{Expected Growth}_{\text{multi}}$, and on the degree to which the scale effect is present, with larger $\frac{\partial\lambda(\psi,N)}{\partial N}$ decreasing $\textit{Expected Growth}_{\text{multi}}$.

Adding a scale effect to the model yields some interesting implications. If we consider a large empire, the scale effect predicts that the empire would have a relatively large potential for innovation. If the empire has no serious competitors, however, then an unstable government would tend to block a relatively large amount of innovation since there is no threat of conflict. The empire may thus see a large number of 'potential innovations', but little innovation that is actually implemented on a large scale. This interpretation fits well with historical evidence. The history of China is full of examples of inventions that were little utilized or even forgotten over time, e.g. mechanical clocks and gunpowder. The Roman Empire produced a workable steam engine, yet the Industrial Revolution would have to wait for almost another 2 millennia. Thus large empires may have the right 'scale' for innovation, but the wrong incentives for the political elites to allow it.

At the opposite extreme in terms of unification from China is India (at least for most of its history). According to Jones (1987) "what distinguished India from early modern Europe and China ... was the degree of political and economic fragmentation and the extraordinarily poor interregional communication." This extreme fragmentation probably contributed to absence of sustained economic growth in India until the twentieth century. Due to the many cultural, commercial, and intellectual ties that connected its various states, Europe however was able to benefit both from its political fragmentation and from some of the economies of scale. "Unity in diversity gave Europe some of the best of both worlds, albeit in a somewhat ragged and untidy way" (Jones 1987).

It is important to keep in mind that this analysis applies to countries in which the government is threatened by innovation and the cost of innovation blocking is not prohibitively high. For example, would the region of the world that the United States occupies have grown faster over the last two centuries if it had been divided politically? If, say, the original 13 colonies had fragmented into several separate countries? The answer is most likely no. Not only were the political elites probably not very threatened politically by innovation (except possibly in the antebellum South) but the high quality of institutions in the US would have made it very difficult for the those elites to have suppressed innovation in any case. Consider also the case of Europe. Two or three centuries ago European unification probably would have been growth retarding as it would have removed the political competition that this paper has argued has been so important to the emergence of sustained growth. This loss would have most likely outweighed any gains from a scale effect. To put it another way, the outcome of the battle of Waterloo was probably growth enhancing. For Europe today however, with good institutions in place, the gains from unification may outweigh the potential losses from removing political competition.

Extensions

In this paper we have introduced the threat of direct conflict with other countries as a mechanism for encouraging unstable governments to block less innovation. We do not view direct conflict as the only mechanism through which political competition between countries can affect growth. We discuss two alternative formulations below.

The first alternative is to replace the conflict and expropriation of a country's resources with a conflict over the division of a trade surplus. The total economic strength of a country would help determine its power in trade negotiations. The stronger country would be able to extract more favorable terms of trade from its weaker competitor. This could be another mechanism through which a rent-seeking government whose political power is threatened by innovation could choose to block less innovation in the presence of competition from other countries.

A second alternative is that a government's stability may not only be threatened by innovation, but also by a falling relative standard of living for the domestic population. Specifically, country 1's population may envy the wealth of country 2's population. The probability of government 1 staying in power would depend on whether an innovation has occurred (with innovation being destabilizing for the reasons discussed in the introduction) and also on the relative (per-capita) income of the two countries, $\frac{y_1}{y_2}$. If country 1 falls behind country 2 in living standards, the government may lose power due to popular pressure. Thus there will be a trade-off between risking innovation and the possibility of falling behind. In particular, this type of model would be more applicable to countries with some degree of democracy or popular representation.

We have shown how an improvement in institutions in country 2 can affect the amount of innovation blocking and growth in the country 1 (see Proposition 2). These "institutional spillovers" however do not change the quality of the institutions themselves in country 1 (represented by the cost of innovation blocking). Political competition between countries could also act as a mechanism for institutional improvement. Consider the case where, because of political competition from other countries, the government in country 1 ex-ante on average benefits from innovation (i.e., a corner solution). This government may find it difficult to credibly commit not to block innovation and this would tend to reduce the incentives of private individuals to devote resources to innovation. They could credibly commit, however, by adopting institutional reform that would make it more difficult more the government to block innovation in the future. In order to model this formally, we would need to extend the basic model presented here to a general equilibrium model with endogenous R&D, etc. We leave this for further research.

Conclusion

How has international rivalry affected long run growth in the world? This paper presents a simple model to answer this question. In particular, the model suggests that if governments are politically threatened by economic change then the presence of rival states can encourage innovation. A corollary of this would be that large empires without serious competitors are not very fertile ground for sustained economic growth. In contrast, the political fragmentation of Europe was an important factor contributing to the emergence of modern growth in that region of the world.

Understanding the institutional environment in which governments operate and in which economic policies are made is essential to understanding the history of economic growth across the world. These institutions help determine the incentives that political elites face with respect to suppressing or encouraging economic change. This paper shows how institutions in one country can affect not only domestic growth but also growth in a competing country.

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Appendix

Proof of the remainder of Proposition 2

Part i:

To determine the effect of an increase in the stability of the government in country 1 on growth in country 1 we need to determine the sign of $\frac{\partial \psi_1^*}{\partial \mu_1}$. Write equations 3 and 4 as follows:

$$G_1(\psi_1^*, \psi_2^*, \mu_1) = 0, (5i)$$

$$G_2(\psi_1^*, \psi_2^*) = 0, (6i)$$

Note that equation 6i implicitly defines ψ_2^* as a function of ψ_1^*. From equation 6i, define the function $\psi_2^*(\psi_1^*)$ and combine this with equation 5i to get $G_1(\psi_1^*, \psi_2^*(\psi_1^*), \mu_1) = 0$.

Then by the implicit function theorem:

$$\frac{\partial \psi_1^*}{\partial \mu_2} = \frac{-\frac{\partial G_1}{\partial \mu_1}}{\frac{\partial G_1}{\partial \psi_1^*} + \frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \psi_1^*}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)}$$

where $\frac{\partial G_1}{\partial \psi_1^*} < 0$, $\frac{\partial G_2}{\partial \psi_2^*} < 0$, $\frac{\partial G_1}{\partial \psi_2^*} > 0$, $\frac{\partial G_2}{\partial \psi_1^*} > 0$, $\frac{\partial G_1}{\partial \mu_1} < 0$.

The numerator of the above expression is positive and the denominator is negative so $\frac{\partial \psi_1^*}{\partial \mu_1} < 0$. Thus an increase in the stability of the government in country 1 will result in less innovation being blocked in country 1 and higher growth in country 1.

Part ii:

To determine the effect of a decrease in the degree of rent seeking in country 1 on growth in country 1 we need to determine the sign of $\frac{\partial \psi_1^*}{\partial f_1}$. Write equations 3 and 4 as follows:

$$G_1(\psi_1^*, \psi_2^*, f_1) = 0, (5ii)$$

$$G_2(\psi_1^*, \psi_2^*) = 0, (6ii)$$

Note that equation 6ii implicitly defines ψ_2^* as a function of ψ_1^*. From equation 6ii, define the function $\psi_2^*(\psi_1^*)$ and combine this with equation 5ii to get $G_1(\psi_1^*, \psi_2^*(\psi_1^*), f_1) = 0$.

Then by the implicit function theorem:

$$\frac{\partial \psi_1^*}{\partial \mu_2} = \frac{-\frac{\partial G_1}{\partial f_1}}{\frac{\partial G_1}{\partial \psi_1^*} + \frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \psi_1^*}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)}$$

where $\frac{\partial G_1}{\partial \psi_1^*} < 0$, $\frac{\partial G_2}{\partial \psi_2^*} < 0$, $\frac{\partial G_1}{\partial \psi_2^*} > 0$, $\frac{\partial G_2}{\partial \psi_1^*} > 0$, $\frac{\partial G_1}{\partial f_1} > 0$.

The numerator of the above expression is negative and the denominator is negative so $\frac{\partial \psi_1^*}{\partial f_1} > 0$. Thus an decrease in the degree of rent seeking by the government in country 1 will result in less innovation being blocked in country 1 and higher growth in country 1.

Part iii:

To determine the effect of an increase in the degree of political competition between the two countries on growth in country 1 we need to determine the sign of $\frac{\partial \psi_1^*}{\partial \phi}$. Write equations 3 and 4 as follows:

$$G_1(\psi_1^*, \psi_2^*, \phi) = 0, (5iii)$$

$$G_2(\psi_1^*, \psi_2^*, \phi) = 0, (6iii)$$

Note that equation 6iii implicitly defines ψ_2^* as a function of ψ_1^* and as a function of ϕ. From equation 6iii, define the function $\psi_2^*(\psi_1^*, \phi)$ and combine this with equation 5iii to get $G_1(\psi_1^*, \psi_2^*(\psi_1^*, \phi), \phi) = 0$.

Then by the implicit function theorem:

$$\frac{\partial \psi_1^*}{\partial \mu_2} = \frac{-\left[\frac{\partial G_1}{\partial \phi} + \frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \phi}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)\right]}{\frac{\partial G_1}{\partial \psi_1^*} + \frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \psi_1^*}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)}$$

where $\frac{\partial G_1}{\partial \psi_1^*} < 0$, $\frac{\partial G_2}{\partial \psi_2^*} < 0$, $\frac{\partial G_1}{\partial \psi_2^*} > 0$, $\frac{\partial G_2}{\partial \psi_1^*} > 0$, $\frac{\partial G_1}{\partial \phi} < 0$, $\frac{\partial G_2}{\partial \phi} < 0$

The numerator of the above expression is positive and the denominator is negative so $\frac{\partial\psi_1^*}{\partial\phi} < 0$. Thus an increase in the degree political competition between the two countries will result in less innovation being blocked in country 1 and higher growth in country 1.

Part iv:

To determine the effect of an increase in the degree of rent seeking in country 2 on growth in country 1 we need to determine the sign of $\frac{\partial\psi_1^*}{\partial f_2}$. Write equations 3 and 4 as follows:

$$G_1(\psi_1^*, \psi_2^*) = 0, (5iv)$$

$$G_2(\psi_1^*, \psi_2^*, f_2) = 0, (6iv)$$

Note that equation 6iv implicitly defines ψ_2^* as a function of ψ_1^* and as a function of f_2. From equation 6iv, define the function $\psi_2^*(\psi_1^*, f_2)$ and combine this with equation 5iv to get $G_1(\psi_1^*, \psi_2^*(\psi_1^*, f_2)) = 0$. Then by the implicit function theorem:

$$\frac{\partial\psi_1^*}{\partial\mu_2} = \frac{-\frac{\partial G_1}{\partial\psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial f_2}}{\frac{\partial G_2}{\partial\psi_2^*}}\right)}{\frac{\partial G_1}{\partial\psi_1^*} + \frac{\partial G_1}{\partial\psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial\psi_1^*}}{\frac{\partial G_2}{\partial\psi_2^*}}\right)}$$

where $\frac{\partial G_1}{\partial\psi_1^*} < 0$, $\frac{\partial G_2}{\partial\psi_2^*} < 0$, $\frac{\partial G_1}{\partial\psi_2^*} > 0$, $\frac{\partial G_2}{\partial\psi_1^*} > 0$, $\frac{\partial G_2}{\partial f_2} > 0$

The numerator of the above expression is negative and the denominator is negative so $\frac{\partial\psi_1^*}{\partial f_2} > 0$. Thus a decrease in the degree rent seeking in country 2 will result in less innovation being blocked in country 1 and higher growth in country 1.

Part vi:

To determine the effect of an increase in the cost of innovation blocking in country 1 on growth in country 1 we need to determine the sign of $\frac{\partial\psi_1^*}{\partial\beta_1}$. Write equations 3 and 4 as follows:

$$G_1(\psi_1^*, \psi_2^*, \beta_1) = 0, (5vi)$$

$$G_2(\psi_1^*, \psi_2^*) = 0, (6vi)$$

Note that equation 6vi implicitly defines ψ_2^* as a function of ψ_1^*. From equation 6vi, define the function $\psi_2^*(\psi_1^*)$ and combine this with equation 5vi to get $G_1(\psi_1^*, \psi_2^*(\psi_1^*), \beta_1) = 0$.

Then by the implicit function theorem:

$$\frac{\partial \psi_1^*}{\partial \mu_2} = \frac{-\frac{\partial G_1}{\partial \beta_1}}{\frac{\partial G_1}{\partial \psi_1^*} + \frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \psi_1^*}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)}$$

where $\frac{\partial G_1}{\partial \psi_1^*} < 0$, $\frac{\partial G_2}{\partial \psi_2^*} < 0$, $\frac{\partial G_1}{\partial \psi_2^*} > 0$, $\frac{\partial G_2}{\partial \psi_1^*} > 0$, $\frac{\partial G_1}{\partial \beta_1} < 0$

The numerator of the above expression is positive and the denominator is negative so $\frac{\partial \psi_1^*}{\partial \beta_1} < 0$. Thus an increase in the cost of innovation blocking in country 1 will result in less innovation being blocked in country 1 and higher growth in country 1.

Part vii:

To determine the effect of an increase in the cost of innovation blocking in country 2 on growth in country 1 we need to determine the sign of $\frac{\partial \psi_1^*}{\partial \beta_2}$. Write equations 3 and 4 as follows:

$$G_1(\psi_1^*, \psi_2^*) = 0, (5vii)$$

$$G_2(\psi_1^*, \psi_2^*, \beta_2) = 0, (6vii)$$

Note that equation 6vii implicitly defines ψ_2^* as a function of ψ_1^* and as a function of β_2. From equation 6vii, define the function $\psi_2^*(\psi_1^*, \beta_2)$ and combine this with equation 5vii to get $G_1(\psi_1^*, \psi_2^*(\psi_1^*, \beta_2)) = 0$.

Then by the implicit function theorem:

$$\frac{\partial \psi_1^*}{\partial \mu_2} = \frac{-\frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \beta_2}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)}{\frac{\partial G_1}{\partial \psi_1^*} + \frac{\partial G_1}{\partial \psi_2^*}\left(-\frac{\frac{\partial G_2}{\partial \psi_1^*}}{\frac{\partial G_2}{\partial \psi_2^*}}\right)}$$

where $\frac{\partial G_1}{\partial \psi_1^*} < 0$, $\frac{\partial G_2}{\partial \psi_2^*} < 0$, $\frac{\partial G_1}{\partial \psi_2^*} > 0$, $\frac{\partial G_2}{\partial \psi_1^*} > 0$, $\frac{\partial G_2}{\partial \beta_2} < 0$

The numerator of the above expression is positive and the denominator is negative so $\frac{\partial \psi_1^*}{\partial \beta_2} < 0$. Thus an increase in the cost of innovation blocking in country 2 will result in less innovation being blocked in country 1 and higher growth in country 1.

DO GOVERNMENTS SUPPRESS GROWTH? INSTITUTIONS, RENT SEEKING AND INNOVATION BLOCKING IN A MODEL OF SCHUMPETERIAN GROWTH

with Azam Chaudhry

Introduction

Sustained growth in per capita income requires innovation. Continued innovation in the production and distribution of goods and services and the introduction of new goods and services is the basic reason why some countries today are wealthy beyond the imagining of a person living in the 18th century. The failure to innovate and change is at the root of why some countries remain poor. Why, historically, has innovation been easier and more attractive in some nations than in others? Obviously this is a complicated question and a full answer would require an in depth historical, political, economic, and cultural study. To be more specific we ask the following: why do the governments (political elites) of some countries adopt policies that discourage innovation and hence reduce long run growth? Why did authoritarian regimes in South Korea and Chile adopt growth promoting policies while similar regimes in other countries, (for example in sub-Saharan Africa) did not? A simple answer could be that some governments simply do not know what policies hurt innovation and growth. We find this answer less than convincing. If we assume that all governments are equally rational and knowledgeable about the set of innovation promoting policies, then the question becomes: why is it in the interests of some governments to block innovation and thereby lower growth? The answer must lie in the institutional environment in which governments operate. And if governments blocking innovations is an important part of why some countries stay poor, the differences in institutions across countries should help explain differences in income per capita across countries. Institutions could include (but are not limited to) the following: who holds political power, what constraints are there on the exercise of that power, property rights, the legal system and the rule of law, various market institutions, etc.

Recent empirical work has begun to focus on variation in institutions in explaining cross country income differences. Hall and Jones (1999) and Acemoglu, Johnson, and Robinson (2000) find that differences in institutions can account for a large share of the observed differences in income per capita across countries. For example, Acemoglu, Johnson, and Robinson (2000) find that institutional differences can explain 3/4 of current variation in income per capita across former European colonies. North and Thomas (1973) in their classic The Rise of the Western World, argue that the institutions that evolved in late medieval Europe were key to Europe's later rise to world economic dominance. Following a somewhat similar line of reasoning, Rosenberg and Birdzell (1986) emphasize the importance of flexibility and innovation, both in the political and economic spheres, to the emergence of sustained growth in the West.

General discussions of the impact of institutions on the economy, and economic growth in particular, include Lin and Nugent(1995) and Rodrik(2000) In particular, there is a large literature on the economic impact of rent-seeking and corruption. The level of rent-seeking occurring in a country is a function of the type of institutions that a country has. Strong property rights and rule of law tends to make rent-seeking more difficult, their absence makes it more attractive. Baumol (1990), Murphy, Shleifer, and Vishny (1991,1993), Shleifer and Vishny (1993), Mauro (1995), and Tanzi (1998) all discuss the economic impact of rent-seeking and corruption. The common thread running through all these papers is the harmful effect of rent-seeking and corruption on economic performance.

If the main rent-seekers in a country are the political elites who control the government, then how does innovation affect the welfare (rent) of the government? If innovation hurts the government then we would expect the government to try to block it. If innovation benefits the government then we would likewise expect the government to encourage innovation. An interesting approach to this problem is that of Acemoglu and Robinson (2000). They argue that if innovation threatens the political power of a government (and hence its rents) then it will try to block innovation. Furthermore these "political losers" from innovation (and hence economic growth) are key to understanding why some countries have historically been open to innovation while others have not.

We expand on this idea by formulating a model of innovation based growth with a rent-seeking government who face the chance of losing power every time an innovation occurs. The government can decrease the flow rate of innovation by accessing a (costly) innovation blocking technology. In the terminology of Dinopoulos and Syropoulos (1999). the government chooses a level of innovation blocking activity (IBA). The higher the level of IBA, the lower the flow rate of innovation. We are not aware of any research in the innovation based growth literature, in which there is a direct role for government in determining the rate of innovation. In Dinopoulos and Syropoulos (1999) innovation blocking activity is combined with a innovation based growth model, but in their paper it is the incumbent monopolist (who controls the innovation), not the government, that has access to this innovation blocking technology.

The contribution of this paper is to highlight the role of institutional factors (such as the degree of rent- seeking in the economy, etc.) in economic growth, through the channel of government policy. The rest of the paper is as follows. Section 2 provides historical motivation for the idea that economic innovation may be politically threatening to those in power. Section 3 presents the basic model with exogenous probability of the current government losing power following an innovation. Section 4 solves the government maximization problem and discusses the effect of various parameters on the optimal level of IBA.

Section 5 extends the basic model of Section 3 to endogenize the probability of losing power following an innovation. Section 6 discusses empirical evidence that is consistent with the model. Section 7 concludes. The proofs of the main results are contained in the Appendix.

Innovation and Political Instability

There are potentially two groups in society that may want to block innovation: economic losers and political losers. Economic losers could include business interests and workers who would be displaced by the introduction of new technology, or new products and services. By political losers we mean those political elites that may lose power from economic change. Acemoglu and Robinson (2000) argue that, "Despite the intuitive appeal of the idea, there are relatively few instances where major economic change was blocked by economic losers...A more important reason, however, may be that the introduction of new technology, and economic change more generally, may simultaneously affect the distribution of political power." We believe that any sustained attempts to supress economic change must have the support of the country's political elites.

In general we can think of three ways in which innovation can politically threaten the current government. First, the nature of the innovation itself could be threatening. Information technologies like printing, satellite dishes, and the Internet could spread information that could induce political instability, especially in repressive regimes that attempt to control the population through ideology, etc. This mechanism is appealing, but unfortunately, no simple way of modeling it presents itself. Second, innovations in the private sector could also shift economic power to groups that are unfavorable to the current regime. These groups can use their new economic strength to undermine the government and replace it with one that is more preferable. This will be the approach taken in Section 5, in which we endogenize the probability of a government losing power following an economic innovation. Third, there may be vested interests that oppose the adoption of a new innovation. For a model of vested interests blocking technology adoption see Krusell and Rios-Rull (1996). Most of these types of models rely on voting mechanisms. If decisions are not made through voting (i.e. the regime is not democratic) then the implication of these models is not clear. For example, if the vested interests are an incumbent monopolist and the regime is non-democratic, then a rent-seeking government could allow the emergence of new innovations and collect greater rents from a larger economy.

The historical record is full of examples of governments blocking innovations when they feel politically threatened by these innovations. Acemoglu and Robinson (2000) cite the reaction of landed elites in England and Germany with those of Russia and Austria-Hungary to industrialization. They note that in England and Germany these landed elites felt more or less secure in their political power and hence did not attempt to block industrialization (i.e. innovation). In Russia and Austria-Hungary, however, the political elites did try to block industrialization as they saw in it a threat to their political power.[10]

Early examples of innovation blocking activities occur in Roman history. Roman rulers were above all concerned with order and stability in the Empire. The following ancedote from Baumol (1990) illustrates this concern:

"There is a story, repeated by a number of Roman writers, that a man - characteristically unnamed- invented unbreakable glass and demonstrated it to Tiberius in anticipation of a great reward. The emperor asked the inventor whether anyone shared his secret and was assured that there was no one else, whereupon his head was promptly removed, lest, said Tiberius, gold should be reduced to the value of mud"

[10]See Acemoglu and Robinson (2000) for a more detailed discussion.

It seems likely that what Tiberius feared was the economic changes that such an invention would bring about, and the resulting instability in the Empire and hence instability in his rule. Another Roman Emperor, Vespasian, "reputedly rejected a design for a water driven hoist to raise heavy stones for fear of causing unemployment" (Cameron 1997). Vespasian's motives were most likely similar to those given above.

According to Landes (1998), in reference to the Islamic world falling behind the West in early modern times, "Islam's greatest mistake, however, was the refusal of the printing press, which was seen as a potential instrument of sacrilege and heresy." A ruler of a society that is based on a religious foundation obviously has a vested interest in blocking innovations that may produce religious (and hence political) instability. In some Islamic countries, this innovation blocking with respect to information technology continues to this day.

One of the most dramatic examples of innovation blocking activity by a government occurred in 1433 when, after a series of voyages that brought the Chinese navy to the eastern coast of Africa, the Chinese emperor forbade further voyages, ordered the destruction of ocean-going vessels, and prohibited his subjects from traveling abroad. The primary consideration for this seems to have been that an expansion in maritime activity could result in a shift in political power inside China.

Japan, after a period of growing contact with the West, also turned inward by government fiat in order to preserve the status quo. Further innovation was not only blocked, but previous innovations were destroyed. Diamond (1997) cites the case of firearm use and manufacture.

"[Traditional samurai warfare] became lethal in the presence of peasant soldiers ungracefully blasting way with guns. In addition, guns were a foreign invention, and grew to be despised, as did other things foreign to Japan after 1600. The samurai-controlled government began by restricting gun production to a few cities, then introduced a requirement of a government license for producing a gun, then issued licenses only for guns produced for the government, and finally reduced government orders for guns, until Japan was almost without functional guns again."

Again, innovation is blocked to ensure government stability.

The case of the New Economic Policy (NEP) in Russia in the 1920's is another example of IBA. Initially, the economic liberalizations of the NEP were introduced to try to salvage the collapsing Soviet economy. In a sense, the NEP was too successful, permitting an increasingly important part of the Russian economy and society to move beyond the state's control. So Stalin launched the so called "second Bolshevik revolution" with the first of his five-year plans and brought a halt to the NEP. According to Cameron (1997) this "from Stalin's view had the further advantage of increasing the state's control over the lives of its subjects and thus preventing attempts to overthrow the regime."

Another contemporary example could be limitations on Internet related technologies and services in China, where the rulers feel that such innovations threaten their political power.

These examples suggest that authoritarian regimes that do not enjoy a secure hold on power or have widespread popular support may try to avoid drastic changes in the economy that come from allowing innovation. Any change in the status quo could cause a loss of political power. This idea is formalized below in the context of an endogenous growth model.

The Model with Exogenous Instability

The basic setup of the model follows Aghion and Howitt (1998). The economy is populated by a continuous mass L of individuals with linear intertemporal preferences given by $u(y) = \int_0^\infty y_\tau e^{-r\tau} d\tau$ where y is the final output (consumption) good and r is the rate of time preference of consumers which equals the interest rate. Final output y is produced using an intermediate good x according to:

$$y = Ax^\alpha \tag{11}$$

where $0 < \alpha < 1$ and x is produced by an incumbent monopolist who produced the last innovation. Every innovation raises A by the constant factor $\gamma > 1$. The subscript t will refer to the number of innovations that have occurred. For simplicity there is no capital accumulation.

Each individual in the economy is endowed with one unit flow of labor which is supplied inelastically. Labor can be used to produce intermediate goods, one for one, or perform research so that $L = x + n$, where n is the amount of labor used in research. If amount n of labor is used in research then innovations arrive randomly with Poisson arrival rate $\lambda(\psi)n$ where $\psi > 0$ is the level of IBA chosen by the government and λ represents the productivity of research technology. λ is a function of ψ such that $\lambda' < 0$ and $\lambda'' > 0$.

How could the government make innovation more difficult? The government could introduce a complicated and protracted approval process for any new innovation. These could be concrete obstacles such as the need for government licenses and/or permits, or obstacles such as bureaucratic delays and red-tapism. The government could also use legal mechanisms to protect the current monopolist in the sense of patent rights that are too broadly interpreted; any innovation that even closely resembles the technology of the incumbent monopolist could be blocked. An important point to be made is that in this model an innovation is said to have occurred if in the process of R&D a new innovation is discovered and the innovation is actually brought to the market. So another interpretation of the government affecting the flow rate of innovation is that it can limit the set of innovations that if discovered can be implemented. For example, the government could prohibit all innovations that use Internet technology. Then the flow rate of innovation would tend to be smaller simply because there are less potential 'usable' innovations that researchers could discover.

Many countries have little, if any, formal R&D sector. How can we apply this models to those situations? If imitation or adoption of technology from advanced countries is not costless or deterministic the model could be applied to developing countries. For example, it may take effort to find out which technology is most appropriate for a country's economic situation. As long as this process is not completely deterministic, then the arrival of (usable) innovations can be said to be a random process. Also, as will be made clear in the presentation of the model, the government, through IBA, influences the size of the R&D sector. Given poor institutions and a government that is threatened by innovation, we would expect to see a small or non-existent R&D sector since the expected payoff to any innovation would be so low.

Let $A_t\beta c(\psi)$ be the cost to government of implementing ψ where β is a constant and $\beta > 0$, $c(0) = 0$, $c'(0) = 0$, $c' \geq 0$, c''¿ 0. The quality of a country's institutions is reflected in the cost of innovation blocking. A country with a strong tradition of rule of law would have a high value of β. The assumption that the cost of implementing any level of IBA is proportional to productivity can be interpreted as the government having to hire (a relatively small number of) workers to implement ψ and hence reflects the wage or that the difficulty of blocking further innovation is increasing in the level (or complexity) of the current innovation.

Firms

We assume that there are a continuum of firms which are engaged in research and development. For simplicity, we abstract from the ownership structure of the firms.[11] If a firm successfully innovates, it becomes a monopolist in the intermediate sector. The monopoly rents are obtained until the next, $(t+1)$st, innovation. After this next innovation occurs, the 'old' monopolist is replaced by the firm with the new innovation. The amount of labor devoted to research is given by the following asset equation where w_t is the wage and V_t is the discounted expected payoff to the $(t+1)$st innovation.[12]

$$rV_{t+1} = \pi_{t+1} - \lambda(\psi_{t+1})n_{t+1}V_{t+1} \tag{12}$$

What this equation implies is that the expected income for the firm with the $(t+1)$st innovation during a particular time interval (rV_{t+1}), is equal to the monopoly rents that the firm obtains with the innovation, minus the expected 'capital loss' that occurs when the $(t+1)$st innovator is replaced, which causes a loss of V_{t+1}. The probability of the next innovation is $\lambda(\psi_{t+1})n_{t+1}$. Rearranging we obtain:

$$V_{t+1} = \frac{\pi_{t+1}}{r + \lambda(\psi_{t+1})n_{t+1}} \tag{13}$$

To find π_t (which is the profit of the t th innovator), we solve the maximization problem:

$$\max_x [p_t(x)x - w_t x]$$

where $p_t(x)$ is the price of intermediate output, Since the final output market is competitive, p must equal the marginal product of x. Let f be the fraction of final output collected by the government as rent.[13] This parameter represents the maximum level of rents that

[11]The general qualitative results obtained in this paper will hold if each individual in the economy has some ownership share(s) in specific firms.

[12]See Aghion and Howitt(1998) for a more detailed exposition of this and what follows concerning firms.

[13]Instead of the government collecting a proportion of final output, y, as rent, the government could collect

is institutionally allowed in any country. Thus, if the country has a institutional mechanism that discourages the level of rents collected by the government, then the value of f will be lower. Examples of these institutional constraints on rent-seeking may be a strong, independent media, a well-established system of property rights, and/or a strong judicial system. Equating the price of the intermediate produect to the marginal product of x, we have $p_t(x) = (1-f)A_t\alpha x^{\alpha}$.

So output is produced, the government takes a fraction f, and the remainder goes on the market. The level of x produced is then just the solution to the incumbent monopolist's profit maximization problem:

$$x_t = \arg\max[(1-f)A_t\alpha x^{\alpha} - w_t x] \tag{14}$$

$$\Longrightarrow \quad x_t = \left(\frac{\alpha^2(1-f)}{\frac{w_t}{A_t}}\right)^{\frac{1}{1-\alpha}} \tag{15}$$

$$\Longrightarrow \quad \pi_t = \left(\frac{1}{\alpha} - 1\right)w_t x_t = A_t\pi\left(\frac{w_t}{A_t}\right) \tag{16}$$

Let $\omega_t = \frac{w_t}{A_t}$, the productivity adjusted wage, which implies that x and π are both functions of ω.

The arbitrage condition for the labor market is given by :

$$w_t = \lambda(\psi_t)V_{t+1} \tag{17}$$

which simply says that the value of an hour in manufacturing is equal to the expected value of an hour spent in research. Substituting in for V_{t+1} and π_t and we get the asset (6) and the labor market clearing (7) equations that describe the dynamics of this model:

$$\omega_t = \lambda(\psi_t)\left[\frac{\gamma\pi(\omega_{t+1})}{r + \lambda(\psi_{t+1})n_{t+1}}\right] \tag{18}$$

$$L = n_t + x(\omega_t) \tag{19}$$

an amount proportional to the productivity parameter, A_t. If this amount of rent does not depend on y, then some simplication of the model will be achieved, however we feel that the formulation in the paper is the most natural.

In the steady state ω, and therefore x and n, will be independent of the level of innovation t, so that in the steady state the labor allocated to both research and manufacturing, and the productivity adjusted wage, are constant over time. So wages, profit and final output are simply scaled up by the same γ (¿1), at every new innovation. Given (6) and (7), we can solve for ω (and therefore for n, x,and y) in terms of $\lambda(\psi_t)$:

$$\omega^* = (\frac{r}{\lambda D} + \frac{L}{D})^{\alpha-1} \tag{20}$$

where

$$D = (\alpha^2(1-f))^{\frac{1}{1-\alpha}}[1 + \gamma(\frac{1}{\alpha} - 1)] > 0 \tag{21}$$

Substituting ω^* into the equation for x, we obtain:

$$x = [\frac{r}{\lambda} + L](1 + \gamma(\frac{1}{\alpha} - 1))^{-1} \tag{22}$$

It is easy to show that the following hold:

$$\frac{\partial \omega}{\partial \lambda} > 0, \quad \frac{\partial n}{\partial \lambda} > 0, \quad \frac{\partial x}{\partial \lambda} < 0, \quad \frac{\partial y}{\partial \lambda} < 0$$

$[assuming x<L]$ Given that $\frac{\partial \lambda}{\partial \psi} < 0$, it follows that:

$$\frac{\partial \omega}{\partial \psi} < 0, \frac{\partial n}{\partial \psi} < 0, \frac{\partial x}{\partial \psi} > 0, \quad \frac{\partial y}{\partial \psi} > 0$$

Thus, an increase in the level of IBA, would cause workers to leave the research and development sector and enter the final output production sector. It can also be shown that the average (or expected) growth rate in this economy in the steady state is:

$$g = \lambda n \ln(\gamma) \tag{23}$$

This implies that $\frac{\partial g}{\partial \psi} < 0$. Therefore, an increase in ψ would cause both λ and n to decrease, which reduces the growth rate.

Government

The net flow of rents to the government at any point in time, τ, is given by: $fy_\tau - A_t\beta c_\tau$. Denoting the current level of technology (hence innovation) as A_0, the present value of the expected wealth of the government is (in the steady state):

$$EW_t = \int_0^\infty e^{-\rho\tau}[fy_\tau - A_t\beta c_\tau](\Pr_\tau)d\tau \tag{24}$$

where ρ is the rate of time preference of the government and $\Pr_\tau$ is the probability of being in power at time τ.[14] Thus the expected wealth of the government can be rewritten as:

$$EW_t = \int_0^\infty e^{-\rho\tau}[\sum_{t=0}^{\infty}\Pi(t,\tau)A_t(f\bar{y} - \beta c)\mu^t]d\tau \tag{25}$$

where $\bar{y} = \frac{y_t}{A_t}$ is the productivity adjusted income and $\Pi(t,\tau) = \frac{(\lambda n\tau)^t}{t!}e^{-\lambda n\tau}$ is the probability that there will be exactly t innovations up to time τ and μ is the probability of the government staying in power when an innovation occurs.

It can be shown that the above integral reduces to the following:

$$EW = \frac{A_0(f\bar{y} - \beta c)}{\rho - \lambda n(\mu\gamma - 1)} \tag{26}$$

Note that, holding other things constant, EW is increasing in f and decreasing in c . Whether EW is increasing or decreasing in λ will depend on the sign of $\mu\gamma - 1$. If $\mu\gamma > 1$ then (again holding the other variables constant) innovation is on average beneficial to the government, even taking into account the probability of losing power when the innovation occurs. If $\mu\gamma < 1$ then on average innovation is bad for the government

[14]It is assumed here that the expected payoff to not being in power is zero. If the expected flow payoff to not being in power at time τ is some positive constant M_0, it is not difficult to show that the greater M_0 is, the less innovation will be blocked by the government. That is, the worse the alternative to being in power is, the more innovation will be blocked. For example, rulers who face execution if they lose power will be more likely to block innovations that are politically threatening than rulers who at worst face a comfortable retirement on the French Riviera

The sign of $\mu\gamma - 1$ plays an important role in our analysis of the optimal level of IBA, ψ, the government chooses and therefore the growth rate. When $\mu\gamma < 1$, the probability of losing power outweighs the additional rent that would be collected with the innovation if power is retained. When $\mu\gamma > 1$, the probability of losing power is outweighed by the additional rent the government can collect with the innovation, if power is retained. This is discussed in detail below.

Solution of the Government's Problem

The government's problem is then to maximize EW with respect to ψ. As shown in Section 3, using equations (6) and (7) we can solve for x, n and y as functions of ψ. It can be shown that the government will choose a level of IBA, ψ, independent of the innovation level, t.[15] We can thus state the government's problem as:

$$\max_{\psi} EW = \frac{A_0(f\bar{y}(\psi) - \beta c(\psi))}{\rho - \lambda(\psi)n(\psi)(\mu\gamma - 1)} \tag{27}$$

A corner solution would imply that $\psi = 0$, and the government would block no innovation. In this case, the cost of blocking innovation would outweigh the benefits (if any) the government would receive. Since the purpose of this paper is to model why it would actually be in the interest of a government to block innovation, we focus on the case where $\psi > 0$. The first order condition, assuming an interior solution, is :

$$f\bar{y}'(\psi) - \beta c'(\psi) + \frac{(\mu\gamma - 1)(f\bar{y}(\psi) - \beta c(\psi))(\lambda'(\psi)n(\psi) + \lambda(\psi)n'(\psi))}{\rho - \lambda(\psi)n(\psi)(\mu\gamma - 1)} = 0 \tag{28}$$

where $\bar{y}$, n, c, and λ are all functions of ψ.

The first two terms on the left hand side of equation (16) represent the net instantaneous marginal benefit due to changes in the level of IBA, ψ. For example, an increase in ψ will

[15] This occurs because the size of each innovation is the same, γ. If the size of each innovation were not the same, then the government may want to choose a different level of IBA for each innovation.

decrease the flow rate of innovation, which causes workers to leave the R&D sector and enter the final good sector. This in turn raises output, so the government collects more rent and the increase in ψ increases the marginal cost.

In addition to this instantaneous marginal benefit and marginal cost, changes in ψ, and hence λ, affect the expected present value of future innovations. This is represented by the last term on the left hand side of equation (16). First, note that $(\lambda' n + \lambda n')$ is always negative. Thus the sign of the right hand side depends on the sign of $(\mu\gamma - 1)$. If $\mu\gamma > 1$, innovation is on net beneficial to the government, and the term on the right hand side is positive and can be interpreted as the cost of lowering the expected present value of future innovations when implementing a higher ψ. If the government increases the difficulty of innovation, this expected present value is lowered. If $\mu\gamma < 1$, innovation is on net harmful to the government, and the right hand side is negative and can interpreted as the benefit of increasing the expected present value of future innovations. If the government increases the difficulty of innovation, the expected present value is increased. Note that if there were no cost to blocking innovation, that is if $c(\psi) = 0$ for all $\psi > 0$, and $\mu\gamma < 1$, then a government would elect to block all innovation in order to remain in power. In summary, a government that is relatively stable accrues an extra cost in blocking innovation, in addition to the increase in c (represented by c'), and a government that is relatively unstable accrues an extra benefit in blocking innovation, in addition to the increase in y (represented by $fy\prime$). We believe that the case of $\mu\gamma < 1$ is the case most relevant for countries the experience prolonged stagnation, for in this case the government is actually hurt (from an ex-ante point of view) by innovation and has an extra incentive in blocking innovation. If $\mu\gamma > 1$ then the government will only try to discourage innovation if 'too much' research is being performed so that the government would like to move some of the R&D workers into the final good sector. Otherwise, it sets $\psi = 0$. Given this, we will assume in the following analysis that $\mu\gamma < 1$.

Let ψ^*be the level of IBA that solves the government's problem. To explain why some governments adopt growth promoting policies (i.e. a lower ψ^*), while other governments adopt growth deterring policies (i.e. a higher ψ^*), we have to examine the effect of changes in (i) the level of rents (f), (ii) the probability of a government staying in power (μ), (iii) the cost technology associated with blocking innovation (β), and (iv) the size of each innovation (γ), on the optimal level of IBA chosen by the government (ψ^*).

Given equation (1), define the function G, as:

$$G(f,\mu,\gamma,\beta,\psi^*) = f\overline{y}'(\psi) - \beta c'(\psi) + \frac{(\mu\gamma - 1)(f\overline{y}(\psi) - \beta c(\psi))(\lambda'(\psi)n(\psi) + \lambda(\psi)n'(\psi))}{\rho - \lambda(\psi)n(\psi)(\mu\gamma - 1)} = 0 \tag{29}$$

Then, using the implicit function theorem (with the appropriate regularity conditions), the partial derivatives that need to be calculated are:

$$(i)\ \frac{\partial\psi^*}{\partial\mu} = -\frac{\partial G}{\partial\mu}/\frac{\partial G}{\partial\psi^*}$$
$$(ii)\ \frac{\partial\psi^*}{\partial\gamma} = -\frac{\partial G}{\partial\gamma}/\frac{\partial G}{\partial\psi^*}$$
$$(iii)\ \frac{\partial\psi^*}{\partial\beta} = -\frac{\partial G}{\partial\beta}/\frac{\partial G}{\partial\psi^*}$$
$$(iv)\ \frac{\partial\psi^*}{\partial f} = -\frac{\partial G}{\partial f}/\frac{\partial G}{\partial\psi^*}$$

To solve the above, it is important to note that $\frac{\partial G}{\partial\psi^*}$ is simply the second-order condition for profit maximization. It can be shown that there exists a $\overline{\psi}$, such that for any $\psi > \overline{\psi}$, $\frac{\partial G}{\partial\psi} < 0$, thus the solution to the government's wealth maximization problem exists.

We are now ready to state the main result of this section:

Given an interior solution to the government's maximization problem, the following hold

(i) The more politically threatened a government is by innovation, the more innovation it will block.

(ii) The greater the degree of rent seeking by the government, the more innovation will be blocked.

(iii) The more costly innovation blocking is, the less innovation will be blocked.

Proof: See Appendix.

Part (i) states that $\frac{\partial \psi^*}{\partial \mu} < 0$. This should be intuitive. Note however that just because the government faces some probability of losing power if an innovation occurs does not mean that the government will necessarily block innovation. The exact level of IBA ψ^* that is implemented depends not only on μ, but also on the other parameters in the model. For example, if the costs associated with blocking innovation are high enough, an unstable government will not block innovation. Thus a government that may lose power from innovations may still choose not to block innovation (set $\psi = 0$), or block very little innovation (set ψ small), because the costs associated with blocking are greater than the benefits. If a country has very good institutions, and hence blocking innovation is very costly, then no innovation will be blocked even in the presence of instability.

Part (ii) states that $\frac{\partial \psi^*}{\partial f}$ ¿ 0. The greater the degree of rent-seeking by the government, the higher is the amount of innovation that is blocked. For a higher f the cost of any IBA level, $A_t \beta c(\psi)$, is a smaller share of total rents $f y_t$ so this cost influences the choice of ψ^* less. For example, if rent-seeking is limited, then the government may not block innovation even if μ is small, simply because the costs are large relative to the size of the rents collected.

Part (iii) states that $\frac{\partial \psi^*}{\partial \beta} < 0$. The higher the costs associated with blocking innovation, the lower the level of IBA. High quality of institutions, such as rule of law, are represented by a large value of β.

In general, the effect of an increase in the size of each innovation on the optimal level of IBA is ambiguous. An increase in γ tends to reduce the extra benefit that the government gets from blocking innovation. But by moving workers from the production sector into the R&D sector, this also increases $f\bar{y}'$ the benefit the government receives by increasing ψ and shifting workers from R&D into final output production. If the marginal benefit from shifting workers from the R&D sector to the production sector is small enough, so the first effect dominates, then less innovation will be blocked.

The Model with Endogenous Instability

In the previous sections, it was assumed that the probability of a government staying in power after an innovation (μ) is exogenous. In this section, we present a simple method of endogenizing this probability. The idea formalized below is that the incumbent monopolist may be replaced by one that is relatively less supportive of the current regime. Basically, economic changes may result in the 'wrong' groups acquiring economic power and influence.

Let us assume that each firm has preferences over the location of the government where $Q \in [0,1]$ represents the current location of the government. The location of government can be interpreted as location on some sort of political spectrum (right vs. left) or more generally over some set of policies. It could also represent regional or ethnic differences.[16] Although we have not been explicit about the ownership of firms in this economy, if we think of each firm being owned by one individual, then the preferences of that firm would simply be the preferences of that individual over the type of government in the country. More generally, if financial development is such that shareholders in a firm form a relatively

[16]See Alesina and Spolaore (1997) for an example of using spatial location to represent different 'types' of governments.

homogenous group (as may occur in underdeveloped economies) then firms could be thought of as having political preferences above and beyond those associated with government policy that directly affects the profits of the firm. If the individual's firm is not the monopolist then his preferences simply 'don't count' since they are not backed by monopoly profits.[17] The preferences of the firms are uniformly distributed over the interval [0,1] where $\sigma_i \in [0,1]$ is the ideal location of the government for firm i.

When the innovation occurs and firm i becomes the incumbent monopolist, it can attempt to unseat the current government. Since in our simple model the incumbent monopolist represents the only source of concentrated economic power outside of the political elites, it seems natural that any serious attempts to change the regime must originate from (or at least have the backing of) that power. If the firm attempts to unseat the government, it will be successful with probability v. If the attempt is successful, the current government is removed and the new government's location is the firm's ideal location σ_i. If the attempt is unsuccessful, the monopolist loses the monopoly and the current innovation is given to a firm arbitrary close to the government.

The utility of the incumbent firm is:

$$U_t^i = V_t - A_t l \left| Q - \sigma_i \right| \tag{30}$$

where l is a parameter that measures the importance of government location relative to monopoly profits. The term A_t is included so that as t becomes large the relative importance of government location to profits stays unchanged.

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[17]Here we are assuming that the country is not a full fledged democracy so government location is not chosen through popular vote. Even with voting, money can still effect government location through campaign contributions, etc. We would expect that the main results of the analysis below would still hold in that case.

Firm i will attempt to unseat the regime if :

$$V_t - A_t l\,|Q-\sigma_i| < vV_t + (1-v)0 \tag{31}$$

which can be written as :

$$|Q-\sigma_i| > (\frac{1-v}{l})\frac{\bar{\pi}}{r+\lambda n} \tag{32}$$

where $\bar{\pi} = \frac{\pi}{A_t}$ is the productivity adjusted profit.

Suppose an innovation has occurred and a new monopolist emerges with preferences, σ_i. Then the probability of an attempt to unseat the government occurring is:

$$\mu_0 = prob\left[|Q-\sigma_i| > (\frac{1-v}{l})\frac{\bar{\pi}}{r+\lambda n}\right] \tag{33}$$

So $\mu = 1 - \mu_0 v$, and it is relatively simple to solve for μ_0, since the distribution is uniform. Depending on the parameters of the model (e.g. l etc.), if the new monopolist if far enough from the current government, it will attempt to dislodge the government.

Note that μ_0, and hence μ, is a function of ψ, the level of innovation blocking activity chosen by the government. It is not difficult to show that $\mu' > 0$. The reason why a firm is less likely to try to unseat the current government if ψ is increased is straightforward. Blocking more innovation raises the present value of expected profits to the incumbent firm by raising current profits ($\frac{\partial \bar{\pi}}{\partial \lambda} < 0$) and by making innovation less likely to occur so that the discount term $r+\lambda n$ decreases. Any new monopolist will earn more profits and therefore has more to lose if a revolt is unsuccessful and thus it will be less likely that a new monopolist will revolt.

With this we can rewrite the government's first order condition as :

$$f\bar{y}'(\psi) - \beta c'(\psi) + \frac{(\mu(\psi)\gamma - 1)(f\bar{y}(\psi) - \beta c(\psi))(\lambda'(\psi)n(\psi) + \lambda(\psi)n'(\psi))}{\rho - \lambda(\psi)n(\psi)(\mu(\psi)\gamma - 1)} +$$
$$\frac{(f\bar{y}(\psi) - \beta c(\psi))(\lambda(\psi)n(\psi)\gamma)\mu'(\psi)}{\rho - \lambda(\psi)n(\psi)(\mu(\psi)\gamma - 1)} = 0 \tag{34}$$

The term $\frac{(f\overline{y}(\psi)-\beta c(\psi))(\lambda(\psi)n(\psi)\gamma)\mu'(\psi)}{\rho-\lambda(\psi)n(\psi)(\mu(\psi)\gamma-1)}$ is always positive since $\mu' > 0$, so it represents an additional benefit to the government from raising ψ.

Thus by endogenizing the probability of innovation threatening the political power of the government we find that the government has an extra incentive in blocking innovation in order to 'bribe' the incumbent monopolist for its support. A 'coalition' between the political elites and the economic elites (the monopolist) could emerge if ψ is sufficiently high so that $\mu = 0$ (or is very small).

Up to this point in the analysis we have implicitly been assuming that firms engaging in research do not take into account the benefit they may receive if they become the monopolist and are able to replace the current government with one closer to their preferences. This myopic behavior by firms may be justified if they are simply unaware of the political power that economic power will bring. If we drop this assumption,retaining the competitive labor market, then only the firms at the 'extreme' of the preference interval will engage in research, other firms being priced out by high wages. This implies that only fringe groups (in terms of preference of government location) pursue R&D. This formulation has some appeal, as it explains situations where minority groups are the most economically active in a society. We feel, however, that it is more reasonable to assume that the political benefits of being the monopolist are not that clear ex-ante, so all types of firms will engage in R&D.

We are now ready to state the main result of this section:

Proposition 2. *Given an interior solution to the government's maximization problem, the following holds:*

(i) The greater the degree of rent seeking by the government, the more innovation will be blocked.

(ii) The more costly innovation blocking is, the less innovation will be blocked.

(iii) The more important government location is relative to monopoly profits, the more innovation will be blocked.

(iv) The greater the probability of successfully unseating the current regime following an innovation, the more innovation will be blocked. Proof: The proof of the above is a simple extension of the methodology used in proving Proposition 1.

Parts (i) and (ii) in Proposition 2 have the same interpretations as Parts (ii) and (iii) in Proposition 1.

Part (iii) states that $\frac{\partial \psi^*}{\partial l} > 0$. The probability of staying in power after an innovation depends on l, with higher l in general associated with greater instability (higher μ). If government location (the identity and/or set of policies of the government) is very important to firm owners, the more unstable the government and the lower the growth rate. An example of this would be the case of a country with strong regional or ethnic divisions. If the current government does not share the same identity with the current monopolist (the group with concentrated economic power) then the government will tend to be more unstable.

Part (iv) states that $\frac{\partial \psi^*}{\partial v} > 0$. The more likely that attempts to unseat the government will be successful, the more incentive the government has to block innovation.

This model predicts that, holding other things fixed, a country with a government at an 'extreme' location (ie. a location near 0 or 1 on the political/ethnic spectrum) would experience more innovation blocking and less growth than a country with a government with a more 'moderate' government (ie. a government located closer to the center of the political/ethnic spectrum). The reason behind this is straightforward. The 'extreme' government faces a higher probability that an innovating firm's political preference will be far enough from the government's location that the firm will attempt to unseat the government, than would a more 'moderate' government. Thus an 'extreme' government would have more incentive to block innovation to prevent any political instability, than would a more centrally located 'moderate' government.

Empirical Evidence

The model assumes that the stability of a government can be threatened by innovation in the economy, and that the ability of the government to block innovation depends on how costly blocking is, that is, how good the country's institutions are. In a country with good rule of law, we would expect it to be more difficult for a government to try to block innovation than in a country without a rule of law tradition. Building on this, it is reasonable that ethnolinguistic fractionalization could measure how potentially threatened by innovation a country's government would be. The more distinct groups that are in a country, the more likely innovation may bring economic power to a group that opposes the current government. This interpretation fits well with the model presented in Section 5.

The model predicts that in countries with good institutions, high levels of ethnic fractionalization should have little effect on the growth rate since it would be too costly for a government to block innovation even if it was in its interest to do so. For countries with poor institutions, high levels of ethnolinguistic fractionalization should be correlated with lower growth since it would be relatively easier for a threatened government to block innovation.

Easterly (2000) tests a similar hypothesis by analyzing the interaction effect of ethnic diversity and institutional quality. Using an index of ethnolinguistic fractionalization (ETHNIC) and a measure of institutional quality (INSTITUTIONS), Easterly performs a regression of the real GDP per capita growth on commonly used control variables, the variables ETHNIC and INSTITUTIONS and an interaction term of these last two variables (His results are presented in Table 1). Easterly finds that by adding the interaction term, ethnic diversity has a significant negative impact on long-run growth (as opposed to the insignificant effect of the INSTITUTIONS term), but strong institutions reduce the negative effects of ethnic diversity. As he puts it, "Ethnic diversity has a more adverse effect on economic policy and growth when institutions are poor. To put it another way, poor institutions have an even more adverse impact on growth and policy, when ethnic diversity is high. Conversely, in countries with sufficiently good institutions, ethnic diversity does not lower growth or worsen economic policy."

Collier (2000) also tests to see the effects of political rights and ethnic fractionalization on economic growth. He regresses cross-country against a standard set of control variables, a variable measuring Ethnolinguistic fractionalization (Elf), a variable measuring political rights and a term interacting the last two variables (See Table 2 for his results). In the baseline regression, Collier finds that increased political rights raises the growth rate, while fractionalization reduces it. After including the interaction term the individual effects of ethnic diversity and political rights on growth vanish, while the interaction term is found to be significant. As Collier notes, "The lack of political rights is economically ruinous in ethnically highly fractionalized societies."

Both the empirical analyses above are consistent with the model presented in this paper.

Conclusion

This paper presents a simple model that explains why some governments choose policies that discourage innovation and lower growth. At the heart of the paper is the idea that a government's stability may be threatened by innovation in the private sector. A government then faces both costs and benefits in choosing any given level of innovation blocking activities. The exact level of IBA chosen (if any) will depend on the interplay of the various parameters in the model. For the case where innovation is on average harmful to the government the following holds: Increases in the probability of losing power following innovation tends to increase the level of IBA and reduce growth. Increases in the degree of rent-seeking by the government tends to increase the level of IBA and reduce growth. Increases in the cost of implementing IBA will tend to decrease the level of IBA and raise growth.

If government blocking innovation, and in general if government adopting polices that are bad for growth. are a major reason why some countries remain poor then understanding the institutional environment in which governments operate is essential to understanding economic growth. To explain why Western Europe was the first region of the world to industrialize and enter on the path of modern growth it seems essential to us to include a discussion of the institutional factors that encouraged innovation and change. Although there has been a large amount of conceptual work done on the impact of institutions on economic growth (for example see North, etc.) relatively little formal modeling has been done. This model highlights the way in which government policy, which is influenced by institutional factors, can affect economic growth. We feel that the explicit modeling of institutional factors in economic growth is an exciting and important research area that needs to be further developed.

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Appendix

Proof of Proposition 1

Part (i): We need to show that for $\psi^* > 0$, $\frac{\partial \psi^*}{\partial \mu} < 0$.

For $\psi^* > 0$ we have an interior solution so that $\frac{\partial G}{\partial \psi} < 0$, therefore we need to show that $\frac{\partial G}{\partial \mu} < 0$.

$$\frac{\partial G}{\partial \mu} = \frac{\gamma(f\bar{y} - \beta c)(\lambda n)'}{\rho - \lambda n(\mu\gamma - 1)} + \frac{(\mu\gamma - 1)(f\bar{y} - \beta c)(\lambda n)'(\lambda n\gamma)}{[\rho - \lambda n(\mu\gamma - 1)]^2}$$

The above can be rewritten as:

$$\frac{\partial G}{\partial \mu} = \frac{\gamma(f\bar{y} - \beta c)(\lambda n)'}{\rho - \lambda n(\mu\gamma - 1)}[1 + \frac{(\mu\gamma - 1)(\lambda n)}{\rho - \lambda n(\mu\gamma - 1)}]$$

This will be less than zero (keeping in mind that $(\lambda n)' < 0$) if

$$1 + \frac{(\mu\gamma - 1)(\lambda n)}{\rho - \lambda n(\mu\gamma - 1)} > 0 \Rightarrow \rho - \lambda n(\mu\gamma - 1) + (\mu\gamma - 1)(\lambda n) > 0$$
$$\Rightarrow \rho > 0$$

which is true by assumption

Part (ii): We need to show that for $\psi^* > 0$, $\frac{\partial \psi^*}{\partial f} > 0$.

For $\psi^* > 0$, we have an interior solution so that $\frac{\partial G}{\partial \psi} < 0$ therefore we need to show that $\frac{\partial G}{\partial f} > 0$.

$$\frac{\partial G}{\partial f} = \bar{y}' + \frac{(\mu\gamma - 1)\bar{y}(\lambda n)'}{\rho - \lambda n(\mu\gamma - 1)}$$

This will be greater than zero (keeping in mind that if $(\lambda n)' < 0$) if $\mu\gamma < 1$.

Part (iii): We need to show that for $\psi^* > 0$, $\frac{\partial \psi^*}{\partial \beta}. < 0$.

For $\psi^* > 0$, we have an interior solution so that $\frac{\partial G}{\partial \psi} < 0$ therefore we need to show that $\frac{\partial G}{\partial \beta} < 0$.

$$\frac{\partial G}{\partial \beta} = -1 + -\frac{(\mu\gamma - 1)c(\psi)^*(\lambda n)'}{\rho - \lambda n(\mu\gamma - 1)} < 0 \Rightarrow \frac{\partial \psi^*}{\partial \beta} < 0$$

The sign of $\frac{\partial\psi^*}{\partial\gamma}$ is in general ambiguous. To see this, note that

$$\frac{\partial G}{\partial\gamma} = \frac{\mu(f\bar{y}-\beta c)(\lambda n)'}{\rho-\lambda n(\mu\gamma-1)}[1+\frac{(\mu\gamma-1)(\lambda n)}{\rho-\lambda n(\mu\gamma-1)}]+f\frac{\partial\bar{y}'}{\partial\gamma}+\frac{(\mu\gamma-1)(f\bar{y}-\beta c)\frac{\partial(\lambda n)'}{\partial\gamma}}{\rho-\lambda n(\mu\gamma-1)}+$$

$$\frac{(\mu\gamma-1)(\lambda n)' f\frac{\partial\bar{y}}{\partial\gamma}}{\rho-\lambda n(\mu\gamma-1)}+\frac{(\mu\gamma-1)^2(f\bar{y}-\beta c)(\lambda n)'\lambda\frac{\partial n}{\partial\gamma}}{(\rho-\lambda n(\mu\gamma-1))^2}$$

From the steady state equation for x, $x=[\frac{r}{\lambda}+L](1+\gamma(\frac{1}{\alpha}-1))^{-1}$ it is not difficult to show that

$$\frac{\partial\bar{y}}{\partial\gamma}<0, \frac{\partial\bar{y}'}{\partial\gamma}>0 \text{ and } \frac{\partial n}{\partial\gamma}>0, \frac{\partial(\lambda n)'}{\partial\gamma}<0$$

It can then be seen that in general the sign of $\frac{\partial G}{\partial\gamma}$ could be either positive or negative depending on the exact specification of the model. It follows that the sign of $\frac{\partial\psi^*}{\partial\gamma}$ is ambiguous.

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WHY CHADS? DETERMINANTS OF VOTING EQUIPMENT USE IN THE UNITED STATES

with Enrico Spolaore

Introduction

The bizarre turn of events that followed the November 7, 2000 presidential election brought unprecedented attention to the use of different voting equipment in the United States. In particular, the reading of punchcard ballots in a few Florida counties became the subject of heated legal disputes that ended with a controversial U.S. Supreme Court ruling on December 12, 2000. During the Florida crisis the media were filled with detailed reports on the mechanics of different voting equipment. Colorful expressions, such as "hanging chads" and "pregnant chads," entered the national vocabulary.[18] That crisis has spurred an ongoing debate on voting equipment choice and election reform. Proposals to develop national or state standards for conducting elections and to fund voting equipment upgrades have been introduced in the U.S. Congress and in numerous state capitals. Voting equipment has moved from being a minor, local aspect of elections to representing an important national issue.

A striking aspect of voting equipment usage in the U.S. is its heterogeneity. All sorts of systems are used across the nation. American voters mark paper ballots, pull levers, punch cards, fill optically-readable forms, or touch electronic screens. Data obtained from Election Data Services (EDS) show the following distribution of voting equipment types across counties in 1999: optical scanners 38.8 % of counties; punchcard machines 20.2 %; electronic machines 8.2 %; lever machines 15.3 %; paper ballots 13.1 %. The distribution as a percentage of registered voters was: punchcard machines 34.1 %; optical 27.6 %; lever

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[18]For an explanation of this terminology, see Section 2.

18.5 %; electronic 9.1 %; paper 1.6 %.[19]

The machines currently in use are based on technologies spanning over a century. Optical and electronic machines have been adopted since the late 1970s. Punchcard voting machines were first introduced in 1964. Lever machines were first used in statewide elections in 1892. In fact, virtually *each* type of voting equipment ever introduced in the U.S. since the 19th century is still used somewhere in the country.[20] More detailed information on the history and characteristics of voting equipment is reported in Section 2.

Such heterogeneity is partly the result of decentralization. While many other democracies have unified national voting systems, in the U.S. choices over voting equipment are highly decentralized - mostly at the county and municipal level.[21] This situation raises an important question: What explains the use of different voting equipment? Why do some counties use punchcard machines (or even older lever machines, or just paper ballots), while other counties use more advanced optical scanners or electronic machines? In a nutshell, Why Chads?

The question is worth addressing for at least two reasons:

1) Voting equipment matters. While the Supreme Court decision in December 2000 ended the legal battle over the recounting of votes in a few Florida counties, the debate over the causes and consequences of voting equipment choice is not over. In a way, it just started, and is here to stay. Such debate can certainly benefit from more accurate and

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[19] The remaining 4.5 % of counties, containing 9.1 % of registered voters, used 'mixed systems' (i.e., two or more types of equipment).

[20] Our main source for historical information is the Federal Election Commission (www.fec.gov/elections.html).

[21] Heterogeneity is only minimally reduced within states. In Pennsylvania, Virginia and several other states *each* type of available equipment is used by one or more counties.

systematic information about the determinants of voting equipment use.

2) By learning about the determinants of voting equipment use across U.S. counties, we can obtain more general insights on the adoption of innovation by public authorities. For decades all over the U.S. local authorities have quietly run a fascinating natural experiment on the adoption of technological innovation in vote-tallying. From it we may learn something useful about the way innovations in general are (or are not) adopted across different jurisdictions.

Why do some counties use older voting machines while others use more updated ones? Vice-President Al Gore among others suggested that those differences reflect economic inequality:

> "The old and cheap, outdated machinery is usually found in areas with populations that are of lower income, minorities, seniors on fixed incomes." (Gore, 2000)

The view that older machinery is used in poorer counties is intuitively appealing, and has been widely reported in the media. For example, according to *The Economist* (June 9, 2001, p. 32) "everybody knows that the worst voting machinery is concentrated in poor areas." Somewhat surprisingly, such widespread belief does not seem to be consistent with the data on the distribution of voting equipment types across counties. In Section 3 we show that, on average, machines of older types are not used in relatively poorer counties. When data on voting equipment from Election Data Services (EDS) are matched with the most recent census data, one finds that the median household income in counties using lever and punchcard machines (the older machinery) is higher than in counties using optical scanners or electronic machines (the newer machinery). Also, summary statistics do not provide *prima facie* evidence that machines of older types are disproportionately used in counties with larger minorities or older population.

In Section 3 we also present logit regressions with different types of equipment as dependent variables. This more formal analysis is consistent with the patterns suggested by the summary statistics. Specifically, we find evidence against the hypothesis that lower income increases the probability of using lever or punchcard machines rather than optical scanners or electronic machines, controlling for other potential determinants of voting equipment choice. If anything, richer counties seem to be more likely to use machines of older type.

Is there a "paradox of chads"? Should we be surprised to find out that many richer counties use older technology, such as punchcard machines, while a large number of relatively poorer ones have switched to more advanced machinery?

We think that this "paradox" can be explained by taking into account the dynamic nature of voting equipment choice. In other words, as we will see, *history matters.*

Specifically, our explanation hinges on two points:

1) all other things equal, a richer county is more likely to adopt a more advanced technology, but

2) among all things that must be equal we should include the county's current technology.

If the richer county has already adopted a more advanced technology in the past, it will benefit less from adopting and even more advanced technology in the future, while the adoption of the newest technology will have the highest benefits in counties that are still using much older technology. As a consequence, richer counties may be leapfrogged by poorer counties.

Section 4 presents a simple model which is consistent with these ideas. The model is consistent with a positive relationship between current income and use of older machinery. However, the model predicts that, once past income has been controlled for, the relationship between current income and use of older machinery should be negative.

Section 5 examines whether the available empirical evidence is consistent with our hypotheses. First, we show that between 1980 and 2000 the share of counties that used optical or electronic machines went from 1 percent to 49.1 percent. The transition took place through reductions in the number of counties that used paper ballots (from 40.4 percent to 12.5 percent) or lever machines (from 36.4 percent to 14.7 percent). By contrast, the share of counties that used punchcard machines barely moved (19.1 versus 19.2). This pattern is consistent with our story.

In order to provide a more direct and formal test of our hypothesis, in Section 5 we also present logit estimates using past values for income. The results provide support for our model. We find that:

1) Income in 1969 has a positive effect on the probability of using older equipment in 1999. In the case of punchcards, such effect is one order of magnitude larger than the effect of 1989 income when one does not control for 1969 income.

2) When income in 1969 is included in the regression, the effect of income in 1989 becomes *negative* (for punchcard machines) or insignificant (for lever plus punchcard).

In other words, the positive correlation between most recent income and use of older equipment is explained by the positive correlation between most recent income and past income. When past income is explicitly taken into account, the effect of current income - as predicted by our model - becomes negative or insignificant.

Hence our analysis provides a consistent explanation for the "paradox of chads." "Chads" are found in counties that used to be richer in the 1960s, when punchcard machines were adopted - and, therefore, on average, are still likely to be richer today. When past income is controlled for, a "nonparadoxical" negative relationship between present income and use of older, outdated equipment emerges.

In Section 6 we extend the analysis to explicitly include another important variable along with income: population size. We argue that, all other things equal, a larger population increases the probability of adopting more advanced voting technology. The aggregate cost of adopting a new technology includes a significant fixed component, which is independent of size. Henceforth, cost per capita is decreasing in the size of a county. Moreover, benefits from adopting more advanced technology may be positively related to total size (for example, the benefits from speedy vote-tallying may be higher in larger counties). Does this imply that larger counties - controlling for income - will be more likely to use more advanced technology? No, for the same reasons why a higher income does not guarantee a better technology. Section 6 contains an empirical analysis of the relationship between historical levels of population and current usage of voting equipment. The results are consistent with our general point. The probability of using lever machines in 1999 is *positively* related to population in 1930 (when larger counties were more likely to adopt state-of-the-art lever machines), but negatively related to population in 1990, when larger counties were more likely to adopt more advanced electronic machines, other things being equal. By the same token, the probability of using punchcard machines is negatively related to population in 1930, but positively related to population in 1970, when punchcard machines were being adopted.

Finally, a word of caveat about the purpose and limits of our analysis. Our paper does not intend to assess whether the distribution of voting equipment in the 2000 election has resulted in the undercount of the votes cast by specific groups (democrats, minorities, etc). Such analysis is beyond our goals and our data. Even further from our objectives is to join the legal and political controversy on the Florida recount, for which we are clearly unqualified. Our study intends to contribute to the ongoing debate on voting equipment choice by making a separate point: cross-county differences in types of voting equipment - *whatever implications* they may have had for different groups of voters in past elections - do not reflect current economic inequality across U.S. counties. Rather, they are the complex result of a series of historical decisions affected by past values of income and population.

In summary, the strikingly heterogeneous distribution of voting equipment in the U.S. can be best understood as reflecting an intriguing "archeology" of historical decisions and trends. In a way, the political economy of voting equipment is like a time machine. New York and Connecticut's antique lever machines mirrors the past economic and demographic preeminence of the Northeast. Punchcard machines in Atlanta, Los Angeles, and Miami witness the expansion of those regions after the Second World War. The electronic machines of New Mexico speak about today's economic and demographic realities.

Types of voting equipment in the United States

As reported by Election Data System, as of April 1, 1999, the 3141 U.S. counties used five different systems to count votes:

1) Paper ballots: 407 counties.

2) Lever machines: 476 counties.

3) Punchcard machines: 625 counties.

4) Optical scanners: 1231 counties.

5) Electronic machines: 261 counties

The remaining 141 counties used mixed systems.[22]

The paper ballot system is the oldest method.[23] It was first adopted in Australia in 1856, and introduced in the U.S. in the second half of the 19th century. In its current form, the paper ballot system employs uniform official ballots on which the names of all candidates are printed. Voters privately record their choices by marking the boxes next to the candidate they select and drop the voted ballot in a sealed ballot box. Many industrial democracies, including Canada and Italy, use paper ballots as their exclusive voting system.

Lever machines were first employed in Lockport, New York in 1892, and were adopted statewide a few years later. According to the Federal Election Committee (2001) "by 1930, lever machines had been installed in virtually every major city in the United States, and by the 1960s well over half of the Nation's votes were being cast on these machines." On lever machines, each candidate is assigned a lever identified by a printed strip. Voters pull down selected levers to indicate choice. When the voter exits the booth, the voted levers are automatically returned to their original position, causing a connected counter wheel to turn. The position of each counter at the close of the polls indicates the number of votes cast on the lever that drives it. Lever machines are no longer made. According to the Federal Election Commission, "the trend is to replace them with computer-based marksense or direct recording electronic systems."

Punchcard voting systems were first used in 1964 by Fulton and De Kalb Counties (Georgia), Lane County (Oregon) and San Joaquin and Monterey Counties (California).

[22]Mixed systems are mainly found in those states, such as Massachusetts and Michigan, in which decisions over vote equipment are not taken by counties but by towns.

[23]The historical information in this section has been obtained from the Federal Election Commission (www.fec.gov/elections.html).

Voters punch holes in the card with a supplied pin. The resulting leftover piece of paper is referred to as a chad (a term of unknown origin).[24] With votomatic cards, the locations at which holes may be punched are assigned numbers. With datavote cards the name of the candidate is printed on the ballot next to the hole to be punched.[25] After voters have punched their cards, ballots are fed into a computer vote-tabulating device.

Optical scanners recognize marks on paper through optical reading techniques. Voters record their choices by filling in a rectangle, circle or oval. The tabulating device reads the votes using 'dark mark logic' (i.e., by selecting the darkest mark within a given set). Optical scanned ballots have been adopted in the U.S. since the 1970s. Optical scanners (also known as 'marksense optical scan systems') are currently considered "state-of-the-art" voting technology, and directly compete with the last type of voting system, electronic machines. With electronic machines (also known as "direct recording electronic" systems, or DRE), the voter directly enters choice with the use of a touch-screen or similar device. The voter's choice are electronically stored via a memory cartridge, diskette or smart card.

Until the early 1970s there existed no national standards on voting equipment. In 1975 the General Accounting Office's Office of Federal Elections sponsored an influential report (*Effective Use of Computing Technology in Vote-Tallying)* which called for more computerization. In 1984 the federal government issued a report on the *Feasibility of Developing Voluntary Standards for Voting Equipment* (Federal Election Commission and National Institute of Standards and Technology, 1984). In a subsequent report, also sponsored by

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[24]Imperfectly punched chads include "hanging chads" (one corner of the chad is hanging on the punchcard), "swinging chads" (two corners are attached to the card), and "pregnant chads" (a hole is punched through a fully attached chad).

[25]Votomatic systems were used by 18.4 % of the counties in 1999. Datavote systems were used by 1.8 % of counties. Since the two systems are basically identical, we aggregate them as "punchcard systems." Our results would not change if we were to consider them as separate systems.

Federal Election Commission and the National Institute of Standards and Technology, Roy Saltman (1988) recommended to phase out punchcard machines in favor of optical scanners and electronic machines. In 1990, the Federal Election Commission proposed the first national performance and test standards for punchcard, optical and electronic voting systems. Decisions on whether to follow the Commission's guidelines and on the actual choice of voting equipment were left to local officials. The recent events in Florida have highlighted one of the technical problems with punchcard machines, that is, the possibility of "undercount" because of imperfectly displaced chads. The relative merits of optical scanners and electronic systems are currently debated by experts and politicians.[26] Both systems are currently purchased by U.S. local officials. A recent study by Ansolabehere et al. (2001), issued as part of the Caltech/MIT Voting Technology Project, has used "residual votes" (i.e., ballots cast for which no presidential preference was counted) as yardstick for "reliability," and has concluded that paper ballots, lever machines and optical scanners are more "reliable" (i.e., less likely to produce uncounted ballots) than punchcard machines and electronic machines. In fact, the oldest system of all, paper ballots, seems to be the most reliable. We will return on these issues in Section 4, when we model the adoption of voting equipment by county officials.

Determinants of voting equipment use: a preliminary analysis

As a first step towards understanding the determinants of voting equipment choice, we consider the following county characteristics:

1) Median household income (1989).

[26] A related controversy has involved the different consequences of precint counting versus central counting of optically scanned ballots (e.g. see Commission on Civil Rights, 2001). Our data does not contain details on different uses of machines of the same type.

2) Population (1990).

3) % Population 65 years or older (1990).

4) % Population classified as minorities (1990).

5) % Population 25 percent or older with Bachelor's degree or higher (1990).

6) Local government revenues per capita (1986-97).

The summary statistics for these variables are reported in Table 1.

Average median household income in 1989 was $28,817 in counties with lever machines, $30,584 in counties with punchcard machines, $28,124 in counties with optical scanners; and $27,992 in counties with electronic machines. That is, lever and punchcard systems are used in counties with incomes above the average median income for all counties. By contrast, median income in counties that use optical or electronic is (slightly) below average. The lowest income is found in counties that use paper ballots ($24,799).

The summary statistics also show that punchcard counties, on average, have a substantially larger population (140007 inhabitants versus an average for all counties equal to 79182 inhabitants). Counties that use lever and electronic machines also have populations larger than average, although the difference is not as large as in punchcard counties. By contrast, counties that use optical scanners are smaller (54601 inhabitants) than average.

The percentage of minorities is higher (19.8 %) in counties that use levers, and lower in counties that used punchcard machines (12.5%), when compared to optical and electronic (17.7% and 16.7% respectively). The percentage is also lower for paper ballots (11.4%). The percentage of seniors is 18% in counties with paper ballots, 14% in counties with levers and optical, 15% in counties with optical, and 13% in counties with electronic.

In order to investigate systematically the relationship between voting methods and county characteristics, we have performed logit estimations (tables 2-4). Logit estimates with each type of counting method as dependant variable are reported in tables 2a-2d. In each table, column (i) shows estimates when only income and population are used as independent variables. In column (ii) we add additional controls (seniors, minorities, population with bachelor's population, all as percentages of the population, plus local government revenues per capita).[27] Column (iii) and (iv) reports standard errors using Huber/White estimators of variance with clustering by state. In table 2e we show logit estimates when we aggregate lever and punchcard machines. In table 2f we show logit estimates when we ask what is the probability of using lever and punchcard machines versus optical and electronic (that is, we drop paper ballots from the sample). Multinomial logit estimates are shown in tables 3 and 4. Table 3 reports multinomial logit estimates using punch card as the base group for comparison. Table 4 reports multinomial logit estimates using punch/lever as the base group (Huber/White standard errors are shown in tables 3b and 4b).[28]

Overall, the logit estimates tend to confirm the regularities one can detect from the summary statistics:

a) paper ballots are used in poorer and smailer counties.

b) we can reject the hypothesis that a lower income increases the probability of using older machines (levers and punchcards) rather than newer machines (optical and electronic). If anything, there seem to be some evidence for the opposite correlation.[29]

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[27]We also performed estimations with additional variables (population density and percentage of votes for the democratic candidate in presidential elections). The variables turned out insignificant and did not change the results.

[28]We have also performed logit estimates with state dummy variables, to control for state effects. The introduction of such dummies does not change the overall results.

[29]This result should not be confused with the prediction that, should one run an "ordered" logit regression, "newer" machines would not be correlated with "higher" income. Since poorer counties *do* use older voting systems (paper), forcing a monotonic relationship on the data may in some cases generate positive estimates

c) analogously, one can reject that a larger percentage of minorities or seniors in the population is associated with a higher probability of using lever machines and/or punchcard machines.

d) higher population is associated with the use of older machines.

Does the lack of a negative correlation between income and older equipment mean that economic considerations are not relevant for the choice of voting equipment? Not at all. In the following section we develop a simple model that can help shed some light on the relationship between income and voting equipment choice.

A model of voting equipment choice

In this section we present a stylized model of voting equipment choice. In order to present the main insights in the simplest possible way, we assume only two periods and three types of equipment.Also, we will assume a deterministic environment. Extensions to allow for a larger (infinite) number of periods and a larger (infinite) number of equipment types, and extensions that allow for uncertainty are straightforward.

In words, our model works as follows. Suppose that two counties - identical in everything except for income - are using technology A, when a better technology B becomes available.[30] Then, the richer county is more likely to adopt B, because its opportunity cost of adopting the innovation is lower (as long as utility is concave in income, the marginal benefits from

for the income effect. However, those estimates do not capture the "nonmonotonicity" in the relationship, which clearly emerges from our unconstrained multinomial logit estimates. In other words, our key finding is that in the data higher income is NOT associated with "newer" equipment, but with "intermediate," "middle-age" equipment, such as punchcard machines.

[30] As discussed below, terms such as "better," "costs," and "benefits" refer to the objective function of the relevant decision maker, the county's local official. More idealistically, one may interpret the utility of the county as equal to the utility of the county's median voter or representative citizen.

alternative uses of income are lower in a richer counties). Now suppose that, after a while, a new technology C, better than B, becomes available. Which county will be more likely to adopt it? The richer county, which is now using B, or the poorer county, which is still using A? It depends. While the opportunity cost of adopting C is lower in the richer county, the benefits from adopting C are also lower. By assumption, switching from B to C will not give as high a gain as the more dramatic switch from A to C. In other words, the net benefits from adopting the new technology C depend on a county's current technology. All other things equal, the less advanced is the county's current technology, the higher are the benefits from switching to the most advanced technology C. If the difference between "benefit effect" (larger in poorer county) and "cost effect" (larger in richer counties) is high enough, we may see a large number of richer counties "leapfrogged" by relatively poorer counties.[31] Nonetheless, our framework implies that, when controlling for past income levels, a higher income today is associated with a lower probability of using older equipment.

More formally, consider a two-period model. In each period, counties can use "type 0" equipment (paper ballots) at no cost. In period 1, a county can adopt "type 1" equipment ("old machines"). In period 2, a county can adopt "type 2" equipment ("new machines"). The quality of period t equipment is denoted by x_t (with $x_2 > x_2 > x_0$, where x_0 is the quality of paper ballots). The utility of county i's decision-maker in period t is given by

$$U_t^i = S(q_t^i) + V(y_t^i - c_t^i) \tag{35}$$

where q_t^i denotes the quality of voting machines in county i at time t, y_t^i is county i's income per capita at time t, and c_t^i denotes voting equipment costs per capita at time t. $S(q_t^i)$

[31]The possibility of leapfrogging in the adoption of innovation is familiar to students of industrial organization, economic development, and international economics. For example, see Aghion and Howitt (2000) and Brezis et al. (1993).

is the utility from voting equipment, and is increasing in q_t^i. $V(y_t^i - c_t)$ is the utility from "consumption" (i.e., from all other uses of income, other than purchasing voting equipment), and is increasing and concave in $y_t^i - c_t$. If at time t the county adopts machines of type t we have $q_t^i = x_t$ and $c_t^i = k_t$, where k_t is the cost of type-t machines.[32] Otherwise, $q_t^i = q_{t-1}^i$ and $c_t^i = 0$.[33]

Implicit assumptions in our model are that:

a) Voting machines do not depreciate from one period to the next. This is a good approximation of reality. Actual machines are very durable, especially since they are used less than a few days a year.

b) Voting machines cannot be resold in a secondary market. This is also consistent with reality - the only major exception being the recent move by Palm Beach County to sell its infamous punchcard machines on eBay in order to finance a state-mandated overhaul of its voting equipment.

It is important to notice that the "costs" of changing equipment "type" do not need to be viewed exclusively as "physical" costs associated with buying new machines. In fact, a large component of those costs may well stem from other "changing costs", such as the physical and psychological costs associated with modyfying existing practices and procedures, the political costs due to the disruption of existing "rents" associated with the use of the old machines (say, end of existing maintainance and storage contracts), etc. In other words, shifting from a *type* of equipment to a different *type* of equipment (rather than replacing

[32]For simplicity, we assume that the costs of adopting type-t equipment are the same for all counties. The model can be easily extended to allow for different costs per capita across counties of different size. We will return to this extension later.

[33]We abstract from "running costs," which could be easily added without much gain of insights.

older machines with "newer" machines of the same old type) may entail additional economic and political costs, over and above the costs of purchasing new machines. In our simple model we abstact from such additional economic and political costs. If we were to allow for them, our conclusions would be strengthened.[34]

County i's decision maker maximizes:

$$U_1^i(q_1^i, y_1^i - c_1^i) + \beta U_2^i(q_2^i, y_2^i - c_2^i) \tag{36}$$

where $0 \leq \beta \leq 1$ is the subjective discount factor.

A brief discussion of the objective function is in order. Our interpretation is that, historically, decisions have been taken by local officials who have maximized their own utility function. What objectives have been pursued by such agents? Certainly not maximization of accuracy. While expert evaluations of the relative performance of different voting equipment have focused mainly on "reliability" (minimization of "residual votes," "spoiled ballots," etc.), it seems unlikely that, before the Florida crisis, accuracy played a paramount role in actual decisions over voting machinery.[35] If "reliability" had been the key goal of local officials, one would be hard pressed to explain why they bothered to adopt newer machines at all, when paper ballots seem to provide the most reliable, accurate system available (Ansolabehere et al., 2001). Either local officials were systematically mistaken on the characteristics of the machines they adopted, or they were willing to trade off reliability with

[34]Moreover, if some depreciation of equipment were to take place over time, the existence of additional economic and political costs associated with changing *type* of equipment could help explaining why some counties may decide to replace their machines with *new* machines of the *old* type rather than with *new* machines of the *new* type (a phenomenon that took place in a few counties historically). This effect would also strengthen our conclusions.

[35]"Reliability" as low "residual vote" should not be confused with the minimization of actual machine failures, which may well be a high priority for local officials. In fact, state and federal voting equipment certifications impose tight standards for machine failure rates. As pointed out by Ansolabehere et al. (2001), human factor (interaction of voter and machine) rather than pure mechanical failure seems to drive much of "error" in voting.

other benefits from more advanced machines.[36] In particular, voting machines are labor-saving devices: they make voting procedures (especially vote-counting) quicker and easier. And the labor saved tends to belong to county officials themselves and their assistants.[37] When priority is given to the speed and convenience of vote counting, mechanized lever machines can be viewed as "progress" with respect to paper ballots, computerized punch-card machines as "progress" with respect to lever systems, etc.[38] More generally, one can assume that innovation in the voting equipment industry is targeted to the satisfaction of its costumers (the county officials), and that, on average, successful (i.e., adopted) innovations must have provided higher utility to such customers.[39] All things considered, it seems reasonable to assume that, from the perspective of local officials, "newer" voting equipment has been perceived as "better" equipment.

In this section we will solve our model for the case $\beta = 0$.[40]

Since $S(.)$ is increasing and $V(.)$ is increasing and concave, it is immediate to obtain the following:

Proposition 1

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[36] A third possibility is that current analyses of voting equipment reliability do not provide correct estimates of relative accuracy.

[37] Voters may also benefit from shorter lines if voting procedures are speeded up by the machines.

[38] Historically, the shift from paper ballots to lever machines might also have been motivated as an attempt by higher officials to reduce voting fraud.

[39] An explicit analysis of the supply side of the voting equipment industry is beyond the scope of this paper.

[40] $\beta = 0$ is a realistic assumption for our model: voting equipment is chosen by local officials with horizons that are unlikely to exceed their terms in office, while, as we have seen, the introduction of new types of voting equipment has taken place over long intervals. The straightforward generalization for $0 < \beta \leq 0$ is available upon request. Not surprisingly, the main effect of a nonzero β is to increase the fraction of counties that switch to type-1 machines in period 1.

In period 1, a county i will adopt voting machines of type 1 if and only if its income is higher than y_1^*, which is implicitly defined by the following equation:

$$S(x_1) + V(y_1^* - k_1) = S(x_0) + V(y_1^*) \tag{37}$$

That is, the richer counties in period 1 will adopt type-1 machineries, while the poorer counties will not.

For example, if $V(.) = ln(.)$, we have

$$y_1^* = \frac{k_1 e^{S(x_1)-S(x_0)}}{e^{S(x_1)-S(x_0)} - 1}$$

Since $S(.)$ is increasing, the benefits from adopting type-2 technology, *ceteris paribus*, are higher for those counties that have not adopted type-1 technology in period 1. Therefore, we have:

Proposition 2

In period 2, a county with $q_1^i = x_0$ will adopt machines of type 2 if and only if its income is above y_2^*, which is implicitly defined by the following equation:

$$S(x_2) + V(y_2^* - k_2) = S(x_0) + V(y_2^*) \tag{38}$$

while a county with $q_1^i = x_1$ will adopt machines of type 2 if and only if its income is above y_2^{**}, which is implicitly defined by the following equation:

$$S(x_2) + V(y_2^{**} - k_2) = S(x_1) + V(y_2^{**}) \tag{39}$$

It is immediate to verify that $y_2^{**} > y_2^*$.

For example, if $V(.) = ln(.)$, we have

$$y_2^{**} = \frac{k_2 e^{S(x_2)-S(x_1)}}{e^{S(x_2)-S(x_1)} - 1} > y_2^* = \frac{k_2 e^{S(x_2)-S(x_0)}}{e^{S(x_2)-S(x_0)} - 1} \quad (40)$$

As shown in Figure 3, when income is correlated across the two periods, a high enough gap between y_2^{**} and y_2^* and a high enough correlation between first-period income and second-period income is consistent with a positive correlation between second-period income and use of *type-1* equipment in period 2. However, it is immediate to obtain the following

Corollary

A positive correlation between second-period income and use of type-1 equipment in period 2 vanishes when conditioning on past income. Specifically, when we look at conditional distributions - that is, at counties with the same income in period 1 - we have that the use of older equipment is either independent of period-2 income (for y_2^{**} large) or negatively associated with period-2 income (for y_2^{**} small).

In the following section we will use our simple model's insights to investigate the relationship between present and past income and voting equipment usage.

History matters: the role of past income

In this section we will investigate whether the empirical evidence is consistent with our hypothesis that the current distribution of voting equipment use is the outcome of historical decisions.

Ideally, we would like to have historical data on voting equipment use of individual counties over the past few decades. Since we do not have such panel data, we first consider aggregate data about the distribution of voting equipment in the 1980 and 2000 elections, as provided in Ansolabehere (2001). As shown in table 5, we find that between 1980 and 2000 the share of counties that used optical or electronic machines went from 1 percent to 49.1 percent. The transition took place through reductions in the number of counties that used paper ballots (from 40.4 percent to 12.5 percent) or lever machines (from 36.4 percent to 14.7 percent). By contrast, the share of counties that used punchcard machines barely moved (19.1 versus 19.2). This pattern is consistent with our story.

In order to provide a more direct and formal test of our hypothesis, we calculate logit estimates using past values for income. The results are reported in tables 8a-8b, and provide strong support for our model. In table 8a we aggregate lever and punchcard (as our "type-1 technology") and obtain the following results:

1) Income in 1969 has a positive effect on the probability of using lever or punchcard machines in 1999. Such effect is larger than the effect of 1989 income in our previous logit estimation (table 2f), when we did not control for 1969 income.

2) When income in 1969 is included in the regression, the effect of 1989 becomes insignificant.

When we consider the probability of using punchcard machines alone (table 8b) we obtain even stronger results, as one may expect from the fact that 1969 income is within the time frame in which punchcard machines were adopted, while lever machines were adopted in many counties before the Second World War.[41] In particular, we have

1) Income in 1969 has a positive effect on the probability of using punchcards in 1999. In fact, such effect is one order of magnitude larger than the effect of 1989 income in our previous logit estimation (table 2c).

[41]Similar but slightly less strong results are obtained using 1959 income.

2) When income in 1969 is included in the regression, the effect of income in 1989 becomes *negative*.

In other words, the positive correlation between most recent income and use of punchcards is completely due to the positive correlation between most recent income and past income (i.e., the county's income when punchcards were actually adopted). When past income is explicitly taken into account, the effect of current income - as expected in our model - becomes negative

By taking explicitly into account the role of historical income, we can provide a factually consistent story about the relationship between income and the use of different voting equipment. Our story provides a solution for the "paradox of chads": "chads" are not found among poorer counties but among counties that used to be richer in 1969 - and, therefore, are still likely to be relatively richer in the 1980s and 1990s. But when past income is controlled for, a "nonparadoxical" negative relationship between present income and use of older punchcard equipment emerges.

History matters: the role of past population size

Income per capita is an important determinant of voting equipment use. But it is not the only determinant. In this section the analysis is extended to include another key variable: population size. We argue that, all other things equal, a larger population increases the probability of adopting more advanced voting technology. The aggregate cost of adopting a new technology includes an important fixed component, which is independent of size. These fixed costs stem from numerous sources, including the indivisibility of machines and the existence of large fixed costs in initial training and "adaptation."[42] Henceforth, cost

[42]See Office of Federal Elections and National Bureau of Standards (1975).

per capita is decreasing in the size of a county.[43] Formally, we can expand the model in Section 3 by assuming that the costs per capita of adopting technology of type t in a county with population equal to N_t are given by

$$k_t + \frac{f_t}{N_t} \tag{41}$$

where f_t is a fixed cost. Moreover, benefits from adopting more advanced technology may be positively related to total size (for example, the benefits from speed in vote-tallying may be higher in larger counties). Hence, our previous specification can be extended to include population as an argument in the *S(.)* function, e.g.,

$$S(q_t N_t) \tag{42}$$

Does our extension to population size imply that *currently* larger counties - controlling for income - will be more likely to use more advanced technology? No, for the same reasons why a *currently* higher income does not guarantee a better technology. What matters is population size *when* the different types of equipment were introduced. Since we have data for population before the Second World War, we can disaggregate lever machines and punchcard machines, and test whether their use today is related to past values of population as predicted by our model. Tables 9a-9b show logit estimates when *past* values of population are included as explanatory variables. The results confirm our general message. As predicted by our model, the probability of using lever machines in 1999 is *positively* related to population in 1930, but negatively related to population in 1990. Controlling for today's population size, countries that were larger in 1930, when lever machines were state-of-the-art, were more likely to have adopted them. But, *controlling* for 1930 size, a larger

[43]This can be viewed as an application of the standard idea that the per capita cost of public goods should be decreasing in size. For a recent discussion of this issue, see Alesina and Spolaore (2001).

size in 1990 means a higher chance of having replaced lever machines with more updated equipment by 1999. By the same token, the probability of using punchcard machines is *negatively* related to population in 1930, but *positively* related to population in 1970.

The extension of the model to include population size adds realism and explanatory power to our basic framework without changing the central insights. For example, the role of population size can also help explain an additional fact, documented in Ansolabehere et al. (2001): counties that abandoned paper ballots were more likely to adopt optical scanners, while counties that abandoned lever machines were more likely to adopt electronic machines. Electronic machines have much higher fixed costs than optical scanners (which, by contrast, have higher variable costs because they require expensive special paper). Hence, we should expect that counties with larger population would adopt electronic machines rather than optical scanners. Since larger counties are also more likely to have used lever machines rather than paper ballots in the past, a pattern lever to electronic/paper to optical is soon established. [44]

Another possible extension of our basic framework entails an explicit role for human capital. The introduction of newer technology, other things being equal, is likely to bring about higher benefits and smaller costs (from learning etc.) when voters and officials have higher education. Since these effects are probably higher for the computerized technologies of the 1980s and 1990s (optical scanners and electronic machines), it is not surprising that the percentage of population with a college degree is positively related with the adoption of such equipment. The analysis of historical levels of human capital in the adoption of older technology is left for further research.

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[44] Of course, factors such as habits and learning may also have played an important role (electronic machines are conceptually similar to lever machines, while optical scanners use a 'paper' technology).

Other extensions could focus on the role of local public finance across different jurisdictions. In our specification we simply assume that the relevant decision maker obtains utility from the county (average or median) "income." In reality, the relationship between a county's income and the resources available to local officials is also mediated by institutional mechanisms and constraints that may differ across jurisdictions. At the empirical level, they are partly captured by the independent effect of current local government revenues per capita in our regressions. The analysis of the effects of these variables from a historical perspective is also matter for future inquiry.

Concluding remarks

In this paper we have documented the relationship between usage of different types of voting equipment and county characteristics. Contrary to widespread belief, machines of older types are not used in relatively poorer counties. We have provided a stylized model in which the adoption of new voting equipment depends on a county's income, population, and existing type of equipment at the time the new technology is introduced. We have successfully tested numerous implications of our model. In particular, as predicted by our theory, when we control for the relevant decision variables (income and population size) at the time in which the older technologies were state-of-the-art, the effects of more recent income and population become negative or insignificant.

Overall, we have found evidence that voting equipment adoption in the U.S. has been characterized by significant "leapfrogging," with the latest technology being adopted by counties that had not adopted the previous state-of-the-art equipment. Our bottom line is that history matters: the current distribution of voting equipment reflects political decisions taken over several decades. Failing to take into account the dynamic aspects of the process can lead to a distorted view of the phenomenon.

Specifically, our analysis helps to clarify the relationship between economic and demographic factors and the adoption of different voting equipment. We have documented how the "worst equipment" is *not* concentrated in poorer counties. However, such finding does *not* imply that economic factors played no role in determining the distribution of current voting equipment. On the contrary, we have emphasized how such distribution is significantly affected by current and past economic and demographic factors. In particular, our analysis implies that, *given current equipment*, higher income is indeed associated with a *higher* probability of updating one's technology.

These findings shed new light on the debate over the causes and consequences of voting equipment choice in the U.S., and correct some misconceptions that have colored such discussions. In particular, our findings seem especially relevant with respect to the current political debate over the allocation of federal funds targeted to the upgrade of voting equipment.

Finally, we think that our study provides valuable insights on the more general issue of the adoption of new technology by decentralized public authorities. We suspect that similar mechanisms and outcomes are at work with respect to other decisions involving the upgrade of durable public goods across different jurisdictions, and that our analysis can shed some light on the political economy of this larger class of political decisions.

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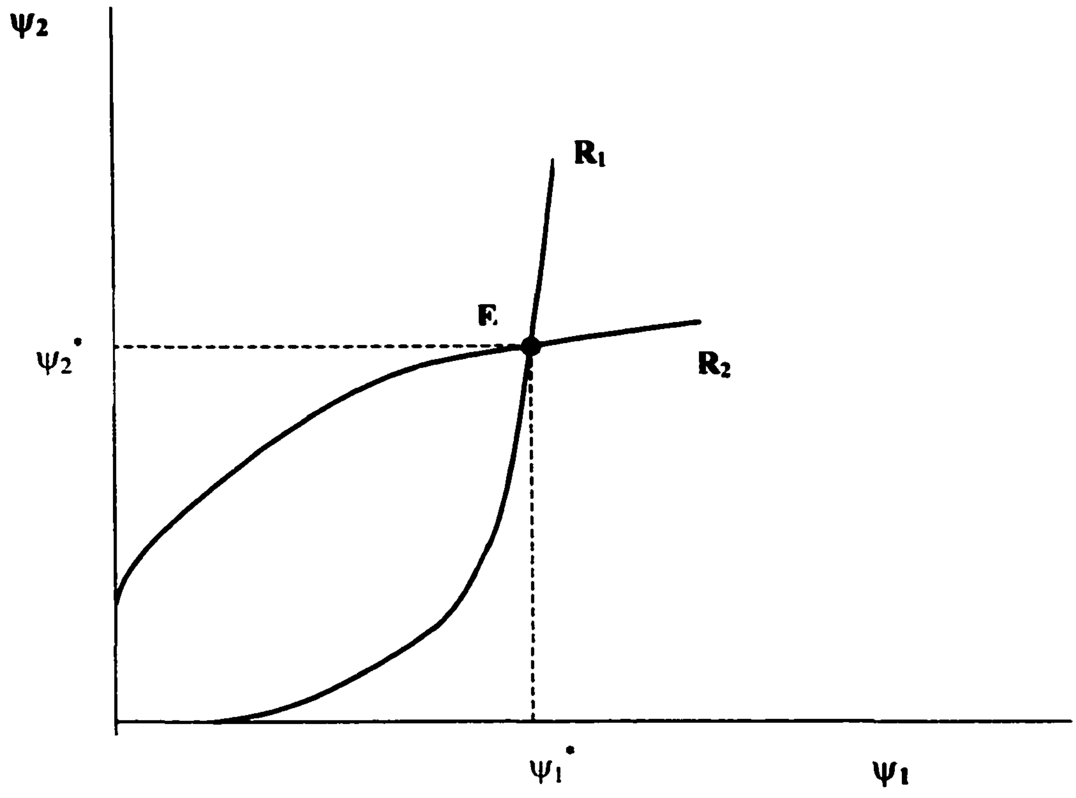

R_1 denotes the reaction function of the government in country 1
R_2 denotes the reaction function of the government in country 2

E is a Nash equilibrium

Figure 1

Institutional Spillovers

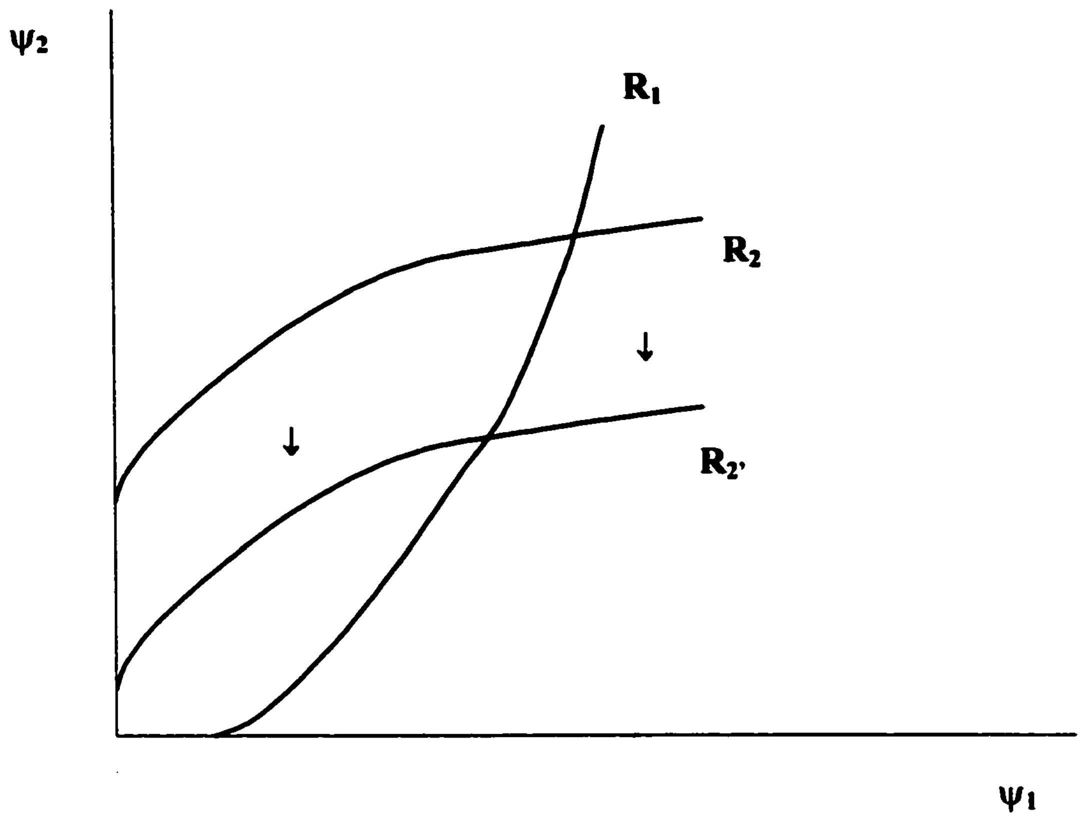

Illustration of Proposition 2 (iv):

A decrease in rent-seeking in country 2 will decrease the level of innovation blocking in country 1 and increase growth in country 1

Figure 2

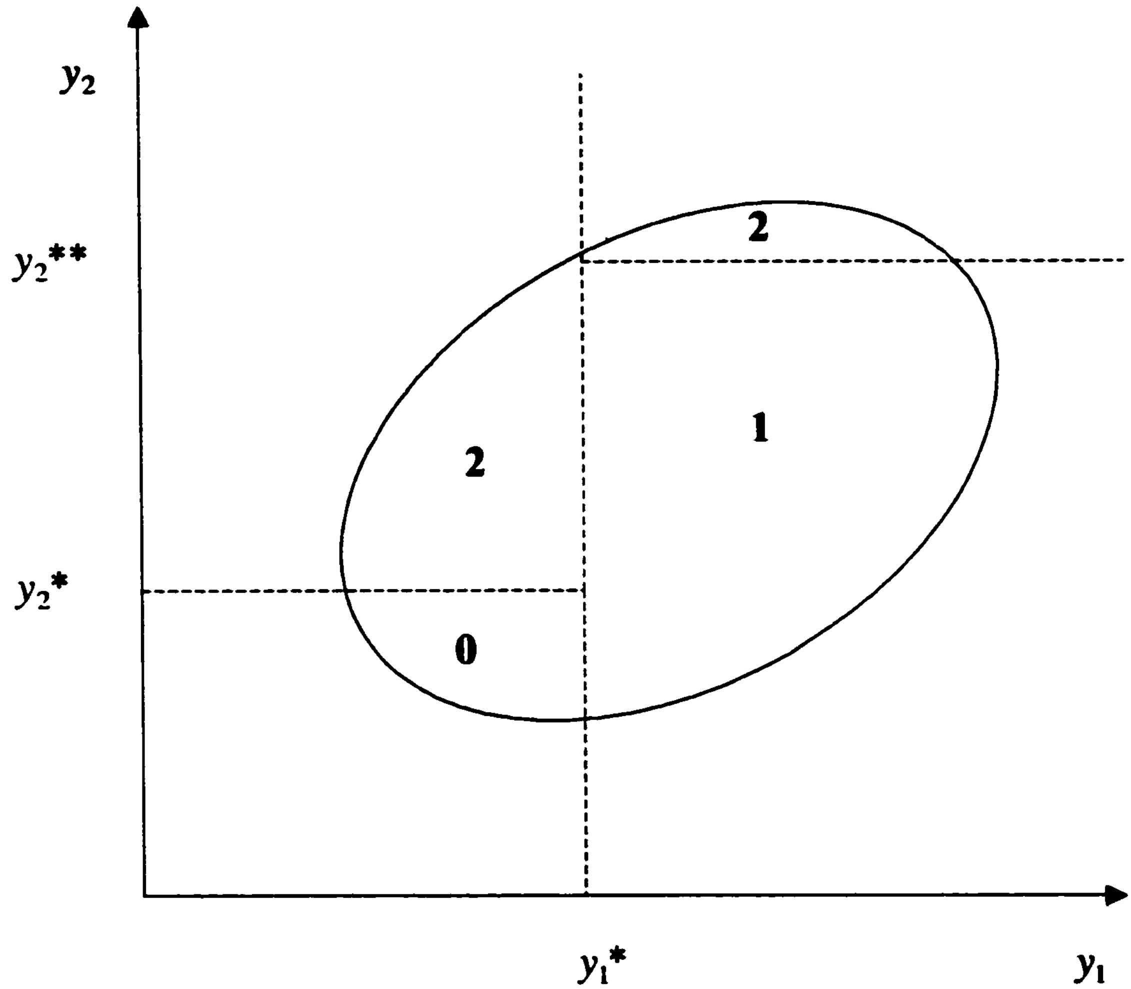

Figure 3

TABLE 1

Summary Statistics

	All	Paper	Lever	Punch	Optical	Elect.	Lever/ Punch	Elec/ Opt.
M Inc 89	28475	24799	28817	30584	28124	27992	29890	28088
Pop 1990	79182	8869	96615	140007	54601	92282	12124 7	61193
% Age 65+	15	18	14	14	15	13	14	15
% Min	15.5	11.4	19.8	12.5	17.7	16.7	15.7	17.5
% Bach.	14	12	13	14	14	13	14	14
Local Govt $	1446	1707	1305	1374	1506	1144	1344	1442

Number of counties = 3141
Number of counties, paper = 407
Number of counties, lever = 476
Number of counties, punch = 625
Number of counties, optical = 1231
Number of counties, electronic = 261
Number of counties, mixed = 141

TABLE 2: Logit Estimates

All results with mixed counties dropped. Standard errors are reported in parenthesis beneath the coefficient estimates. Median Income, Population, and Local Government Revenues per Capita in the 1000's.
* denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

Table 2a

Paper

	(i)	(ii)	(iii)	(iv)
Median Income 1989	-.0258** (.0115)	-.0794*** (.0169)	-.0258 (.0241)	-.0794** (.0383)
Population 1990	-.12 *** (.00844)	-.1035*** (.00852)	-.12*** (.0382)	-.1035*** (.0369)
% Age 65+		.0486416*** (.0152558)		.0486416 (.0350578)
% Minority		-.0145374*** (.0039053)		-.0145374 (.0147063)
% Bachelors		.0752856*** (.0148393)		.0752856** (.0332496)
Local Gov. Revenues/cap.		.0872*** (.0352)		.0872 (.0574)
Log Likelihood	*-886.10886*	*-852.94436*	*-886.10886*	*-852.94436*

Number of observations = 2999
Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 2b

Lever

	(i)	(ii)	(iii)	(iv)
Median Income 1989	.00985 (.00710)	.047*** (.0109)	.00985 (.0289)	.047 (.0329)
Population 1990	.000199 (.000161)	.000160 (.000.168)	.000199 (.000321)	.000160 (.0369)
% Age 65+		-.0399883*** (.0144685)		-.0399883 (.0359365)
% Minority		.0134158*** (.0029389)		.0134158 (.0102091)
% Bachelors		-.0569643*** (.0118547)		-.0569643*** (.0192237)
Local Gov. Revenues/cap.		-.3471*** (.0901)		-.3471 (.3726)
Log Likelihood	*-1309.8533*	*-1268.0139*	*-1309.8533*	*-1268.0139*

Number of observations = 2999
Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 2c

Punch

	(i)	(ii)	(iii)	(iv)
Median Income 1989	.0444*** (.00650)	.0475*** (.01)	.0444*** (.0157)	.0475* (.0293)
Population 1990	.000692*** (.000215)	.00146*** (.000265)	.000692* (.000428)	.00146*** (.000553)
% Age 65+		-.0619581*** (.0133427)		-.0619581 (.0436589)
% Minority		-.0226474*** (.0035292)		-.0226474** (.0107334)
% Bachelors		-.0423815*** (.0101155)		-.0423815* (.0241772)
Local Gov. Revenues/cap.		-.1884*** (.0713)		-.1884 (.1767)
Log Likelihood	*-1488.3204*	*-1442.9768*	*-1488.3204*	*-1442.9768*

Number of observations = 2999
Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 2d

Optical

	(i)	(ii)	(iii)	(iv)
Median Income 1989	.00618 (.00589)	. 00759 (.00858)	.00618 (.0183)	.00759 (.0246)
Population 1990	-.00117*** (.000301)	-.00187*** (.000340)	-.00117** (.000539)	-.00187*** (.000664)
% Age 65+		.0439749*** (.0102525)		.0439749* (.0260792)
% Minority		.014416*** (.0023926)		.014416** (.00701)
% Bachelors		.0343289*** (.008214)		.0343289** (.0147417)
Local Gov. Revenues/cap.		.0845 (.0527)		.0845 (.1285)
Log Likelihood	*-2019.195*	*-1984.4268*	*-2019.195*	*-1984.4268*

Number of observations = 2999

Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 2e

Electronic

	(i)	(ii)	(iii)	(iv)
Median Income 1989	-.011 (.00972)	-.0373*** (.0136)	-.011 (.0412)	-.0373 (.0515)
Population 1990	.000240 (.000181)	.000364** (.000189)	.000240 (.000184)	.000364 (.000293)
% Age 65+		-.1301422*** (.0203253)		-.1301422** (.0587795)
% Minority		-.0073817* (.0039369)		-.0073817 (.0215262)
% Bachelors		.0043609 (.0131989)		.0043609 (.0235818)
Local Gov. Revenues/cap.		-.9965*** (.1578)		-.9965*** (.3235)
Log Likelihood	*-885.44545*	*-827.82887*	*-885.44545*	*-827.82887*

Number of observations = 2999

Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 2f

Lever/Punch

	(i)	(ii)	(iii)	(iv)
Median Income 1989	.0353*** (.00604)	.0594*** (.00895)	.0353* (.0188)	.0594** (.0246)
Population 1990	.00127*** (.000279)	.00193*** (.000309)	.00127*** (.000441)	.00193*** (.000598)
% Age 65+		-.0686848*** (.0112502)		-.0686848** (.0321606)
% Minority		-.0051772** (.0025467)		-.0051772 (.0103535)
% Bachelors		-.0687412*** (.0090527)		-.0687412*** (.0173012)
Local Gov. Revenues/cap.		-.3343*** (.0633)		-.3343* (.1797)
Log Likelihood	*-1916.0679*	*-1843.9015*	*-1916.0679*	*-1843.9015*

Number of observations = 2999

Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 2g

Lever/Punch (with paper counties dropped)

	(i)	(ii)	(iii)	(iv)
Median Income 1989	.0225*** (.00608)	.043*** (.00904)	.0225 (.0181)	.043* (.0251)
Population 1990	.000966*** (.000258)	.00159*** (.000294)	.000966** (.000399)	.00159*** (.000553)
% Age 65+		-.0493391*** (0117387)		-.0493391 (.0328123)
% Minority		-.0077561*** (.0026036)		-.0077561 (.0099886)
% Bachelors		-.0578793*** (.0090527)		-.0578793*** (.0160235)
Local Gov. Revenues/cap.		-.1799*** (.0626)		-.1799 (.1569)
Log Likelihood	*-1739.6329*	*-1699.4657*	*-1739.6329*	*-1699.4657*

Number of observations = 2999

Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

TABLE 3: Multinomial Logit Estimates

All results with mixed counties dropped. Standard errors are reported in parenthesis beneath the coefficient estimates. Median Income, Population, and Local Government Revenues per Capita in the 1000's. Base group for comparison is Punch Card
Table 8b reports multinomial logit estimation results using Huber/White estimator of variance with clustering by state.
* denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

Table 3a

	Lever	Electronic	Optical	Paper
Median Income 1989	.0016898 (.0134885)	-.071355 *** (.0160111)	-.0328987*** (.01143)	-.108792*** (.0192097)
Population 1990	-.0005234** (.0002662)	-.0001427 (.0002649)	-.0028792*** (.000391)	-.10104*** (.0084515)
% Age 65+	.0143359 (.0185185)	-.073691*** (.0234139)	.0857917*** (.0150121)	093480*** (.0194585)
% Minority	.0299783*** (.0042573)	.0120657** (.0050199)	.0279057*** (.0038061)	.0075926 (.0050757)
% Bachelors	-.02031 (.0144546)	.0303002** (.0156993)	.0590741*** (.0112173)	.103665*** (.0174836)
Local Gov. Revenues/cap.	. -.1548112 (.1079107)	-.803326*** (.1733754)	.3015399*** (.0803753)	.352951*** (.0853416)

Log Likelihood = -3877.3706
Number of observations = 2999

Table 3b

	Lever	Electronic	Optical	Paper
Median Income 1989	.0016898 (.0416653)	-.0713552 (.0580642)	-.0328987 (.0282271)	-.1087927*** (.0429349)
Population 1990	-.0005234 (.0006048)	-.0001427 (.0003752)	-.0028792*** (.0007164)	-.101041*** (.0362983)
% Age 65+	.0143359 (.0546441)	-.0736911 (.0714956)	.0857917** (.0412294)	0934801** (.0463201)
% Minority	.0299783** (.0132743)	.0120657 (.0234535)	.0279057*** (.0102305)	.0075926 (.0179357)
% Bachelors	-.02031 (.0296048)	.0303002 (.0285346)	.0590741*** (.0261835)	.1036652*** (.0424105)
Local Gov. Revenues/cap.	. -.1548112 (.4083854)	-.8033263** (.3623208)	.3015399 (.1916999)	.3529519* (.1947933)

Log Likelihood = -3877.3706
Number of observations = 2999

TABLE 4: Multinomial Logit Estimates; Punch/Lever Aggregate

All results with mixed counties dropped. Standard errors are reported in parenthesis beneath the coefficient estimates. Median Income, Population, and Local Government Revenues per Capita in the 1000's. Base group for comparison is Punch Card/Lever aggregate.
Table 9b reports multinomial logit estimation results using Huber/White estimator of variance with clustering by state.
* denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

Table 4a

	Electronic	Optical	Paper
Median Income 1989	-.0709019*** (.0148925)	-.03318*** (.0098188)	-.1087107*** (.0182841)
Population 1990	.0000534 (.0002356)	-.0025936*** (.0003745)	-.1006475*** (.0084507)
% Age 65+	-.0797589*** (.0219173)	.0791193*** (.012535)	.0871535*** (.0176673)
% Minority	-.0040822 (.0042822)	.0115665*** (.0027643)	-.0087151** (.0043471)
% Bachelors	.0391928*** (.0146099)	.0674331*** (.0097107)	.1117743*** (.0165751)
Local Gov. Revenues/cap.	-.7345114*** (.1672639)	.3680136*** (.0691487)	.4192669*** (.074916)

Log Likelihood = -3161.3701
Number of observations = 2999

Table 4b

	Electronic	Optical	Paper
Median Income 1989	-.0709019 (.0524239)	-.03318 (.0261779)	-.1087107*** (.041473)
Population 1990	.0000534 (.0003443)	-.0025936*** (.0007664)	-.1006475*** (.0362795)
% Age 65+	-.0797589 (.0588864)	.0791193*** (.0308081)	.0871535** (.0402802)
% Minority	-.0040822 (.021863)	.0115665 (.0096826)	-.0087151 (.0188239)
% Bachelors	.0391928 (.0245616)	.0674331*** (.0186062)	.1117743*** (.0371306)
Local Gov. Revenues/cap.	-.7345114** (.3274512)	.3680136** (.1861445)	.4192669** (.1898538)

Log Likelihood = -3161.3701
Number of observations = 2999

TABLE 5

Usage of Voting Equipment in the 1980 and 2000 Elections

	% Counties 1980	% Counties 2000
Paper	40.4	12.5
Lever	36.4	14.7
Punch	19.1	19.2
Optical	0.8	40.2
Electronic	0.2	8.9
Mixed	3.0	4.4

Source: "*A Preliminary Assessment of the Reliability of Existing Voting Equipment*", The Caltech/MIT Voting Project, Version 1: February 1, 2001.

TABLE 6

AVERAGES – HISTORICAL POPULATION AND MEDIAN FAMILY INCOME

	All	Lever	Punch	Elect	Optical	Paper	Lev/Pun	Elc/Opt
MInc89	28142	28817	30574	27918	27792	24799	29814	27814
MInc79	27888	27332	30580	27517	27830	24824	29173	27774
MInc69	23322	23004	26314	22690	22770	21138	24884	22756
MInc59	16243	15361	18793	15363	15770	15317	17316	15698
Pop90	76166	96615	139259	92282	54584	8869	120806	61314
Pop80	69104	94366	121996	85300	48533	8948	110029	55076
Pop70	61636	94153	104961	75128	41501	8193	100291	47490
Pop60	54406	87565	87694	66246	37112	8591	87639	42304
Pop50	45829	79208	67676	53893	32182	9263	72624	36053
Pop40	40118	72850	54925	45618	28805	9969	62605	31805
Pop30	37380	69062	49749	41219	27081	10216	58023	29604

(Mixed Counties, the District of Columbia, Alaska and Hawaii dropped from the sample)

TABLE 7: Correlations

Table 5a: Correlation Matrix, Median Family Income 1989, 1979, 1969, 1959

	Income 1989	*Income 1979*	*Income 1969*	*Income 1959*
Income 1989	1			
Income 1979	0.87913	1		
Income 1969	0.848535	0.89219	1	
Income 1959	0.694591	0.775071	0.882233	1

Table 5b: Correlation Matrix, Population 1990-1930

	P1990	*P1980*	*P1970*	*P1960*	*P1950*	*P1940*	*P1930*
P1990	1						
P1980	0.99231	1					
P1970	0.96842	0.98996	1				
P1960	0.93652	0.96769	0.99211	1			
P1950	0.86569	0.91033	0.95343	0.98112	1		
P1940	0.79904	0.85327	0.90777	0.94639	0.98941	1	
P1930	0.76071	0.81963	0.87898	0.92238	0.97626	0.99655	1

TABLE 8: Historical Income Logit Estimates

All results with mixed counties dropped. Standard errors are reported in parenthesis beneath the coefficient estimates. Median Income, Population, and Local Government Revenues per Capita in the 1000's.
* denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.

Table 8a

Lever/Punch

	(i)	(ii)	(iii)	(iv)
Median Income 1969	.0578*** (.0126)	.091*** (.014)	.0578 (.0465)	.091*** (.0368)
Median Income 1989	.00528 (.0105)	.0197 (.0124)	.00528 (.0257)	.0197 (.027)
Population 1990	.000942*** (.000269)	.00136*** (.000310)	.000942** (.000436)	.00136** (.000605)
% Age 65+		-.0677762*** (.011929)		-.0677762** (.0324112)
% Minority		.0021351 (.002754)		.0021351 (.0103593)
% Bachelors		-.0788039*** (.0093558)		- .0788039*** (.0169909)
Local Gov. Revenues/cap.		-.4337*** (.0746)		-.4337** (.2167)
Log Likelihood	*-1879.9487*	*-1793.974*	*-1879.9487*	-1793.974

Number of observations = 2962

Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 8b

Punch

	(i)	(ii)	(iii)	(iv)
Median Income 1969	.1732*** (.0161)	.193*** (.0175)	.1732*** (.0396)	.193*** (.0408)
Median Income 1989	-.0599*** (.0126)	-.0569*** (.015)	-.0599** (.0264)	-.0569** (.0267)
Population 1990	.000262 (.000183)	.000760*** (.000258)	.000262 (.000328)	.000760 (.000480)
% Age 65+		-.0591836*** (.0147482)		-.0591836 (.0490966)
% Minority		-.0122754*** (.0037583)		-.0122754 (.0099833)
% Bachelors		-.0536086*** (.01071)		-.0536086** (.0233077)
Local Gov. Revenues/cap.		-.4545*** (.097)		-.4545* (.2718)
Log Likelihood	*-1407.5589*	*-1360.5877*	*-1407.5589*	*-1360.5877*

Number of observations = 2962

Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

TABLE 9: Historical Population Logit Estimates

All results with mixed counties dropped. Standard errors are reported in parenthesis beneath the coefficient estimates. Median Income, Population, and Local Government Revenues per Capita in the 1000's.
*** denotes significance at the 10% level, ** denotes significance at the 5% level, and *** denotes significance at the 1% level.**

Table 9a

Lever

	(i)	(ii)	(iii)	(iv)
Population 1930	.00433*** (.00101)	.00507*** (.00107)	.00433** (.00218)	.00507** (.00209)
Population 1990	-.00174*** (.000652)	-.00215*** (.000735)	-.00174* (.00106)	-.00215* (.00128)
Median Income 1989	.0161** (.00854)	.0579*** (.0122)	.0161 (.0334)	0579* (.0359)
% Age 65+		-.0619088*** (.0161329)		-.0619088* (.0354578)
% Minority		.0151031*** (.0032171)		.0151031 (.0116579)
% Bachelors		-.0665901*** (.0128679)		- .0665901*** (.0203334)
Local Gov. Revenues/cap.		-.3978*** (.0985)		-.3978 (.3725)
Log Likelihood	*-1263.0142*	*-1208.7098*	*-1263.0142*	*-1208.7098*

Number of observations = 2946
Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.

Table 9b

Punch

	(i)	(ii)	(iii)	(iv)
Population 1930	-.00180** (.000822)	-.00247*** (.000930)	-.00180 (.00146)	-.00247* (.00133)
Population 1970	.000938** (.000478)	.00175*** (.000603)	.000938 (.000802)	.00175** (.000884)
Median Income 1969	.1774*** (.0162)	.1982*** (.0178)	.1774*** (.0393)	.1982*** (.0399)
Median Income 1989	-.0604*** (.0128)	-.0581*** (.0151)	-.0604** (.0267)	-.0581** (.0274)
% Age 65+		-.0517037*** (.0148848)		-.0517037 (.0490287)
% Minority		-.0105686*** (.0037785)		-.0105686 (.0101945)
% Bachelors		-.0515015*** (.0108287)		-.0515015** (.02371)
Local Gov. Revenues/cap.		-.4759*** (.0987)		-.4759* (.2789)
Log Likelihood	*-1394.5174*	-1352.0327	*-1394.5174*	*-1352.0327*

Number of observations = 2944

Columns (i) and (ii) report standard logit estimates. Columns (iii) and (iv) report logit estimation results using Huber/White estimator of variance with clustering by state.