Political Regimes, Bureaucracy, and Scientific Productivity

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Can a scientist trust that the government is going to pay him or her fairly? In the science–government relationship, an incumbent may be better off if he or she does not provide—or does not provide a fair pay *to public scientists. We propose a simple game-theoretic model for understanding the trust problem in the relationship between governments and scientists. The model shows how with reliable governments (democracies), bureaucratic contracts (e.g., secure tenure) are not optimal since they have low-powered incentives (in contrast to the high-powered private-sector type of contracts) and run against scientists' responsiveness to government demands. However, with nonreliable governments (dictatorships), bureaucratic contracts are second-best solutions because they protect scientists against the possibility of governments' misbehavior (i.e.,* ex post *opportunistic defections, such as canceling research programs overnight). An empirical analysis confirms the predictions: bureaucratic contracts enhance scientific productivity with nonreliable governments (dictatorships) but hamper scientific productivity with reliable governments (democracies).*

Can a scientist trust that the government is going to pay him or her fairly? Fairness is important for a scientist who undertakes a costly asset-specific investment before his or her research is completed, evaluated, and paid for. A wrong evaluation or misconduct by the payer is a risk a researcher has to consider before engaging in a long, difficult career. Usually, the political concern is the opposite: can the government trust that the scientist would not take advantage of the obscurity of his or her subject to conceal the research he or she is really doing or its quality? Most work on the subject has focused on this particular problem: the moral hazard of the agent (i.e., the state scientist). In this article, we explore the other point of view: the moral hazard of the principal (i.e., the government). We contend that the

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relationship between powerful governments and scientists is subject to problems of credibility similar to the ones described in the interaction between, for instance, powerful governments and bankers (North and Weingast 1989) or between powerful governments and interest groups (Horn 1995; Moe 1984, 1990). The reason is that, once scientists have undertaken costly asset-specific investments in a given research, they are in a weak situation *vis-à-vis* the government, which may take opportunistic advantages such as not rewarding them properly.[1]

As most scholars point out, when dealing with bankers or with interest groups, powerful governments tend to create institutional devices through which they *tie* their hands to solve their lack of credibility (Kydland and Prescott 1977). Like Ulysses bound to the mast, by accepting limitations on its own caprice, a government can increase its capacity to achieve its ends (Holmes 1988). These limitations often take the form of bureaucratic rules that reduce governmental discretion for controlling the public administration (Horn 1995; Moe 1990; Williamson 1999). Civil service arrangements, which grant public employees autonomy from political interferences in staff policy, are a known example of those bureaucratic rules (Frant 1993). Nevertheless, although the literature agrees that institutions matter for policy outcomes, it is not clear what the particular effects of bureaucratic rules are. While some authors argue that bureaucratic rules are efficiency enhancing (Rauch 1995), others claim that they are efficiency decreasing (Moe and Caldwell 1994). In particular, in science policy studies, we lack both theoretical models and comparative empirical evidence to contrast the different impact of bureaucratic rules on scientific productivity. To start with, Science and Technology policy is still an under-theorized field (Guston 1996; Sapolski 1975) without clear predictions on which factors lead to more bureaucratic rules in the relationship between governments and scientists.

This article argues that, in the case of state scientists, the effects of bureaucratic rules depend on the type of political regime a country has. A simple game-theoretic model and a subsequent empirical comparison show how *bureaucratic rules produce better science in dictatorships but worse science in democracies*. In a dictatorship, bureaucratic rules are a solution to the credible commitment problem created by the ruler who does not face constraints to his or her potential opportunistic behavior regarding science policy. In a dictatorship, the benefits of bureaucratization (i.e., tying ruler's opportunistic hands) are higher than its costs (i.e., lack of flexibility). In a democracy, on the contrary, the problem of credible commitment is less acute because rulers are constrained by checks and balances that prevent them from undertaking opportunistic actions against scientists—as a result, bureaucratic arrangements are less useful. In a democracy, the costs of bureaucratic rules would thus be higher than their limited benefits.

This study aims at answering why governments tie their hands in the management of scientists through bureaucratic rules and what the effects of those bureaucratic rules over scientific productivity are. We address these research questions by exploring the impact of regime type over scientists and making use of principal–agent theory (PAT) as an appropriate method. The main contribution is theoretical, bringing the three elements together (regime type, administration type, and policy outcomes) in a simple explanation, inspired by simple game theory, that produces falsifiable propositions. The article first joins the principal–agent and political regime literatures for the study of Science and Technology and, second, shifts the analytical focus within PAT to the trustworthiness of the principal. The theoretical hypotheses are subject afterward to a preliminary empirical assessment using some of the few existing data sets on the issue as well as some examples to illuminate the workings of the theory.

The article begins by explaining why PAT offers a suitable framework to model the relationship between governments and scientists. It then focuses on the dimension of principal–agent relations—the problem of time inconsistency—that is, key to explaining differences in the institutional devices that link a government with its scientists. We then develop a game-theoretic model based on time-inconsistency problems, which endogeneizes the government's decision over the type of contract (more/less "bureaucratized") with scientists. It also predicts a country's level of science production as a function of the political regime and the degree of scientists' bureaucratization. The study finally offers evidence of the theoretical hypotheses for dictatorships and democracies, respectively.

Why a Principal–Agent Model?

In popular accounts of science, scientists are often portrayed as selfless individuals, working for humankind. Earlier sociological explanations argued that extrinsic rewards, such as position and money, play a minor role in science (Hagstrom 1965, 19). Here, however, we assume that scientists are self-interested.[2] For simplicity, we assume that position, money, and direct rewards are instrumental goods even for selfless actors, which allows us to treat scientists as *agents* of the government (here the *principal*). The article, thus, relies on PAT and takes a contractual approach toward explaining public science organizations and hierarchies.[3]

A growing strand of literature in science policy (see e.g., Braun 1993; Caswill 1998; Guston 1996; Morris 2003; Van der Meulen 1998) has adopted the PAT perspective in the following way: a *government* requests the *scientists* to perform certain tasks that the principal is not able to perform directly (Guston 1996, 230, our emphasis). The key question is "how do nonscientists get scientists to do what we all, as citizens, have decided?" (229), and the key variable is the information asymmetry between the two main actors. We depart from this literature in three different ways. First, we focus on the simplest model—with the government as the principal and the scientists as the agents—ignoring intermediate actors.[4] In doing so, we are making a rough simplification, but our aim is to analyze the interplay between the two essential actors in science: those who ultimately manage science policy and those who ultimately do science. Second, we use a one-shot game without repetition.[5] Third, our model focuses on the possibility of principal's misbehavior.

The problem traditionally addressed by PAT is the design of a contract to limit the agent's misconduct—the well-known issues of *moral hazard* and *adverse selection* (Pratt and Zeckhauser 1985). The agent is seen as the main source of problems, while the problems created by principals, such as the possibility of not rewarding the agent properly, have been overlooked. Yet principals' misconduct must also be taken into account, especially in the public realm where the principal (e.g., government) has a political nature and is thus more powerful than the standard private-sector principal (e.g., manager). As Moe (1990) has emphasized, PATs—primarily developed for understanding firms—assume the enforcement of contracts by a third party, but problems may arise when one of the parties happens to be that third party at the same time (i.e., the government).

Governments can renege on their pacts by, for example, unilaterally changing the terms of those pacts through new *ad hoc* regulations. PAT models applied to politics often overlook the full consequences of the exercise of "public authority" (Moe 1990) or "political power" (Moe 2005). Governments have extraordinary and, to a certain extent, unpredictable powers: governments at time t cannot bind those at time $t + 1$, and the incentives to renege are often substantial (Moe 1990, 220). Once agreements are struck, there is no external enforcement mechanism to police them when one of the parties is the government. Following Moe (1990, 213), the goal of our theory is to include this "neglected side of the story" of PAT in the analysis of science policy.

Time-Inconsistency Problems

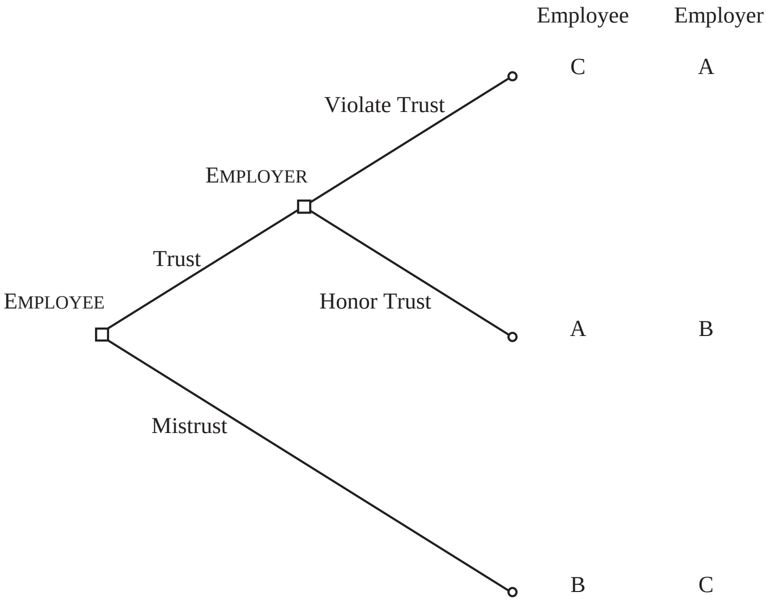
> Once upon a time, on the banks of a great river lay a town called Hamelin. One day, an extraordinary thing happened to disturb the peace: a black sea of rats swarmed over the whole town. The terrified citizens flocked to plead with the town councilors to free them from the plague of rats. Just then, a stranger proposed to the city council: "for a thousand florins, I'll rid you of your rats!" "A thousand florins!" exclaimed the Mayor. "We'll give you fifty thousand if you succeed!" Next day, by the time the sun was high, there was not a single rat in the town. There was even greater delight at the town hall, until the piper tried to claim his payment. "Fifty thousand florins?" exclaimed the councilors, "Never!" "A thousand florins at least," cried the pied piper angrily. But the Mayor broke in. "The rats are all dead now and they can never come back. So be grateful for fifty florins, or you'll not get even that."

Written by economists, the plot of this traditional tale could have been different: the pied piper would have rationally anticipated that, once the town was free of rats, it would no longer be in the interest of the Mayor to reward him properly. *Ex post*, it would be more rational for the Mayor to use the 50,000 florins to build a hospital in a swing district or divert them directly to his own pockets. Therefore, the piper would probably have stayed at home and the story ends right at the beginning. The tale of the pied piper illustrates nicely the problem of time-inconsistent preferences that is inherent to politics.

In fact, the tale has been used to show the problems of credibility for "committing against opportunistic behavior" that arise in the relationship between governments and citizens (Sala-i-Martin 2004). Ironically, it has not been used to shed light on the relationship between real-world mayors (governments) and real-world pied pipers (public employees). For instance, North and Weingast (1989) analyze the time-inconsistency problem inherent to the relation between rulers and bankers. They show that the more likely, it is that the sovereign will alter property rights for his or her own benefit, the lower the expected returns from investment and the lower, in turn, the incentives to invest that economic agents have. We contend that if this time-inconsistency problem arises in the relationship between a ruler and the *people who sometimes invest in the relationship with her* (e.g., bankers who invest their capital), it is even more likely to happen in the relationship between a ruler and the *people who normally invest in the relationship with her* (e.g., public employees who invest their human capital).

The pied piper's dilemma has an obvious solution in polities with rule of law and an independent third party capable of enforcing contracts between public authorities and private agents. In that case, the mayor and the piper could have signed a contract specifying the details of the transaction. However, and this is the starting point of the theoretical model described here, not all transactions can be established in a formal contract, as developments in organizational theory have been increasingly emphasizing. For example, Miller (1992) considers that the relation between employers and employees is similar to the "commitment problem" game developed by Kreps (1990). In Miller's adaptation of the game (see Figure 1), the employee moves first and has a choice of trusting the superior (working hard) or not trusting the superior (making a minimum effort). If the employee trusts the superior, the latter has a choice of honoring trust and giving a proper reward such as paying $10 per each piece the employee produces, granting a promotion, not discounting work contracts in difficult times, or the superior can violate trust by, for instance, cutting the piece rate to $5 once he realizes how many pieces the employee is able to make, canceling a scheduled promotion, or laying off excess

Figure 1.
The Commitment Problem



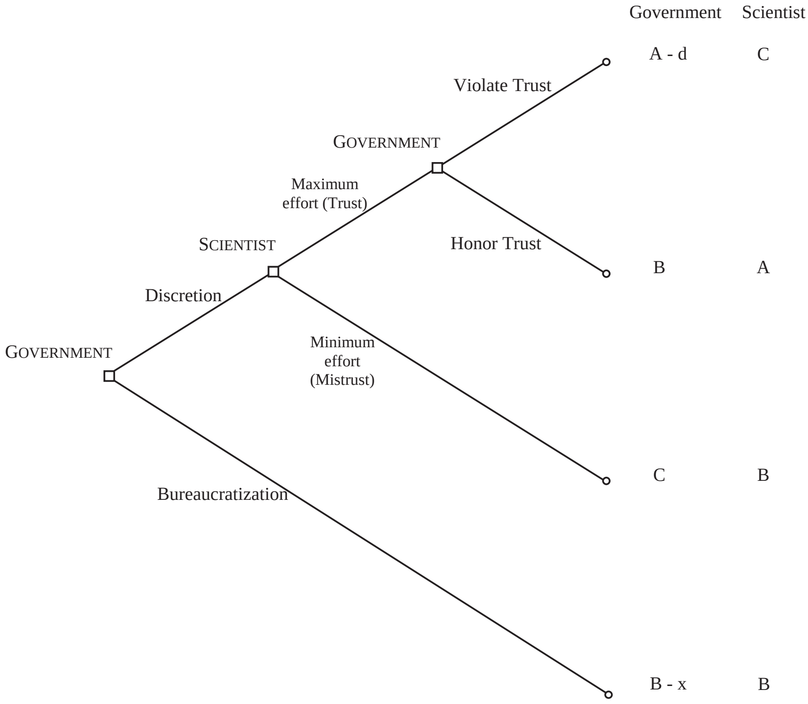
Sources: Employer's outcome ranking A > B > C. Employee's outcome ranking A > B > C Mistrust (payoffs B and C represents a Pareto-suboptimal Nash equilibrium. (Figure adapted from Miller 1992.)

employees in times of crisis. In this movement, the employer tends to have incentives to violate trust because he frequently obtains a direct benefit from that violation and this would leave the subordinate worse off than if he failed to trust the superior. Anticipating this violation of trust, the employee frequently refuses to trust the employer, which results in an outcome of minimum effort—a Pareto-suboptimal Nash Equilibrium.[6]

The Credible Commitment Game between Government and Scientists

The interaction between government and scientists can be modeled by a two-person game like the one shown in Figure 2. A strong

Figure 2.
The Positive Control Game



Notes: Scientist's outcome ranking A > B > C. Governments' outcome ranking A > B > C.

simplification is made here: several government politicians from several departments are reduced to a single actor—the government—and, therefore, we are ignoring their internal collective action problems. Similarly, thousands of scientists are reduced to another single actor—the scientist. All intermediate layers of the research hierarchy in a country and all the separate institutions that mediate among actors (research councils, universities) are outside the scope of this analysis. Although a more comprehensive and realistic approach would require including some of those actors in a more complex setting, the game representation used here is a heuristic device to depict an essential feature of the relationship, similar to what Miller (1992) or Abraham and Prosch (2000) do for the employer–employee interaction.

The game is similar to Miller's trust game between an employer and an employee depicted above, but now, the government (the employer) has the choice of playing the trust game—retaining its discretion in the management of scientists—or not playing it and "tying its hands" in the management of scientists through a process of bureaucratization. The term "bureaucratization" in this paper refers to the standard definition of bureaucratic rules used by economists (Tirole 1994). Bureaucratization is thus the limits to government's discretion in its relationships with state employees—in this case, scientists. With bureaucratization, a government constrains *ex ante* its power to hire, fire, promote, and fix incentives to scientists. Governments may tie their hands in the management of scientists in two main ways. First, bureaucratization can be implemented through delegating staff policy to a politically autonomous institution such as a *corps* of university professors (or other type of scientists), as is the case in countries like France or Spain. Governments are not free to select, promote, fire, or introduce monetary incentives to those scientists grouped in autonomous *corps*. Second, bureaucratization may also involve the enactment of laws and statutes through which governments limit their future actions in the relationship with scientists. For example, when governments issue rules that guarantee secure tenure or automatic promotion as a function of seniority, governments are reducing their discretion in personnel management.

Bureaucratization gives predictability to actors' payoffs. The assumption behind is that, instead of confronting unpredictable rewards and incentives from political governments, scientists will deal with predictable rules about rewards and punishments—rules enforced by relatively autonomous bodies such as university councils or administrative corps of scientists. Another feature of bureaucratized institutions is that the incentive structure is low powered. Since, in principle, there are more subordinates than superiors within organizations, there are almost always several candidates for a promotion in any kind of organization.

The idea is that in a bureaucratized organization, you must more closely follow a step-by-step promotion system from one level to the one right above it. Without bureaucratic rules, the government could promote any scientist to whatever position. Instead of the high-powered (although less credible) incentives from governments, with bureaucratization, scientists have low-powered incentives (although more credible because they are made by nonpolitical peers), which will be clearly issued in statutes and regulations. With bureaucratization, scientists will not obtain the maximum payoff (A) because governments will not be able to offer them high monetary rewards or promotions to the top levels of administration in exchange for maximum efforts. At the same time, bureaucratization also prevents the worst outcome for scientists (C) because they are less exposed to government's opportunistic actions. As a result, bureaucratization induces scientists to exert a *medium effort*, halfway between the maximum and the minimum effort. Scientists will exert a higher research effort than the minimum one because they know that if they do so, they will receive some reward, like a slow promotion; however, they put less effort in than they would have had they expected high-powered rewards from the government.

Conversely, when they decide to grant bureaucratic autonomy, governments do not enjoy the benefits of a high-powered system of incentives (they only obtain a *medium effort*), but they also avoid the worst payoff (C) (Kydland and Prescott 1977, 473). Unlike what happens to public employees, governments face a cost ($-x$) for using bureaucratization: they must pay employees for life, and they lose the flexibility to respond to external shocks that demand fast changes to the size and the composition of the civil service. Bureaucratization, thus, plays the role that Falaschetti (2002, 165) attributes to hand-tying institutions: mechanisms that *cannot totally eliminate* principals' moral hazard but that *increase the cost* of acting opportunistically. In general, bureaucratization prevents best and worst outcomes for both players, and it can be seen as a second-best option that is preferred when the best solution involves too many risks for the actors.

The payoff structure of the game can be illustrated with the example of the German scientific developments in the 1930s. Before the Nazi regime came to power, there was a high level of bureaucratization among scientists. German universities were state institutions and all faculty members were subject to a bureaucratized career civil service (Beyerchen 1977). Moreover, there exists a wide consensus that the German government obtained relatively good scientific returns as a result. On the contrary, when the Nazis came into power, they adopted a highly discretional approach to science, overturning many of the existing bureaucratic rules.[7]

In terms of the model depicted here, the Nazi regime moved from the predictable lower branch of the tree (bureaucratization) to the more unpredictable higher branch (discretion). This implies that, sometimes, the Nazis could achieve extraordinary results: scientists loyal to the party, or those who believed they would be properly rewarded, were ready to exert "maximum effort" in their research. The Nazis' great scientific and technological achievements in weaponry are an example (Wintrobe and Breton 1986).[8] Yet the Nazi government was not able to obtain maximum efforts from the bulk majority of scientists. Apart from the fact that many scientists were either purged or forced into exile, most of those who remained at their positions opted for a "minimum effort" strategy, taking advantage of their informational advantages. Despite close monitoring, the Nazis did not know for sure which type of scientific breakthrough those scientists could make.

The story of Curt Herzstark, inventor of the first pocket calculator, represents an extreme example of the unpredictability of the Nazi's strictly controlled science (see Stoll 2004). Thanks to his informational advantages, Curt Herzstark did not want to exert maximum effort to develop a tool that could be nationalized by the Nazi regime—and without a significant chance of obtaining a proper reward, especially because he was Jewish. However, while he was imprisoned in the Buchenwald concentration camp, an old competitor and colleague recognized him and informed the camp commander that Herzstark had previously been working on the development of a revolutionarily small calculator. Soon, using his high discretion, a Nazi official took Herzstark aside: "I understand you've been working on a new thing, a small calculating machine . . . We will allow you to make and draw everything. If it really functions, we will give it to the Führer as a present after we win the war. Then, surely, you will be made an Aryan" (Stoll 2004, 86). Herzstark was conscious that "if I can make this calculator, I can extend my life. Right there I started to draw the calculator, the way I had imagined it" (86). By chance, the Nazis had overcome the information asymmetry problem with one scientist: they knew quite precisely which type of discovery Curt could make, and they were ready to pass him through their powerful incentive system.

Herzstark understood that if he could develop the calculator, he would extend his life by at least some months; otherwise, his fate would be the same as the rest of the prisoners. He was allowed to spend his spare time working on the calculator, later called *Curta*. He worked much harder than he would have under a system of bureaucratic incentives, and he could have produced the highest payoff (A) for the Nazi officials if the Allies had not freed the camp before the invention was completed. This example illustrates, with one of the most extreme cases one can think of, how difficult it is for highly authoritarian regimes to induce scientists to undertake "maximum efforts," unless they are ideologically committed to the dictator. Given the highly discretionary behavior of autocratic authorities, Herzstark-like scientists will only exert maximum research efforts if, by chance, authorities are able to overcome the information asymmetry problem and know more-or-less precisely what a given scientist can achieve. It is thus likely that many other *Curta*-like breakthrough inventions and discoveries remained under-researched in Nazi Germany.

The scientist can make a maximum effort (trust) or a minimum effort (mistrust), but what does "maximum effort" mean? We refer here to two types of research work that are potentially subject to governments' time-inconsistency problems. First, "maximum effort" would be to work hard and overtime in research tasks, similar to what Curt Herzstark did. Second, "maximum effort" may also involve undertaking asset-specific investments—an effort that is intrinsic to science. Once the asset-specific investment has been made, the scientist is in a weaker bargaining position *vis-à-vis* the government, and the latter may abuse its position of power. On the contrary, "minimum effort," similar to Miller's (1992) version of the game, would mean maintaining a level of effort enough to avoid being fired.

If the scientist exerts maximum effort, the government can honor trust, which in this case means rewarding the scientist. This probably happens in many cases. For instance, many scientists were properly rewarded by the Nazis. Governments are not reneging on the promises made to scientists all the time. However, in the cases of maximum effort depicted above, the government has an incentive to violate trust, like in Kreps' or Miller's games. Governments have incentives in $t+1$ to violate trust (e.g., diverting the 50,000 florins promised to the piper to other ends) and often do so.

That also happens in democratic settings. A close example is that of Mariano Barbacid. In 1996, the newly elected Spanish conservative government recruited Barbacid, co-discoverer of the human oncogenes and a well-known national figure, to manage the new state-of-the-art Spanish National Cancer Centre (*Centro Nacional de Investigaciones Oncológicas* [CNIO]). Barbacid was promised total support from the Government and a €20 million budget a year. Yet in its third year, the center's budget was unexpectedly threatened with a one-third cutback. A journalist (Sampedro 2000) commented at the time that "[t]he budget . . . is hardly over a .1 percent of the National Health System, but it surely represents an irresistible temptation for a manager in distress" [our translation]. Barbacid faced the same threat again in 2001 and 2002, and commented that "we have achieved a great deal, but without a long-term commitment from the Government, our efforts may be wasted . . . I am rather disappointed because when I came back [from the USA] I thought that the CNIO would change the attitude of the government regarding science" (Bosch 2003, 1). Up to this point, the government–scientist game in Figure 2 is identical to the one used by Kreps or Miller. However, the capacity for taking an opportunistic decision that changes the status quo (e.g., reneging on the promise made to Barbacid) or, using Cox and McCubbins' (2000) terms, the *decisiveness* of a government, is limited in some political settings.[9] This limit to the governments' decisiveness is captured by the parameter d (costs for making decisions) in the government's payoff.

Those constraints stem from the existence of the separation of powers within a polity. The incumbent or his or her political party may be the only relevant actor, for instance, and then he or she is entirely free to violate trust. The discretion of many governments is restricted by the existence of different sorts of constraints. Several variables have been developed in comparative politics to account for the existence of those constraints, such as Acemoglu, Robinson, and Verdier's (2004, 24) "constraints on the Executive," or Tsebelis' (1995) "veto players." The assumption in this study, based on this comparative literature, is that democratic governments face more constraints on the executive (or more veto players) than authoritarian ones.

In the case of Barbacid, public opinion acted as a veto player or a constraint that prevented the government from reneging on the promise made to him. The scientist resisted the first attempt to curve down the

CNIO's budget in 2000 when the story went to the press. He used his public visibility and his reputation to change the planned cutback. In 2001, he granted a two-page interview with the main Spanish newspaper, *El País*, which stands closer to the social-democrat opposition party, in which he underlined the difficulties in carrying out research in Spain and highlighted his particular problems with the government (Barbacid 2001). As a result of the impact of those statements in the Spanish media, the government was forced to cancel the planned cutback.

Very decisive governments [$d < (A - B)$] have a higher payoff for violating trust ($A - d$) than for honoring trust (B).[10] Dictatorships, where in principle there are no significant players who can veto the ruler's decisions, would fall into this category. In polities where the constraints for decision making are strong enough [$d > (A - B)$], like well-established democracies, the government will conversely prefer to honor trust rather than to violate it. The existence of a government with limited decisiveness [$d > (A - B)$] can paradoxically solve the problem of trust in the model because the scientist's choice has changed in relation to Miller's game: now the options are choosing minimum effort, which gives the scientist a payoff of B, or choosing maximum effort, which gives her the highest payoff (A).

Consequently, the initial choice of the government (concerning bureaucratizing or not) depends on its decisiveness. When the limits to the decisiveness are high [$d > (A - B)$], the government obtains a higher payoff by choosing "discretion" over "bureaucratization" as the scientist exerts a maximum effort. The payoff for the government in case of "discretion" will be B. In case of "bureaucratization," the government obtains ($B - x$), which is always a lower payoff. The reason for this payoff is that governments face a cost ($-x$) for using bureaucratization: many times, they have to pay scientists for life, and they lose flexibility to respond to external shocks demanding, for example, fast changes in the scientific priorities or in the size and composition of scientific units. Thus, when there is low decisiveness, the government does not need to bureaucratize its scientists. Conversely, when the limits for taking decisions are low for the government ($d < [A - B]$, a situation of *high decisiveness* like dictatorships), as the scientist makes a minimum effort, the government must balance the payoff C of "discretion" against the payoff ($B - x$) of "bureaucratization." If the costs x are not high enough [$x < (B - C)$], the government would prefer bureaucratization.

To sum up, there is a substitution effect between the separation of powers and the bureaucratization of a public administration. *In order to induce scientists to exert a level of effort above the minimal one, governments must either possess low decisiveness or bureaucratize state scientists.*

The game has, up to now, assumed that politicians are in a void, so they can freely choose whether to keep discretion or to introduce bureaucratic rules. To complete the theoretical section, a different status quo is assumed to make the scenario more realistic. Imagine that, instead of the absence of bureaucratic rules, the starting point is a situation of high bureaucratization of scientists. If the elimination of bureaucratic arrangements did not imply costs, the prediction of the model would be that very decisive countries (dictatorships) would keep the level of bureaucratization while less decisive countries (democracies) would change toward a more flexible and discretionary approach. However, de-bureaucratization processes also involve costs for governments since they may imply the elimination of, for example, secure tenure or other bureaucrats' privileges and the reduction of the level of autonomy enjoyed by certain administrative corps. The literature has shown extensively how civil service reforms in many Western European countries aimed at reducing bureaucratic autonomy have been opposed by intense public service unions' mobilizations (Peters and Pierre 2001, 1-11). It is thus plausible to assume that scientists, through their webs of social interactions, will oppose certain de-bureaucratization processes that could, for instance, threaten their tenures. The general statement by Moe (1990, 144) on how bureaucratic organizations resist reforms that "once a bureaucracy is created, the political world becomes a different place because civil servants are now political actors in their own right" could also be applied to state scientists. Following the literature on the failure of de-bureaucratization reforms, one may therefore assume that there are contexts where de-bureaucratization is so costly that parameter x may have a positive sign—that is, adding to payoff B instead of subtracting. For example, keeping bureaucratization gives the government the support (or the lack of opposition) of key (public-sector) unions. Government, facing a choice between a high level of bureaucratization (which gives it a payoff of $B + x$) and recovering some degree of discretion (which gives it a payoff of B), will tend to keep the actual levels of bureaucratization. In sum, the following hypotheses may be derived from the simple model deployed here.

> Hypothesis 1: *Ceteris paribus*, when governments are not very decisive [d > (A – B)], bureaucratization of scientists is not necessary, and if the costs of an eventual de-bureaucratization are not high [if B > (B – X)], governments will choose a high level of discretion in scientific policy. In this case, the outcome of the game would be socially the most efficient: **Discretion/ Maximum Effort/ Honor Trust**.
>
> Hypothesis 2: *Ceteris paribus*, when governments are not very decisive [d > (A – B)], bureaucratization of scientists is not necessary, but, if the costs of an eventual de-bureaucratization are high [(B – X) > B], governments will keep the high level of bureaucratization. The outcome of the game would be the second-best one: **Bureaucratization.**
>
> Hypothesis 3: *Ceteris paribus*, when governments are very decisive [d < (A – B)], bureaucratization of scientists is necessary, and, if bureaucratization costs are not high [x < (B – C)], there will be a bureaucratization of scientists. The outcome of the game would be the second-best one: **Bureaucratization.**
>
> Hypothesis 4: *Ceteris paribus*, when governments are very decisive [d < (A – B)], bureaucratization of scientists is necessary, but if bureaucratization costs are very high (x < B – C), there will not be bureaucratization of scientists. The outcome of the game is the worst one: **Discretion/Minimum Effort**.

Table 1 summarizes the predicted scientific productivity according to the four hypotheses. It shows scientists' incentives under different combinations of regime type (high decisive/dictatorship or low decisive/ democracy) and type of scientific contract (more/less bureaucratized). An empirical contrast of these hypotheses is provided later.[11]

Bureaucratization, Scientific Productivity, and Dictatorships

The relationship between regime type and scientific productivity analyzed here is based on a two-step argument. First, the ruler decides the

Table 1. Predicted Scientific Productivity as a Function of Regime Type and the Level of Bureaucratization

	Low Bureaucratization of Scientists (politicians enjoy more Discretion)	High Bureaucratization of Scientists (politicians enjoy less Discretion)
More decisive governments (dictatorships)	(1) Hypothesis 4: Minimum effort, low Scientific Productivity	(2) Hypothesis 3: Medium effort, medium scientific productivity
Less decisive governments (democracies)	(3) Hypothesis 1: Maximum effort, high scientific productivity	(4) Hypothesis 2: Medium dffort, medium scientific productivity

type of scientific contract: more or less bureaucratization of scientists. Second, the type of contract induces scientists to choose their "research effort," which, in turn, affects the scientific productivity of the country.

For the case of dictatorships, the first step implies that those where the costs of bureaucratization are not very high will tend to establish bureaucratized contracts, while in those dictatorships where costs are high enough, rulers will tend to keep a high degree of discretion. The second step entails that dictatorships with bureaucratized scientific contracts will tend to have higher scientific productivity than dictatorships with high discretion. The first step is difficult to contrast from a quantitative point of view and, in this section, we only aim to provide some anecdotic evidence to illuminate the workings of the theory regarding dictatorships. A quantitative analysis of the second step is nevertheless provided, and one can observe how, controlling for the money spent in science, those dictatorships with high levels of bureaucratization have higher scientific productivity.

Why Some Dictatorships Bureaucratize Their Scientists

Why is it that all dictatorships do not establish bureaucratized contracts with scientists if they know that bureaucratization gives them higher levels of scientific productivity? In the theoretical model, we use parameter x to symbolize the costs that rulers must pay for bureaucratization. Costs x may be assumed to be quite similar across countries, but the difference between payoffs B and C may vary a lot, depending on what political economists define as rulers' survival strategies (Bueno de Mesquita *et al.* 2003; Olson 1993).

As Bates (2001) suggests, the study of modern European absolutism can shed light on the problems that some post-colonial African states have experienced. Modern European absolutism contributed with active public policies to the economic development of their societies while African kleptocrats have not shown much interest in providing public goods to their citizens. For Bates, with few exceptions, African post-colonial rulers are less likely to view their economies as a strategic resource to survive in office than modern absolutists. Contrary to Louis XIV, who needed to develop his economy if he wanted to raise taxes to have an army able to win wars abroad and to quell internal rebellions, Mobutu did not need to do so because of the abundance of natural resources and foreign aid he enjoyed.

The survival strategy of Mobutu-like rulers does not depend on the quality of their policies, and similarly, one cannot expect that increasing scientific productivity represents an asset for their survival in office either. The main risks those rulers face are conspiracies, many of them within their own rank and file (see Acemoglu, Robinson, and Verdier 2004). Yet tracing back to at least modern European absolutism, there are examples of rulers who considered that their survival depended critically on the economic (and thus scientific) development of their countries. Two of the most known absolutist rulers were precisely the creators of two of the first state institutions of employed and salaried scientists: in 1666, under the advice of Colbert, Louis XIV established the French Academy of Sciences, and in 1700, Frederick II of Prussia put in place the Berlin Academy of Sciences (Fisher and Lundgreen 1975, 546-9). From the beginning, the scientists of the French Academy enjoyed a remarkable level of bureaucratization and, soon afterward, their Prussian counterparts would also achieve an important degree of autonomy from politicians' interferences in science.

In sum, one could classify autocrats into (1) those whose survival in office mainly depends on the provision of public goods like overall economic performance and, thus, they may be interested in increasing scientific productivity; and (2) those whose survival in office mainly depends on the provision of private goods to core constituencies, and thus have no real interest in scientific outcomes. While the former are mostly interested in *positively* motivating public employees (i.e., inducing them to undertake costly asset-specific investments), the latter are mostly interested in *negatively* motivating them (i.e., preventing them from taking certain actions). The evolution of science under Franco's regime (1939-75) in Spain illustrates this difference in survival strategies.

Francoism can be divided into two periods. During the first period (1939-57), cabinets adopted a very discretionary approach to science. In the aftermath of the Spanish Civil War (1936-9), Franco's rule was based on repression and on the loyalty of the ruling elite's factions. At the university, loyal scholars replaced dead, purged, or exiled professors (nearly half of the academia) during the early 1940s. While the university traditionally recruited its members through a classic career system, the regime implemented in its first years the so-called "patriotic examinations" that primarily evaluated the loyalty to the Francoist ideological principles. The aim of this selection, expressed explicitly in the University Ordering Law (1942), was ideological control.[12] In a research environment of total uncertainty, literature has shown that scientists exerted minimum research efforts and that the result was very low scientific productivity (Fernández-Carro 2002).

Government scientific centers were also explicitly controlled. Although theology was the only addition to the scientific program in the new Higher Council on Scientific Research (*Consejo Superior de Investigaciones Científicas* or CSIC), the latter exerted ideological control over scientists along the ideals of National Catholicism and of a vindicated imperial scientific tradition.[13] CSIC was also intended to help the development of a self-sufficient national industry, imitating the Nazi German autarchic model. "Unshakeable loyalty" to the New State's principles was a requisite to become a CSIC scientist, and researchers were not under civil service status. Except for those committed to the regime from the very beginning, the great bulk of scientists enjoyed limited opportunities to direct research projects, compete for senior positions, or manage laboratories (see Santesmases 1998, 323). Consequently, again, productivity was extremely low. As González Blasco and Jiménez Blanco (1979, 100) remark, Spain has not yet had a Nobel laureate in science since the CSIC was established.[14] Science in early Francoism suffered scientists' mistrust of the government. As far as prizes and positions were not related to performance, the incentives for the remaining scientists were low and the best response was to limit efforts to a minimum.

Franco's survival strategy changed during the 1950s. After the struggling economy had led to serious riots and demonstrations in several cities, Franco shifted his policy priorities toward the provision of public goods. He appointed several ministers known as the *Technocrats*, uncommitted to the fascist ideology and who launched market-oriented economic reforms. They began the so-called *Desarrollismo*, a period of fast economic development. The reforms included a transformation of the public service to make it more professional and career oriented. More importantly for this study, during the 1960s, state scientists' careers came under the Civil Service Act and became lifelong: Spanish scientists, thus, became bureaucratized and more autonomous from politicians' interferences. Did scientists move from minimum to medium levels of effort as a result of their bureaucratization? It is difficult to assess this, given the lack of reliable bibliometrical accounts on the period, but the Science Citations Index database (SCI) records a sharp increase in scientific productivity at the end of the dictatorship: 831 publications in Science and Social Sciences in 1973 and only nine publications in the period until 1972.[15]

Bureaucratization and Scientific Productivity in Dictatorships

The historical evolution of Franco's rule illustrates how dictators, when their survival depends on fostering economic development, choose to tie their hands in the management of scientists through what has here been called bureaucratization. If the predictions of the model are correct, one should observe a higher scientific productivity in those dictatorships that have bureaucratized their scientists than in those that have not.

One of the best proxies for the scientific productivity of a country (SPC) is its Science Production, measured as the number of publications recorded in the SCI.[16] As a country's total science production depends, to start with, on its number of inhabitants, we must divide the Science Production of each country by the size of the population. There is consensus in the literature that the degree of economic development of a country is the most important determinant of its scientific productivity (Cole and Phelan 1999, 14; Price 1963). Given this, the relevant question that should be answered nowadays according to Cole and Phelan (1999, 15) concerns not the degree of impact of gross domestic product (GDP) over scientific productivity, but why there are countries—like Israel—which produce far more science than one should expect based on its wealth, while others—like Italy—produce far fewer than its GDP would indicate. We aim to address this question here.

In addition, the low number of observations in our regressions both for dictatorships and democracies—and therefore the reduction in degrees of freedom that comes from including many control variables—means that there is an additional reason to introduce countries' degree of development within our dependent variable.[17] Consequently, we define the SPC as science production by the gross domestic product of that country.[18] SPC is thus an artificial construct aimed at measuring the capacity of a country to produce science independently of its population and wealth. SPC is the capacity a country has to produce science controlling for its population and level of development. Our theoretical model proposes that this scientific capacity may be affected by changes in scientists' type of contracts.

As a proxy for the bureaucratization of scientists in dictatorships, we use the Weberianess Score developed by Evans and Rauch (1999), which is the most comprehensive attempt to build up a quantitative index of bureaucratization for non-Organisation for Economic Co-operation and Development (OECD) countries. The Weberianess Score and the indexes of bureaucratization we use for democracies below are similar as they all measure the extent of nonpolitical recruitment/promotion/firing of public employees. Therefore, they are coherent with our model because they try to capture the autonomy of civil servants in relation to politicians. However, we need to emphasize that those indicators are just proxies because their authors do not restrict the analysis to state scientists, but they study general public service organization. We assume that public researchers and academics in public universities work under similar recruitment and incentives systems as their colleagues in other sectors of the public administration while also recognizing that there might be exceptions to this assumption.[19] The Weberianess Score—a continuous variable that ranges from 0 to 14—measures the degree of bureaucratization for 35 developing countries around 1992. Because in this section we are interested in dictatorships, we have removed the democracies from the sample.[20]

Model 1 in Table 2 shows the effect of bureaucratization on the SPC without any control variables. Despite the relative low number of observations (28), bureaucratization exerts a positive significant impact on the quality of science. Therefore, it seems that the type of contract

Table 2. Determinants of Scientific Productivity in Dictatorships

Model Variables	1	2	3
Constant	1.935	–6.275	7.438**
	(2.540)	(4.899)	(2.701)
Bureaucratization (Weberianess Scale)	.762**	1.593*	–.472
	(.330)	(.739)	(.366)
Expenditure in science 1990		1.459	
		(4.23)	
Expenditure in science 2000			7.639***
			(1.587)
R^2	.170	.725	.675
N	28	9	16

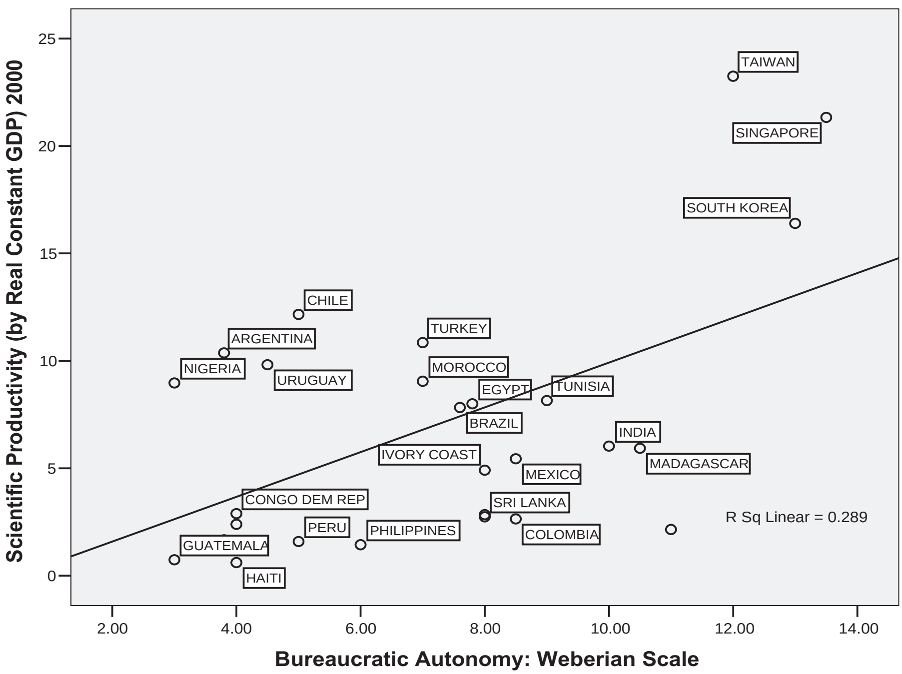
* p < .10; ** p < .05; *** p < .01 (two-tailed).
Notes: Unstandardized regression coefficients; standard errors are in parentheses. Dependent variable is Scientific Productivity of Countries (by Real Constant GDP) in 2000.

between government and scientists, bureaucratized or not, makes a difference in the SPC (the science production of the country according to its population and economic development).

In the literature on developed countries (see Cole and Phelan 1999), scientific productivity has been found to be dependent also on the country's expenditure on research and development (R&D) and on its human capital stocks. We use control variables for those factors in our posterior analysis of democracies. The unavailability of reliable data for dictatorships on those variables prevents us from properly controlling for these alternative factors. The existence of some consistent data on R&D expenditure for some countries and some years permits the tests deployed in models 2 and 3, which control for the money invested in science. We take data on Expenditure in Science from the World Development Indicators, which collects the percentage of the GDP devoted to scientific activities.

Two major problems question the validity of models controlling for R&D expenditure (models 2 and 3). The number of observations is extremely low in both cases (9 and 16, respectively) for extracting any relevant conclusion. Also, the independent variables in models 2 and 3 do not show consistent behavior: while the significant impact of bureaucratization eliminates the significance of Expenditure in Science in 1990 (model 2), the effect of the Expenditure in Science in 2000 makes bureaucratization insignificant in model 3. This behavior points to problems of multicollinearity, confirmed by the high bivariate correlations existing between bureaucratization and the available measures of expenditure (.7 and .8, respectively). Further observations beyond the scope of this article would be needed to properly control the effect of expenditure and further theoretical exploration on the possible causal relationships between bureaucratization and Expenditure in Science would also be required.[21] In sum, despite the limitations of these data, it seems that our independent variable—bureaucratization—exerts a positive effect on the scientific productivity of dictatorships. (Figure 3).

Figure 3.
Bureaucratic Autonomy and Scientific Productivity in Dictatorships



Bureaucratization, Scientific Productivity, and Democracies

Similar to dictatorships, there are two steps to be empirically contrasted for democracies: the decision of governments over scientists' type of contract and whether democracies with lower bureaucratization perform better in terms of scientific productivity than democracies with high bureaucratization. Again, the first step is difficult to test quantitatively and, here, we only provide some illustrative examples of how certain democracies that had inherited highly bureaucratized scientific contracts decided to de-bureaucratize their science system. Akin to the previous analysis of dictatorships, a quantitative study of the second step is given and one can observe how, contrary to what happened with dictatorships, controlling for countries' money spent in science and levels of human capital, democracies with lower levels of bureaucratization exhibit higher scientific productivity.

Why Some Democracies Debureaucratize Their Scientists

We expect that democratic governments do not need bureaucratization to prevent scientists from undertaking "minimum efforts" in research. However, if the status quo in a country is bureaucratization, democratic rulers will have to balance the potential benefits of de-bureaucratization (the difference between a maximum and medium research effort under bureaucratization) with its potential costs: the opposition of some scientists who enjoy secure tenure and other privileges of bureaucratic autonomy.

In most countries, scientists—like other civil servants—have shown strong resistance against any attempt of de-bureaucratizing them (Peters and Pierre 2001, 1-11). A large body of evidence (see Pierre 2001, 133) shows how opposition platforms have been created against many proposals for changing the *status quo* of scientists, university professors, or other civil servants. Yet in other contexts, the costs of reducing bureaucratization have been lower for different reasons. For instance, voters may not support an overprotected and less efficient bureaucracy with some power to change the decisions taken by a democratically elected government. That could be the case, at least partially, of the United Kingdom, which de-bureaucratized its science through pseudo-privatizations of public laboratories (Boden *et al.* 2004). Even though the profile of protests was low and some scientists welcomed the opportunity to compete for better salaries, there was also notable resistance to change in the United Kingdom coming from scientists and civil society movements who feared a loss of independence in public advice by state scientists.

Bureaucratization and Scientific Productivity in Democracies

We move now to the second step: the impact of bureaucratization over scientific productivity in democracies. Tables 3 and 4 show the results obtained by two different proxies for bureaucratization in democracies: closed-ness and bureaucratization. Results are similar in both cases. We use the same dependent variable as for dictatorships—the SPC—and we add variables to control for expenditure in R&D and the level of human capital.

In Table 3, the proxy for bureaucratization is the variable developed by Schnapp (2000) that we re-term *Closed-ness*.[22] A continuous variable that ranges from 1 to 6, *Closed-ness* portrays the career systems of 17 European countries in the 1970s, 1980s, and 1990s, and aims to capture the degree of autonomy of civil servants in relation to politicians. Open civil service systems are those where politicians enjoy more discretion for managing public employees; closed civil service systems are those where public employees are "closed" to politicians' interferences. A

Table 3. Determinants of Scientific Productivity in Democracies (I)

Model Variables	1	2	3
Constant	59.396***	38.622***	34.769*
	(6.144)	(11.778)	(16.827)
Bureaucratization (*Closed-ne*ss)	–5.554***	–3.804**	–3.562*
	(1.573)	(1.679)	(1.883)
Expenditure in Science 2000		7.516**	7.487*
		(3.748)	(3.874)
% of Population with Tertiary Education			.194
			(.585)
R^2	.454	.576	.579
N	17	17	17

* p < .10; ** p < .05; *** p < .01 (two-tailed).
Unstandardized regression coefficients; Standard errors in parentheses.
The dependent variable is Scientific Productivity of Countries in 2000.

Table 4. Determinants of Scientific Productivity in Democracies (II)

Model Variables	1	2	3
Constant	15.228**	7.881	7.488
	(6.168)	(6.772)	(7.798)
Bureaucratization (inverse of OECD Debureaucratization)	−1.864***	−1.538***	−1.519***
	(.501)	(.497)	(.537)
Expenditure in Science 2000		6.217**	6.070*
		(2.947)	(3.299)
% of Population with Tertiary Education			.055
			(.915)
R^2	.339	.435	.435
N	29	29	29

* p < .10; ** p < .05; *** p < .01 (two-tailed).
Unstandardized regression coefficients; Standard errors in parentheses.
The dependent variable is Scientific Productivity of Countries in 2000.

paradigmatic example of the latter would be the organizational structures based on autonomous administrative corps like those existing in France or Spain. Examples of the former would be the Netherlands, Sweden, or the United Kingdom.

Model 1 in Table 3 presents the results without any control variables and bureaucratization exhibits a highly significant effect on scientific productivity. As predicted in the theoretical part, this effect is *negative*: the more bureaucratization in democracies, the less scientific output. The availability of reliable data for democracies allows us to introduce more sophisticated controls here. In models 2 and 3, we include the two independent variables most extensively analyzed by the literature and which show a significant and positive effect on scientific productivity when we do not include bureaucratization in the equation. Expenditure in Science for the year 2000 (again from the World Development Indicators) controls for the share of GDP devoted to science, and the Percentage of Population with Tertiary Education is the available human capital variable that correlates the most with science production. Contrary to what happened in dictatorships, the bivariate correlations among the independent variables are relatively low (in all cases < .6) and do not indicate any serious problem of multicollinearity.

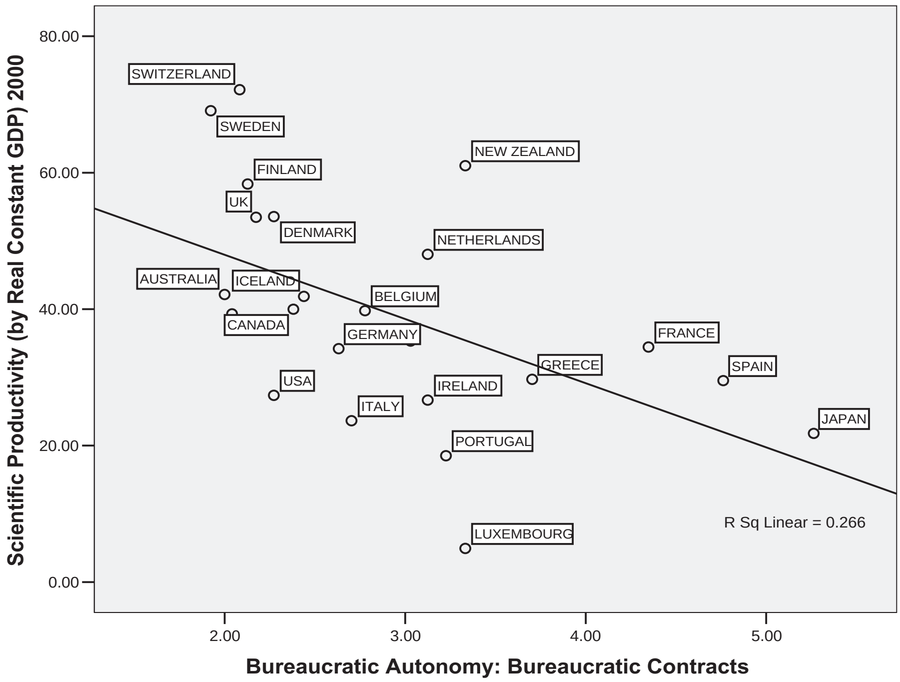
The inclusion of Expenditure in Science in model 2 reduces the significance of bureaucratization, but the latter keeps an independent and significant (at 5 percent) effect on scientific output. Model 2 can be interpreted in this way: an increment of 1 point in the 1-6 scale of bureaucratization (*Closed-ness*) decreases by 3.8 the number of scientific papers by unit of a country's wealth in 2000. To complete the picture, model 3 includes a second control variable: a proxy for human capital. With it, bureaucratization and expenditure in science present slightly lower coefficients to those in model 2 and have lost some significance (falling from 5 percent to 10 percent). Nevertheless, both keep their significant effect (negative in the case of bureaucratization and positive in the case of expenditure), which is especially remarkable given the drop in the degrees of freedom in an analysis with only 17 observations.

One of the most remarkable findings is that the percentage of population with tertiary education—which showed a strong significant effect on scientific productivity in previous studies, and which also exhibits here a significant impact when it is included as the only independent variable—loses completely its statistical significance when expenditure and bureaucratization are included. While no definite conclusions may be extracted from a fairly small-N study, it seems that the bureaucratic nature of scientists' contracts may affect the scientific outputs of a country even more than the variables traditionally explored by the literature.

These results are more solidly confirmed in the analysis shown in Table 4 where the proxy for bureaucratization is a combination of two indexes of human resources practices in public administrations created by the OECD (2004, 17). They capture the *debureaucratization* of public administrations: to what extent OECD countries have substituted new public management practices (e.g., more flexibility and more discretion for political managers) for traditional bureaucratic contracts (e.g., more stability and rigidity in contracts and more predictability in civil servants' careers).[23]

In general, the results in Table 4 are very similar to those in Table 3. The major difference is that the proxy for bureaucratization of scientists used here remains highly significant, at 1 percent, even when the two control variables are included (model 3).[24] As in Table 3, the inclusion of bureaucratization diminishes the explanatory power of two variables traditionally associated with scientific productivity. First, to an even greater extent than in Table 3, bureaucratization decreases the importance of the money spent in science (Expenditure in Science 2000) for explaining scientific productivity. Second, it completely eliminates the effect of the human capital variable most highly correlated with scientific productivity (Percentage of Population with Tertiary Education). In the light of the small-N empirical analyses shown in this section, we cannot claim that our hypotheses are fully contrasted for either democracies or dictatorships. Nevertheless, they point out an interesting and so far unexplored relationship, which should encourage future research on both state employees in general and scientists in particular: the opposite effect of bureaucratization on the efficiency of public employees depending on the political regime. (Figure 4).

Figure 4.
Bureaucratic Autonomy and Scientific Productivity in Democracies



Conclusions

This article has analyzed the relationship between political regime, type of administration, and policy outcomes—in particular, science policy outcomes that, unlike many other policy outcomes, allow certain cross-country comparisons given the existence of international data sets such as the SCI. This study complements the work of Fernández-Carro (2002), focusing on the relationship between regime-type and science policy outcomes that shows theoretically and empirically how democracies provide a better environment for scientific productivity. The study also complements Lapuente Gine's (2006) analysis of the relationships between political regime and type of administration. He develops and tests a game-theoretic explanation for why regimes with high decisiveness (e.g., dictatorships), when interested in providing public goods, tend to bureaucratize their public administrations.

As Moe (1997) points out, formal models applied to understanding bureaucratic structures tend to be too complex, and their implications threaten to be so hedged about by qualifications and conditions that they are either trivial or difficult to interpret or apply. On the contrary, the model presented here is simple, with propositions not dependent on complex qualifications and conditions. The propositions are easy to interpret and test, as shown in the empirical section of the paper. Despite being straightforward, they are not trivial, as they contain two—to a certain extent—counter-intuitive findings. First, when rulers are interested in producing science, the more powerful a ruler is, the more he or she will tend to bureaucratize his or her administration. Second, bureaucratization produces an opposite effect on policy outcomes depending on the political regime—it increases the efficiency of policies in dictatorships and decreases the efficiency in democracies.

Future research would expand the scope of the empirical analysis by including larger data sets as well as paying attention to within-country differences. For example, the United States can be seen as a natural experiment for analyzing the effects of bureaucratization of scientists in democracies, as there is a system of intramural laboratories in which employees are generally civil servants and another of extramural research in which employees are generally not civil servants. At the theoretical level, future inquiry should tackle the within-democracies and within-autocracies differences that one may suspect exist in governments' level of "decisiveness" regarding scientists. Further developments of the theoretical model should also account for the potentially important role that "intermediate agents," such as Research or University Councils, may play. It is straightforward to see their relevance, but it is difficult to include their systematic impact within a model like the one used here—especially taking into account the problems of finding reliable data on those intermediate agents and their composition (that is, to what extent their preferences differ from those of politicians and scientists).

The bottom line is that there are differences in the scientific productivity between dictatorships and democracies. There are also differences within political regimes. This work contends that those differences are due to the effect of an intermediate variable, the bureaucratization of scientific contracts. Through bureaucratization, dictatorships reduce the high uncertainties and time inconsistencies inherent to the relationship between powerful principals (governments) and agents that need to make costly asset-specific investments (scientists). Bureaucratization is a second-best solution to prevent the "minimum research effort" expected in noncredible environments like dictatorships. It also precludes the "maximum research effort" expected in more credible environments like democracies. In other words, bureaucracy makes science more productive when governments are not reliable, but it makes science less productive when governments are trustworthy.

Notes

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[1] Except where cited, this study concerns nonappropriable science intended for publication, both basic and applied. Following David (1998), we separate it from appropriable knowledge that can become a patent or help to develop an industrial process for a firm, for instance. Most of nonappropriable science is paid by the government, carried out in public organizations, and published. Although tightly linked, nonproprietary and proprietary sciences are different. Appropriable knowledge allows a different incentive system for agents—e.g., an easier one based on result sharing (Fernández-Carro 2007).

[2] We follow the criticism of those assumptions by the Interest Theory literature in sociology of science. See, for instance, Barnes and Dolby (1970), Mulkay (1991), or Barnes (1985). We also assume self-interested behavior by politicians. Similar to Braun (1993, 139), it is assumed here that it is not economic efficiency that guides the actions of politicians in their relations with scientists. Both authoritarian and democratic rulers are driven by what Moe (1990) defines as political efficiency: they are interested in remaining in office.

[3] This *contractualist* perspective joins the concerns of science policy studies with those of the so-called "*social contract of science*," the tacit promise of science "*to deliver goods to society in return for its patronage with no string attached*" (Rip 1990, our emphasis, cited in Guston 1996).

[4] Other studies focus on intermediate agencies, such as research councils (Braun 1993, 139) or in public or private laboratories as agents.

[5] Van der Meulen (1998) suggests that repeated games could provide stability to the government-scientists relationship, along with other intermediate institutions, but he finds that a pure game is unstable. As suggested by political economists, ultimately no clear predictions may be derived from repeated games, because of the implications of the Folk Theorem (see Falaschetti 2002, 163). We follow these authors in considering that, at least initially, one-shot games are the best way of tackling the game-theoretic interaction among actors. Future extensions of the game developed here should allow for the possibility of repetition as well as the introduction of other potentially relevant actors.

[6] The essence of the game is a problem of information asymmetry for both actors. Employees do not know what managers will do and managers can never be sure what employees' marginal cost of effort functions looks like. Employees are systematically trying to protect that informational advantage, but, if they trust the manager and work hard, the latter may discover the employees' real marginal cost of effort functions (Falaschetti 2002, 163).

[7] Just two months after the Nazi seizure of power, Hitler issued the "Law of the Restoration of Career Civil Service" (April 7, 1933) through which Nazi officials took over the reins of scientists' tenure, promotion, and incentives. As a consequence, many unreliable scientists were soon dismissed (Beyerchen 1977, 12-14, 43-7; our emphasis). The law created uncertainty, especially to those most directly affected by it ("*those of 'non-Aryan' descent*"), but also to any scientist, since it became discretional and opened up for interpretation on the second motive for dismissal: "*those whose previous political activities did not guarantee that they would at all times unreservedly serve the new state*."

[8] Wintrobe and Breton (1986, 909; our emphasis) show how, even in the most totalitarian dictatorships, "*superiors and subordinates, in effect, trade with each other.*" Superiors seek to buy informal services–services that cannot be codified in formal documents—and, in exchange, they offer informal payments, such as rapid promotions.

[9] For Cox and McCubbins (2000), one of the main trade-offs political systems face is between *decisiveness*, the capacity to take political decisions, which increase with the degree of concentration of powers, and *resoluteness*, the capacity to show a long-term commitment to the policies enacted in a concrete moment, which decrease with the degree of concentration of powers.

[10] Following Kydland and Prescott, it does not mean that governments are *always* going to renege on their promises and it is important to remark here that, "the reason that they [policy-makers] should not have discretion is not that they are stupid or evil but, rather, that discretion implies selecting the decision which is best, given the current situation" (1977, 487).

[11] This paper focuses on the differences between authoritarian regimes and democracies, but it is plausible to believe that there are also notable within-democracies and within-autocracies differences in the relevant variable here—i.e., "decisiveness" regarding scientists. Future research should address up to which extent within-regime differences may affect, first, bureaucratization levels among scientists and, second, overall levels of scientific productivity. This research will probably require both a more refined theoretical model as well as more encompassing data sets than the existing ones.

[12] This Law put the university under the National-Catholic ideals and the *Falange*'s mainly fascist principles: "*Third Article. The University, inspired by the Catholic sense, inherent to the Spanish academic tradition, will bring its teaching to the catholic moral and dogma, and to the rules of the current cannon Law. Fourth Article. The Spanish University, in harmony with the ideals of the National-Syndicalist State, will adjust its teaching and its educational tasks to the Movement programmatic concerns*." From University Ordering Law: *Ley de 29 de julio de 1943 sobre Ordenación de la Universidad española, Boletín Oficial del Estado 212*, July 31, 1943, pages 7.406 to 7.431; our emphasis. The Movement (*Movimiento* or *Movimiento Nacional*) dubs the ruling coalition.

[13] In a speech to the general council of the CSIC, General Franco stated explicitly its mission: "*The Spanish regime does not hinder or hamper the legitimate scientific freedom but wants and demands that the research activity subordinates and adjust itself to the spiritual and material needs of the country . . . This is all about our yearning for empire*" (CSIC Annual Report 1946-47, 1948). See also Santesmases and Muñoz (1993, 156).

[14] This is not formally true, since the Spanish-born Severo Ochoa won the Nobel in 1959. Nevertheless, Ochoa's research cannot be considered an example of "Francoist science" but, quite the opposite, of the problems of Franco's discretionary science, since Ochoa left Spain as a result of Franco's rebellion in 1936. He made his academic career in the United States and only returned permanently when the dictatorship was over. He had begun his career under the democratic Second Republic. Moreover, he was a pupil and a *protegée* of the last Prime Minister of the Republic's Government and, although he was never directly involved in politics, both his life and his career would have been in danger for this reason in the case he had returned to the country.

[15] The reliability of the SCI database is built upon the way it selects the covered journals, by the number of its articles' citations. Following Bradford's Law, most of the cited literature is published in a very few journals: SCI weekly selects those whose articles are cited often. Journal selection is, thus, in some way automatic. Articles published in these journals are then indexed. Mutual citations are eventually used to evaluate the relative importance of the articles themselves, the journals, their authors, the institutions they work for, and the countries these institutions are in. Although the database started working early in the 1960s, the first complete analyses of countries began in the 1980s. These analyses mainly consist in the counting of the number of papers published in the SCI covered journals, the country's production for a certain year. This rough number strongly depends on the country's size and wealth, and normalization is needed to compare among countries.

[16] Cole and Phelan (1999) discuss why SCI is the best feasible alternative to use as a proxy to a country's science production. It could be argued that some of SCI publications do not come from state scientists but from private sector scientists to whom, obviously, our theoretical predictions do not apply. However, private firms publish very basic science papers—ranging from almost none in developing countries to 6-9 percent in developed ones (Hicks 1995).

[17] The results do not change if we use a country's science production divided by population as a dependent variable and the level of economic development as an independent variable. It simply decreases the degrees of freedom in our already small-N statistical analysis. For that reason, we prefer to include GDP in our dependent variable following the suggestion of several scholars in the field (e.g., Cole and Phelan 1999).

[18] Equivalent to dividing Scientific Productivity (by population) by per capita GDP because "population" is dividing both in the numerator and in the denominator. Real GDP figure is taken from the Penn World Tables (constant 1996 international $).

[19] Public research centers and universities often have personnel policies different from those of the general public administration. There are no data sets devoted to public bureaucracies in the field of science. More importantly, when a Civil Service Act exists within a country, in general, scientists are covered by it. That is the case in most continental European countries where state scientists are legally treated like regular civil servants. We therefore consider that the indexes of civil service level of bureaucratization are the best feasible alternative proxies for scientists' level of bureaucratization.

[20] Evans and Rauch's original list includes Argentina, Brazil, Chile, Colombia, Congo Democratic Republic, Costa Rica, Dominican Republic, Ecuador, Egypt, Greece, Guatemala, Haiti, India, Israel, Ivory Coast, Kenya, Malagasy Republic, Mexico, Morocco, Nigeria, Pakistan, Peru, Philippines, Portugal, Singapore, South Korea, Spain, Sri Lanka, Syria, Taiwan, Thailand, Tunisia, Turkey, and Uruguay. We removed those countries that had a score lower than 2.5 as an average of Freedom House's freedom ratings between 1972 and 1992. The lack of information in some of the independent variables limits the final number in the analysis to about 25 countries.

[21] Rauch's (1995) findings may be useful in this sense. He shows how higher levels of bureaucratization—measured through the adoption of Civil Service Commissions in U.S. municipalities during the Progressive Era (1900-20)—led to the allocation of higher percentages of local budgets to long-term investments such as infrastructure and lower to short-term policies. Something similar could be happening in the cases analyzed here (that is, more bureaucratized states make more long-term investments such as expenditure in research), but further research is needed to falsify it.

[22] Schnapp calls this variable *openness* using data from Auer, Demmke, and Polet (1996). Since we inverted its values, we renamed it *Closed-ness* to facilitate the comparison with the other empirical analyses.

[23] The two OECD indexes are *individualisation* and *delegation*. "Individualisation is measured by the degree to which the management rules and practices vary according to the individuals and less according to the group" (OECD 2004, 17) and focuses on the way in which incentives are applied to public servants. "Delegation" levels are measured by where decision making power is located, from the central bodies (normally outside the control of politicians) to line departments and lower administrative levels (where elected politicians enjoy more discretion). We combined both indexes for simplicity, but the results are almost identical if we use any of them as proxies for bureaucratization since they are highly correlated.

[24] This is mostly due to the fact that the number of observations has increased from 17 (Table 3) to 29 (Table 4).

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