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Essays on Political Economy of Technological Development

A dissertation submitted in partial satisfaction

of the requirements for the degree

Doctor of Philosophy in Political Science

by

Natalia Lamberova

2020

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ABSTRACT OF THE DISSERTATION

Essays on Political Economy of Technological Development

by

Natalia Lamberova
Doctor of Philosophy in Political Science
University of California, Los Angeles, 2020
Professor Daniel Simon Treisman, Chair

This dissertation explores the incentives that drive political leaders to invest in Research and Development (R&D) policies even though such investments are risky, less visible to the public than many other options, and typically bear fruit only after the incumbent has already left office. I provide several explanations and explore the economic consequences of political incentives that shape government R&D policy.

I argue that the mere policy choice of investing in R&D improves the incumbent's perceived competence among voters. Using a formal signaling model, I show that, under a set of conditions, the separating equilibrium is possible: a competent incumbent invests in (riskier) R&D policy, while a less competent incumbent invests in safe projects (infrastructure). I test the conclusions of this model by conducting survey experiments in the US and Russia and find that in both countries, respondents see pro-R&D politicians as more competent compared to control politicians.

Turning to a setting with weak institutions, I show that government can use

investment in R&D as a vehicle for rent seeking, as the risky nature of such investment makes it hard to distinguish between policy failure and technology failure. Due to the inherent difficulty of accessing the value of patents produced with government funding, such funding encourages the growth of low-quality patents. The proliferation of low-quality patents in the technology market reduces the incentives to produce high-quality patents – a typical "lemon problem." Such problems arise even if the government has a significant stake in technological development. In a cross-country setting, I document the wide discrepancies in the impact of government funding on the creation of patented technologies and show that countries with higher levels of corruption have a greater patenting efficiency, creating more patents on paper, but that does not translate into actual technological development. To achieve causal interpretation, I apply the difference-in-difference approach to data on Russia's government policy to support nanotechnology to show how government support for innovation reduces the overall quality of patents in the supported field.

Technological progress is an important factor in economic development, yet it can be a destabilizing force, upending the existing balance of power in the economy. Such changes can be unwelcome to a government that would like to preserve the status quo. Yet instead of stifling innovation, the incumbent can channel it into the hands of loyal supporters by directing government grants towards them and providing additional benefits that are contingent on the success of the R&D project. Using the trajectory balancing approach for all companies that applied for the Russian program of R&D support via government subsidy, I show that politically connected companies are more likely to obtain government R&D grants. Furthermore, they reap greater benefits from it in form of improved gross profits and return on assets, compared to unconnected companies. I also find that they receive greater volumes of government contracts during the phase of assessment of the progress of their R&D project.

The dissertation of Natalia Lamberova is approved.

Nico Voigtlaender

Chad J. Hazlett

Daniel N. Posner

Daniel Simon Treisman, Committee Chair

University of California, Los Angeles

2020

To my parents

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CHAPTER 1

Introduction

1.1 Focus of the dissertation

This dissertation is comprised of three essays in political science which explore the political incentives to support Research and Development (R&D). Why do some leaders devote significant funds to fostering innovation even though such investments are risky, less visible to the public than many other options, and typically bear fruit only after the incumbent has already left office? I provide several explanations and explore the economic consequences of political incentives that shape government R&D policy. The three essays share a common approach to investigation of the political incentives that drive government policy choice. In each essay, I introduce a game-theoretic model that describes the hypothesized mechanism that drives the incumbent to invest in R&D. These models render observable implications that are tested against the data using causal inference tools. Each model attempts to reconcile observed large-scale government efforts to support innovation with the apparent disincentives to do so that arise from the perspective of economic-voting models and the political economy of incumbent survival.

Essay 1 suggests that the mere policy choice of investing in R&D improves the incumbent's perceived competence among voters. Next, essay 2 explores the setting with weak institutions and shows that, in the presence of rent seeking, a large part of government R&D investment is wasted, resulting in Akerlof's "lemons problem" in the market for patents. Finally, essay 3 tackles the fact that technological development can be a destabilizing force, upending the existing balance of power in the economy. Such changes can be unwelcome to a government that would like to preserve the status quo. Yet instead of stifling innovation, the incumbent can channel it into the hands of loyal supporters by applying different policy regimes to them.

From a social welfare standpoint, the rationale for government investment in R&D is clear: technological advancement is an important determinant of sustained economic growth (Romer, 1990; Aghion and Howitt, 1990; Aghion et al., 1998), yet many research projects are risky and may require a long-term commitment of resources and infrastructure (Izsak, Markianidou and Radošević, 2013). As the creator of new knowledge is unlikely to reap all of its rewards, the societal benefits of R&D generally exceed its private ones. Stiglitz (2015) notes that "Knowledge can be viewed as a public good, and the private provision of a public good is essentially never optimal." Not surprisingly then, governments worldwide spend a great deal of money on promoting R&D.[1]

While the normative argument for government involvement in R&D is clear, the positive explanation of its existence is less so. Why do political actors who control government resources have incentives to invest in R&D instead of, say, sponsoring voters' consumption? The political incentives that governments face are in many respects similar to the incentives of private companies. Studies of economic voting (Cohen and Noll, 1991; Duch and Stevenson, 2006; Fiorina, 1978; Lewis-Beck, 1986; Huber, Hill and Lenz, 2012) emphasize that voters care only

[1]In 2010, the EU outlined five main long-run goals for the 2020 Strategy and pledged to devote 3% of GDP to R&D support. In the US, the government spent $39.9 billion on R&D in 2017 (Sargent, 2018), comparable to the $44.3 billion budgeted for elementary and secondary education.

about recent policy benefits, a shortsightedness that provokes inefficient public policy due to the responsiveness of government policies to citizens' preferences (Page and Shapiro, 1983). However, if electoral rewards for beneficial policies decay rapidly, then reelection pressures induce policymakers to lean toward opportunistic short-term policies, underinvesting in welfare-enhancing policies with benefits that take longer to materialize (Achen and Bartels, 2008; Keech, 1980; Sobel and Leeson, 2006).

Both theoretical and empirical investigations of the political foundations of R&D need to take into account the specifics of this type of government activity. First, *the time between the investment and utilization of the new technology is longer than that of most projects and often exceeds the officeholder's term in office.* For example, in medicine, the average time lag between a scientific finding and its implementation is 17 years (Morris, Wooding and Grant, 2011). Second, *even interim results of government investment in R&D are less visible than other avenues*, such as infrastructure and education. This, in turn, makes it harder for the incumbent to expect a boost in popularity as a consequence of welfare-promoting policy. By contrast, projects which have more visible interim results can help incumbents gain public support even before their completion. For example, in an analysis of the construction of the Autobahn network in Nazi Germany, Voigtländer and Voth (2014) show that highway construction was effective in boosting popular support for the government not only through its impact on the economy but also by sending a powerful signal related to the competence of the incumbent responsible for the construction.

The third distinctive feature is that *new technologies can empower new actors.* The incumbent elite may fear being deposed by those who are empowered by a new technology, an effect that Acemoglu and Robinson (2006*a*) term "political displacement."Sometimes, governments block innovation in an attempt to shield the established elite from economic losses (Mokyr, 1990, 1992*b*). This view makes the political decision to promote innovation an even greater puzzle. Finally, *investment in R&D is riskier than other types of government investment*, since knowing whether a certain technology resulting from it will be successful prior to its outcome is at best difficult. This dissertation examines the set of political incentives to invest in Research and Development in light of these traits.

1.2 Brief overview of arguments and evidence

Essay 1 suggests that investing in R&D improves the incumbent's perceived competence among voters. First, I construct a formal signaling model. It demonstrates that, if the incumbent cares about reelection and his policy's economic outcome, and the median voter cares about whether the incumbent is competent of not, the separating equilibrium is possible: a more competent incumbent invests in (riskier) R&D policy, while a less competent incumbent invests in safe projects (infrastructure). I test the conclusions of this model by conducting survey experiments in the USA and Russia. I use a paired-vignette design and ask respondents to compare a treatment (pro-R&D) politician to a control (pro-education, pro-infrastructure, or pro-short-term innovation) politician. I find that in both USA and Russia, respondents see pro-R&D politicians as more competent compared to control politicians. I corroborate my findings with cross-country evidence using a directed acyclic graph approach to causal identification. I find that countries with higher levels of government R&D expenditures have, on average, higher levels of government approval.

Essays 2 and 3 rely on selection on observables approaches to causal identification: difference-in-difference and trajectory balancing, respectively, to examine the outcomes of government R&D policy interventions in Russia. The Russian setting serves as an excellent laboratory to study both political incentives to invest in R&D and the consequences of such incentives. Before the collapse of the USSR, the Soviet/Eastern European scientific community accounted for close to one-third of the world's scientists and engineers as well as R&D expenditures (Sagasti, Salomon et al., 1994; Graham and Dezhina, 2008). With severe economic crisis hitting Russia in 1991, no money was available to continue R&D funding, leading to shortages of lab supplies and months of unpaid wages (Ganguli, 2017*a*). By 1993, the Russian government estimated that there was a 35.2 percent decrease in the researchers working in higher education institutions (Graham and Dezhina, 2008). In the early 2000s, with the economy recovering, observers still saw Russia's science and technology as its "major untapped resource" (Sher, 2000). Despite the USSR's scientific legacy, Russia's innovative performance remains astonishingly low (Gianella and Tompson, 2007). The explanations for such poor performance include the deterioration of human capital (Gaddy and Ickes, 2013), weak intellectual property rights protection (Aleksashenko, 2012), and territorial imbalances in access to world technologies through multinational corporations (Crescenzi and Jaax, 2017). Among many determinants of unsatisfactory innovative performance, scholars underscore two: weak demand for R&D in the economy and low government funding for R&D (Alexeev et al., 2013). Starting in late 2000s, the Russian government introduced various programs to bolster technological development, with mixed results.

In 2008, it instituted a large-scale effort to bolster innovation in nanotechnology by providing government grants directly to inventors. Having patents in the relevant field (nanotechnology) was one of the main criteria for obtaining a grant. Essay 2 examines the impact of this policy by applying the difference-in-difference approach. It shows how government support for innovation reduces the overall quality of patents in the field of nanotechnology relative to other fields. I explain this unexpected result by offering a game-theoretic model in which, under rent seeking and weak institutions, a government that has a significant stake in technological development invests in R&D even if it simultaneously encourages growth of "lemons," resulting in Akerlof's "lemons problem" in the market for patents and technology transfer. In addition to the causal identification of the impact of government R&D funding on patent quality in Russia, I document the wide discrepancies in the impact of government funding on the creation of patented technologies across the world. I show that countries with higher levels of corruption have a greater patenting efficiency, creating more patents on paper, but that efficiency does not translate into actual technological development.

In the third essay, I explore the claim that political elites have the incentive to stifle innovation and hypothesize that they can instead channel it into the hands of loyal supporters by directing government grants towards them. Unlike pork-barrel forms of favoritism central to the literature on the value of political connections, such support would require some efforts on the part of the recipient so that it actually produces technological advantage. I examine the "Decree 218" (Postanovlenye 218) government R&D policy. The main feature of this grant is that manufacturing companies that implement projects can be the direct recipients of public funding that has been earmarked for universities. The company that implements the project pays for up to half of the R&D costs using the funds that it received from the government. It then conducts the project jointly with its university partner (Decree218, 2020). Using the trajectory balancing approach for all companies that applied for the Russian program of R&D support via government subsidy in 2010–2016, I show that politically connected companies are more likely to obtain government R&D grants. Furthermore, they reap greater benefits from winning a grant in the form of improved gross profits and return on assets, compared to unconnected companies. I find that, unlike unconnected companies, politically connected firms receive higher volumes of government contracts during the mandatory assessment of progress on their R&D project undertaken under Decree 218 grant. This evidence is consistent with the view that they are incentivized to devote greater efforts to their R&D project relative to unconnected companies, explaining higher positive impact of the Decree 218 grant on economic performance.

CHAPTER 2

The Puzzling Politics of R&D: Signaling Competence through Risky Projects

2.1 Introduction

Governments have historically had a major hand in science and technology through investment in research and development (R&D), the key input in creation of new technologies (Izsak, Markianidou and Radošević, 2013). From a social welfare standpoint, the rationale for government investment in R&D is clear: Many research projects are risky and may require a long-term commitment of resources and infrastructure (ibid). As the creator of new knowledge is unlikely to reap all the benefits, the societal benefits of R&D generally exceed its private benefits. Stiglitz (2015) notes that "Knowledge can be viewed as a public good, and the private provision of a public good is essentially never optimal." Not surprisingly, governments worldwide spend a great deal of money on promoting R&D.[1]

While the normative argument for government involvement in R&D is more or less clear, the positive explanation of its existence is very much less so. Why do political actors who control government resources have incentives to invest in R&D instead of, say, sponsoring voters' consumption? The political incen-

[1] In 2010, the EU outlined five main long-run goals for the 2020 Strategy and pledged to devote 3% of GDP to R&D support. In the US, the government spent $39.9 billion on R&D in 2017 (Sargent, 2018), comparable to the $44.3 billion budgeted for elementary and secondary education

tives that governments face are in many respects similar to the incentives of private companies. Studies of economic voting (Cohen and Noll, 1991; Duch and Stevenson, 2006; Fiorina, 1978; Lewis-Beck, 1986; Huber, Hill and Lenz, 2012) emphasize that voters care only about recent policy benefits, a shortsightedness that provokes inefficient public policy due to the responsiveness of government policies to citizens' preferences (Page and Shapiro, 1983). **?** provide experimental evidence that voters are especially sensitive to recent economic activity. Vasilyeva and Nye (2013) show that the provision of public goods is closely related to the political competition. However, if electoral rewards for beneficial policy decay rapidly, then reelection pressures induce policymakers to lean toward opportunistic short-term policies, underinvesting in welfare-enhancing policies with benefits that take longer to materialize (Achen and Bartels, 2008; Keech, 1980; Sobel and Leeson, 2006).

In a paper justifying retrospective voting analysis, Key and Cummings (1966) note: "[Voters] are not likely to be attracted in great numbers by promises of the novel or unknown." Similarly, promises of future good performance are discounted completely in Ferejohn (1986). Yet investment in R&D is unlikely to boost incumbent's popularity from the perspective of retrospective voting either: the fruits of government R&D policy rarely ripen by the time the incumbent stands for re-election. Wittman, Weingast and Hibbs (2009) points to the lack of consensus in empirical work on whether prospective voting, retrospective voting, or their mixture, provides the best explanation for voter behavior. But given the importance of recent economic outcomes on reelection probability, why would policymakers spend money on risky long-term projects?

The explanation I offer is that voters consider R&D investment to be a signal of leaders' competence. While they cannot reap the benefits of these investments before the election, they realize that an incompetent leader, being unable to select proper projects, would be more willing to spend on consumption goods. Voters' preferences to reelect competent leaders therefore create incentives for R&D investments. Of course, the signaling nature of such investments creates incentives even for an incompetent leader to invest in R&D, as she would want to pool, in equilibrium, with a competent one. In the theoretical model, I analyze conditions under which a separating equilibrium exists; naturally, separation is welfare-enhancing. Then, I investigate the empirical implications of the model using a cross-country data set and survey experiments in the US and Russia.

Both theoretical and empirical investigations of the political foundations of R&D need to take into account the specifics of this type of government activity. First, *the time between the investment and utilization of the new technology is longer than that for most projects and often exceeds the officeholder's term in office.* For example, in medicine, the average time lag between a scientific finding and its implementation is 17 years (Morris, Wooding and Grant, 2011). Second, *even interim results of government investment in R&D is less visible than other forms of government investment*, such as infrastructure and education. This, in turn, makes it harder for the incumbent to expect a boost in popularity as a consequence of welfare-promoting policy. By contrast, projects the interim results of which are more visible can help incumbents gain public support even before their completion. For example, in an analysis of construction of the Autobahn network in Nazi Germany, Voigtländer and Voth (2014) show that highway construction was effective in boosting popular support for the government not only through its impact on the economy but also by sending a powerful signal related to the competence of the incumbent responsible for the construction.

The third distinctive feature is that *new technologies can empower new actors.* The incumbent elite may fear being deposed by those who are empowered by a new technology, an effect that (Acemoglu and Robinson, 2006*a*) terms " political displacement". Sometimes, governments block innovation in an attempt to shield the established elite from economic losses (Mokyr, 1990, 1992*b*). This view makes the political decision to promote innovation an even greater puzzle.[2] Finally, *investment in R&D is riskier than other types of government investment*, since knowing whether a certain technology resulting from it will be successful prior to its outcome is at best difficult.

Given the factors that seemingly make investment in R&D unattractive for incumbents, why do governments do so at such high levels and opportunity cost? Examining observational data from OECD countries and a cross-national opinion survey, I find that governments that increased their R&D funding enjoyed higher approval ratings. The effect is greater than the effect of increased government spending on education. To know what to condition on to make a causal claim requires making assumptions about how a web of variables influence each other, the treatment, and the outcome. This is formalized by constructing a directed acyclic graph (DAG) that expresses our assumptions about which variables (do not) influence each other. From this DAG we can determine the appropriate variables to control for. I employ a plausible DAG, and test whether the conditional independences implied by such a DAG hold in the data or not (Pearl, Geiger and Verma, 1989), effectively a generalization of falsification tests such as balance testing. Given the difficulty of identifying causal effects in a cross-country setting, I further apply a sensitivity analysis (Cinelli and Hazlett, 2020) to my main results. To fully eliminate the discovered effect of the government R&D expenditures on citizens' attitudes, the unobserved confounders (orthogonal to the covariates) would have to be able to explain more than 17.6% of the residual variance of both the treatment and the outcome.

[2] A situation in which incumbent leaders empower certain interest groups with a long-run technological advantage is discussed in detail in Anonymous (2019).

While the cross-country evidence is suggestive of the argument that government investment in R&D can improve the perceptions of citizens, it is not conclusive. To provide additional evidence not subject to confounding concerns, I conduct a paired-vignettes survey experiment in the USA, a country that has a robust tradition of government support of R&D, and Russia, where the modern history of government involvement in R&D started, for all practical purposes, in 2008. The results of the experiment suggest that pro-R&D politicians are regarded as more competent than those that prioritize infrastructure or education spending. This to true in the the contexts of both democratic politics in the US and authoritarian politics in Russia. Still, there are some significant dissimilarities between the two countries: e.g., in the US, R&D spending raises expectations of competence but not on overall economic performance, while in Russia competence perceptions and economic expectations are highly correlated.

The rest of the paper is organized as follows: Section 2.2 briefly reviews the existing literature. Section 2.3 contains the theoretical model. Section 2.4 introduces the cross-country evidence. Section 2.5 analyzes the survey experiment. Section 2.6 provides discussion, while Section 2.7 concludes.

2.2 Related Literature

The importance of technological development for economic growth has long been recognized by scholars, and many have studied the role of government policy in this domain. Indeed, Google Scholar offers more than 220,000 articles evaluating the impact of government R&D policy on different aspects of the economy. Moreover, current literature in economics suggests that government R&D policies matter. For example, Akcigit, Baslandze and Stantcheva (2016) suggest that lower R&D taxes spur the inflow of the most productive researchers from abroad.

Using a natural experiment in UK tax policy toward R&D, Guceri and Liu (2017) show that each dollar of government expenditure in R&D leads to more than a dollar of increase in private R&D spending. In addition, Akcigit, Ates and Impullitti (2018) demonstrate that the introduction of the 1981 Experimentation Tax Credit in the US generated large welfare gains over the long run. Acemoglu et al. (2016) recommend that the transition from dirty to clean technologies be aided by both government subsidies for R&D and tax credits. Along with direct R&D subsidies and tax incentives, incumbents can influence innovative activity by altering intellectual property protection policies. Such policies do not necessarily boost overall inventiveness but can sometimes redirect inventive efforts to new areas Moser (2005). In addition, governments can establish prizes targeted at the creation of specific technologies. For example, medical innovation prizes create a buy-out mechanism to compensate pharmaceutical firms for developing drugs that are socially valuable but unattractive for private firms to produce and market Kremer and Williams (2010). Such *ex ante* prizes and patent buyout mechanisms, together with the publicity they generate, could deliver an additional boost to invention after the awarding of a prize, as discussed by Moser and Nicholas (2013).

Despite the abundance of literature evaluating the impact of government R&D investment, I failed to find a single study evaluating political incentives to make such investments. This paper excludes consideration of R&D specific to military innovation, as the incentives for such investment are self-evident[3]. In the most closely related paper available, Akcigit, Baslandze and Lotti (2017) argue that government R&D subsidies led to greater profits for politically connected firms with no change in their efforts to produce new technologies.

This paper also relates to the wide literature on government popularity and

[3]See Taylor, 2016 for a review.

approval. In their paper "What Makes Governments Popular?" Guriev and Treisman (2016) assess a panel of government ratings from 128 countries including both democracies and authoritarian states, over the years 2005-2014. They find that strong economic performance is robustly correlated with higher approval in both democracies and non-democracies, approval is higher in the year of a presidential election in both types of regimes. In non-democracies, information matters: greater press freedom and internet penetration result in lower approval while internet censorship is associated with higher approval. In another paper Guriev and Treisman (2018) closely examine autocratic regimes and show that autocrats artificially boost their popularity by convincing the public they are competent via propaganda, co-optation of elites and censorship. My work does not contradict their findings, but suggests that policy choice could also be applied as a useful tool to signal competence both in democratic and autocratic settings using the results of survey experiment in United States and Russia.

This paper also relates to the wide literature on economic voting: (Key and Cummings, 1966; Ferejohn, 1986; Wittman, Weingast and Hibbs, 2009) emphasize the importance of the past economic results for future voter behavior. At the same time,the objective performance metrics can be hard to bolster in the short-run Dynes and Holbein (2020). . Some studies have argued that the choice of economic policy can be used as a signal of competence: Voigtländer and Voth (2014) analyze construction of the Autobahn network in Nazi Germany to demonstrate that highway construction was effective in boosting popular support beyond the direct economic benefits (such as declining unemployment near construction sites). At the same time, Schnakenberg and Turner (2019) show that signaling may decrease the welfare of the voters if politicians forego the information from lobby groups in order to signal their non-involvement in corruption. Harding and Stasavage (2013) suggest that, in an environment in which attributing outcomes to executive actions is difficult, electoral competition can lead to changes in policies for which executive action is verifiable. In the context of African primary education, for example, they found that electoral competition gave government an incentive to abolish school fees—a more visible action but one that had less effect on the provision of school inputs, since executive actions on these issues were more difficult to monitor. These papers highlight the importance of visibility of interim results of government policy for electoral benefit. Apart from citizens' inability to observe a policy outcome in time to update their perceptions concerning a politician's type before reelection, citizens can value short-term policies per se. Using both municipality-level data and a survey experiment conducted in Brazil, Bursztyn (2016) shows that low-income voters are likely to favor redistributive programs, such as cash transfers that increase their incomes in the short run, over investments in education, as demonstrated by their survey and incentivized choice experiments.

In this context, employing R&D expenditures to signal competence seems counterintuitive, as the interim results of such investments are less visible to voters compared to other types of public goods provision. Such expenditures target long-run outcomes and are also highly risky, since the majority of R&D projects fail. However, I argue, conversely, that the risky nature of R&D projects allows incumbents to showcase their competence. Harbaugh (2010) proposes a model that demonstrates how, in gambles involving both skill and chance, a strategic desire to avoid appearing unskilled generates behavioral anomalies consistent with prospect theory's concepts of loss aversion, framing effects, and probability weighting. Under a set of conditions, the agent is better off taking risks in an environment where failure is more likely and an observer can infer the agent's type before the outcome of the gamble is observed. Furthermore, the importance of skill signaling increases in more volatile environments. This intuition holds in the context of market volatility: Ochoa (2013) finds a positive and statistically significant cross-sectional relation between reliance on skilled labor and expected returns, which increases in times of high aggregate volatility and decreases by one-third when volatility decreases to normal levels.[4]

In short, the abundance of literature investigating the impact of government R&D expenditure on technological development and the economy in general suggests the importance of this issue. At the same time, specific traits of R&D expenditures make it seemingly unappealing for politicians, given existing theories of political economy. This paper aims at reconciling this apparent contradiction.

2.3 The Model

In this section, I introduce a simple model in which a leader makes a decision on whether to invest in R&D and voters decide whether to re-elect the leader.

2.3.1 Setup

There are two strategic agents:

a) an incumbent political leader, who can be of one of the two types of τ, either competent ($\tau = \tau_H$) with probability θ or incompetent ($\tau = \tau_L$) with probability $(1 - \theta)$; and

b) the median voter.

The leader can either commit to investing in a safe project that guarantees immediate results or to pursuing a risky policy such as investment in R&D. The median

[4]Interestingly, Galor and Savitskiy (2017) find that, in an environment characterized by aggregate productivity shocks, loss aversion is a more sustainable trait, whereas in an environment characterized by greater volatility, loss-neutrality can generate higher success rates.

voter observes the leader's choice and decides whether to reelect the incumbent.

The leader receives utility from retaining her office. If she is reelected, she receives utility V from staying in power and 0 otherwise. Additionally, she cares about the result of her policy. The payoff of a risky project depends on the competence of the incumbent. If she is competent, she selects a project that generates a high expected payoff. If she is incompetent, she is less likely to select R&D projects with good prospects yet is equally able to carry out the safe alternative. The leader knows her own type, and the voters have a common prior of a high type θ.

I assume that investment in R&D by a competent leader with ability $\tau = \tau_H > 0$, results in a payoff of R with probability τ_H discounted at a rate δ and a payoff of 0 with probability $1 - \tau_H$. An investment by an incompetent leader (τ_L) always results in a failure. An investment in a safe project results in the payoff of W. This amount represents the opportunity cost, e.g., foregone consumption, of the risky project.

Voters care both about economic returns and the leader's competence. For clarity, I assume that the leader's skill level enters the median voter's utility function directly, with the parameter α being the relative weight assigned to the leader's skills. Denote by s the strategy profile. Then,

$EU_v = Returns + \alpha E(\tau|s)$,

where $Returns = W$ if the safe project was chosen, $Returns = 0$ if the R&D project was chosen by the incompetent leader, and $Returns = R$ if the R&D project was chosen by the competent leader. Finally, $E(\tau|\cdot)$ is the expected contribution of the leader's type to the voter's payoff; this expectation is conditional on both the policy that the voter observed and the reelection decision she makes. If the incumbent is retained, the expectation in $E(\tau|\cdot)$ is conditional on the observed policy choice; if the leader is new, $\tau = \tau_H$ with probability θ and 0 with probability $1 - \theta$. If indifferent, the voter reelects the incumbent.

The timing of the game is as follows:

1. The incumbent leader is assigned a skill level $\tau \in \{\tau_L, \tau_H\}$, with probabilities θ and $1 - \theta$, respectively.

2. The leader commits to pursuing either a safe or a risky project.

3. Upon observing the leader's choice, the voter decides whether to reelect the incumbent.

4. Players receive their payoffs.

I focus on perfect Bayesian equilibria of the game (Osborne and Rubinstein, 1994).

Figure 2.1 shows the game tree.

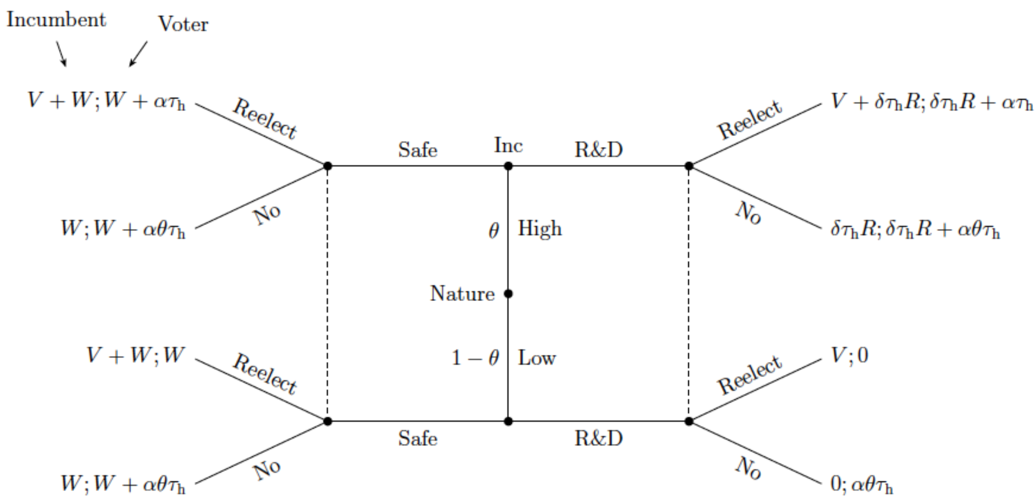

Figure 2.1: Game Representation

2.3.2 Analysis

Let us start by considering the possibility of a separating equilibrium. In a perfect Bayesian equilibrium, this is possible only if the high type chooses R&D while the low type chooses the safe investment. If this is the case, the median voter's expected utility from reelecting the incumbent is W, conditional on the announcement of the safe project, and $\delta\tau_H R + \alpha\tau_H$ if the R&D project is announced. Replacing the incumbent if the risky project is chosen results in expected utility of $\theta\delta\tau_H R + \alpha\theta\tau_H$, as the low-skilled challenger will not be able to complete the R&D project. If the safe project is announced, replacing the incumbent brings expected utility of $W + \alpha\theta\tau_H$.

The median voter supports the high-skilled incumbent that committed to R&D if and only if

$$(1-\theta)(\delta R + \alpha)\tau_H > 0,$$

which is always true as $\tau_H > 0$.

The high-skilled leader never deviates from R&D policy in a separating equilibrium, because $W \neq \delta\tau R$, so a separating equilibrium in which a high-skilled incumbent chooses the safe project is impossible. Thus, after observing the choice of the safe project, the voter knows that the leader is incompetent. It is straightforward to verify that in this case the incumbent is not reelected. Still, it might be optimal for the incompetent incumbent to choose the safe project as long as the benefits of having the office, V, are not too high:

$$W > V.$$

Finally, it is incentive compatible for the high-type leader to choose R&D if and only if

$$\delta\tau_H R > W.$$

The following proposition summarizes the above discussion.

Proposition 1 *There exists a separating equilibrium in which the high-skilled leader signals her type by choosing the R&D project and is re-elected, and the low-skilled leader chooses the safe alternative and is replaced by the challenger, as long as the following conditions are fulfilled:*

$$\delta \tau_H R \geq W \geq V. \tag{2.1}$$

These conditions are fulfilled for a wider range of other parameters when the expected reward, R, is high, when the future is not discounted too much (δ is high), and when the "skill differential" τ_H is high.

The comparative statics is very intuitive. If the value of the office is not very high (for example, in a low-corruption term-limited environment), policy choice signals politician's competence.

Naturally, if the value of the office is very high, candidates cannot use (binding and, therefore, costly) campaign promises to signal their type, as the low-type candidate prefers to pool even at a high cost. Here, if the value of office is high relative to the expected returns of the safe project, candidates necessarily pool. Under what conditions do both types of the incumbent pool, pursuing the same strategy?

To describe pooling equilibria, we need to analyze the beliefs that voters have upon observing the chosen policy. Suppose that the observed policy choice is R&D and let p denote the probability that the leader is of the competent type. For the median voter, re-electing the incumbent results in the expected payoff of $p(W + \alpha\tau_H) + (1-p)W$. Voting for the challenger brings, in expectation, $p(W + \alpha\theta\tau_H) + (1-p)(W + \alpha\theta\tau_H)$. Re-arranging terms, the voter chooses to reelect the incumbent if and only if the probability that the leader is of the high type is $p \geq \theta$. Similarly, assuming that the safe project is chosen, let q denote the probability that the leader is of high type. The voter chooses to reelect the incumbent if and only if $q \geq \theta$.

Given our assumption that the voter, if indifferent, reelects the incumbent, it is straightforward to show that there is no pooling equilibrium where both types of incumbents choose safe project: it is always profitable for the competent incumbent to choose R&D policy, since, after observing this deviation, the voter would infer that the incumbent is competent and reelect him. Thus, the competent leader receives $V + W \leq V + \delta\theta R$ after deviation.[5]

On the other hand, a pooling equilibrium where both types choose R&D is indeed possible. In a high-corruption, no term limit environment less competent incumbent prefers to choose R&D policy at a cost of economic loss to choosing a safe project and revealing her incompetence.

Suppose that both types of politicians invest in R&D. Again, the voter knows with certainty the incumbent's type if two types choose different actions, and assigns beliefs θ and $1 - \theta$ to high type and low type, respectively, if two types choose the same action. The voter will reelect the incumbent that played R&D: $\theta(\delta\tau_h R + \alpha\tau_h) = \theta(\delta\tau_h R + \alpha\theta\tau_h) + (1 - \theta)\alpha\theta\tau_h$.

The payoff of the high-skilled incumbent is $V + \delta\tau_h R$. Deviating to the safe project, she will get $V + W$. Since $\delta\tau_h R > W$, deviation is not profitable. The payoff of the low-skilled incumbent is V. Deviation gives her W that is less that she has in the pooling profile. Formally, we can state the following proposition.

Proposition 2 *Suppose that $V > W$ and $\delta\tau_h R > W$. Then there exists a pooling equilibrium in which both candidates choose the R&D project, and the median*

[5]Assuming that the voter re-elects the incumbent, if indifferent, is without much loss of generality: the resulting pooling equilibrium with both types investing in safe project would not survive the " intuitive criterion" (Cho and Kreps, 1987)

voter reelects the incumbent.

The simple theoretical model suggests that at relatively low levels of gains from office, there is a separating equilibrium for competent and incompetent politicians, in which the former invests in R&D and the latter in the safe project, while the voter, interpreting the policy choice as a quality signal, chooses to reelect only the pro-R&D politician. At the moderate levels of gains from office, it is the expected outcome of each policy that determines the equilibrium: if expected gains from the R&D policy exceed the expected gains from the safe project, even the low-skilled politician will choose to invest in R&D, while voters reelect only a pro-R&D politician. Otherwise, there is a possibility of signaling: the low-skilled politician always invests in the safe project, while the high-skilled politician invests in R&D (again, voters reelect a pro-R&D politician only). For very high gains from office, there is no signaling in choosing the R&D policy as the candidates 'pool': both types of politicians invest in R&D. In this situation, there is overinvestment in R&D, which is suboptimal from a social welfare point of view.

2.4 Cross-Country Evidence

In this section I present a cross-country evidence consistent with the effect of government R&D expenditures on government approval among citizens. In the absence of a verifiable source of causal identification, the analysis relies heavily on the set of assumptions. I illustrate the causal assumptions of my cross-country study according to the method proposed by Pearl (1995). This approach allows me to state a set of assumptions about the data-generating process and to choose a set of control variables consistent with them. Figure 2.2 displays a directed acyclic graph (DAG), where nodes represent variables and edges, or arrows, the causal links between them, including the direction of influence. For instance, as shown by the direction of the arrow at the top left of the graph, *Institutions* have an impact on *Economic Volatility*, but the reverse is not true. The absence of edges between nodes constitutes an important assumption in the DAG. The variable *Skill Preference*, which is unobserved, corresponds to α in the theoretical model discussed in Section 2. The variable $Approval_{t-1}$ represents government approval in the previous period (lagged), whereas the variable *Approval* is government approval in the current period. Similarly, RD_{t-1} is the government's investment in R&D in the previous period, whereas *RD* is government investment in R&D in the current period. $Approval_{t-2}$ and RD_{t-2} stand for twice-lagged approval and R&D expenditures, respectively. *Political Competition* is a measure of political competition, and the variable *Country* denotes time-invariant country-specific effects (its inclusion in a model is just inclusion of country fixed effects). Though simplified, this representation of the real-world situation clarifies the assumptions made in the cross-country study. A choice of DAG, such as this one, prescribes which variables should (and should not) be conditioned on in order to estimate a causal effect of government R&D expenditures on popular approval of the government.

Figure 2.2 presents the structure of assumptions employed in my cross-country study.

Applying the backdoor criterion to the graph implies the existence of adjustment sets, controlling for which would allow me to make causal claims about the effect of government R&D expenditures on citizen approval of the government. Among them, I choose the adjustment sets that do not include *Institutions* or *Skill Preference* (as those are unobserved) and include the variable *OECD*, since our sample is focused on OECD countries. This leaves us with three sets of variables that we could adjust for to identify effect of government R&D expenditures

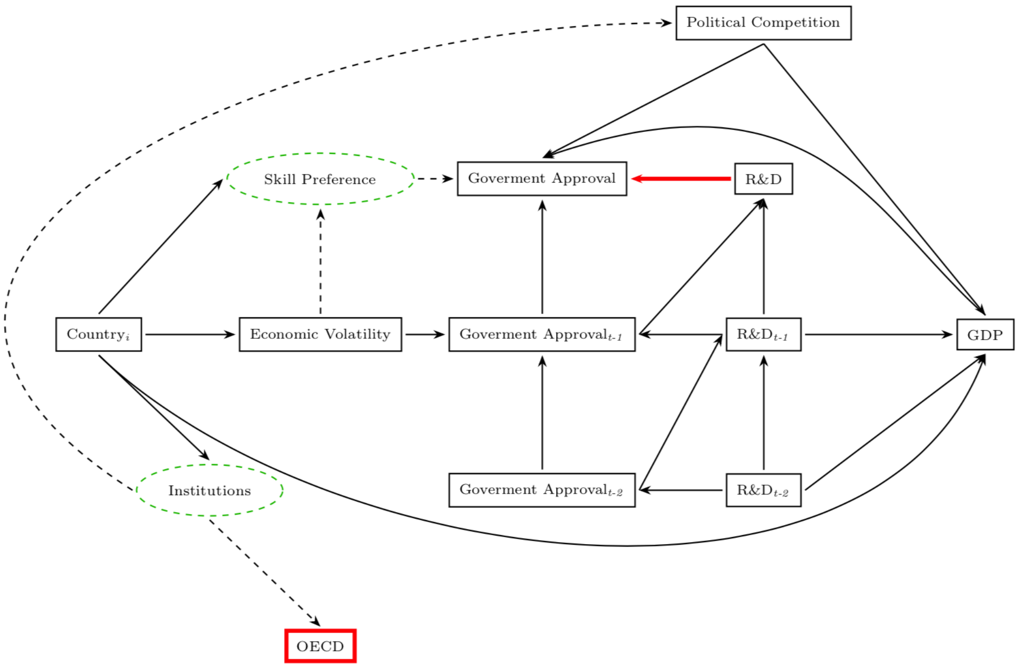

Figure 2.2: Directed Acyclic Graph

on popular approval under this DAG, shown in Table 2.1. They present two different sets of controls necessary to calculate the total effect of government R& D expenditures on popular approval (Total Effect 1 and Total Effect 2) and one adjustment set that recovers the direct effect.

One major concern in cross-country panel data is unobserved country-specific but time-invariant confounders. Including country fixed effects addresses the bias that these confounders introduce. An important assumption in these models is that past treatments and outcome outcomes do not directly influence current treatment and outcomes — or that they do so only for a limited number of years shorter than the duration of the panel (see Imai and Kim (N.d.)); here I assume that past government R&D only directly affects future R&D for one yaer, and likewise with government approval. Similar assumption are commonly made

Variables	**Adjustment Set 1**	**Adjustment Set 2**	**Adjustment Set 3**
GDP	✓	✓	✓
lag.Approval	✓	✓	✓
political.competition	✓	✓	✓
lag.R&D	✓	✓	
Volatility		✓	✓
Country	✓	✓	✓

Table 2.1: Feasible Adjustment Sets for Effect of R&D on Approval

in existing work examining government approval, (see e.g. Lebo and Norpoth, 2011). Similarly, researchers have often estimated the effect of government R&D using a single lag (see e.g. Levy and Terleckyj, 1983).

In quasi-experimental designs, it is common practice to demonstrate that treatment and control groups are balanced in their distributions of pre-treatment variables, lending credibility to the claim that treatment assignment does not depend on potential outcomes. An analogous but more extensive set of tests is possible in that DAGs produce a number of observable implications in the form of conditional independence relationships that should hold in the data if the DAG is correct. For this DAG, there are 33 such expected conditional independences, each detailed in the Appendix. Each such relationship can be tested similarly to a balance test. Results are presented in Figure 2.3. I find that most of conditional independencies hold, with the exception of positive relation between political competition and lagged R&D expenditures.

Having estimated models using these conditioning sets presented in Table 2.1,

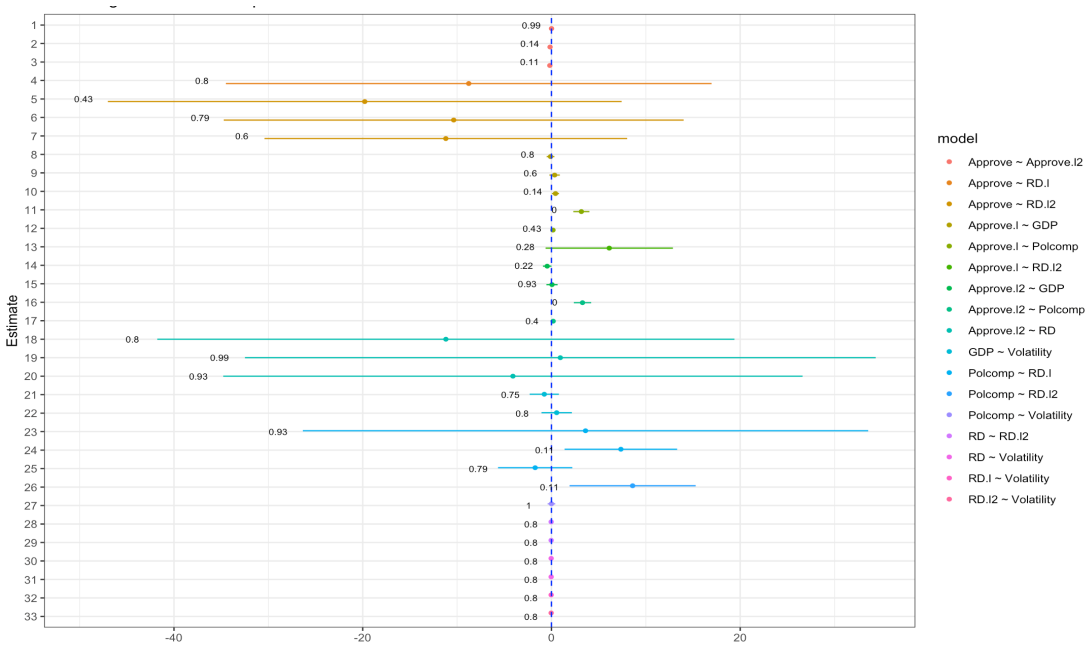

Figure 2.3: Conditional Independencies

I recognize that the assumptions captured in this DAG — specifically regarding confounders omitted from it — may be incorrect. I thus employ sensitivity analyses that characterise the types of omitted confounders that would alter the conclusions reached in my analysis 2.4.1.3.

2.4.1 Government R&D Spending and Government Popularity

2.4.1.1 Data

The data required for this analysis are cross-country data on government R&D expenditures and government budgets. I have these only for OECD countries, reported by UNESCO OECD (2017). While this sample is restricted to OECD countries, it also accounts for more than 90% of all government expenditures in the world. Government approval here derives from Gallup (2018), denoting the approval ratings of the government obtained from a representative sample of citizens for each country on a yearly basis. The respondents are asked the following question: "In this country, do you have confidence in each of the following, or not? How about national government?." Despite the fact that they do not address popular perceptions of politician quality, the Gallup data are widely used as a marker of approval of government actions in the literature Hetherington (1998). I calculate the economic volatility variable by summing the number of times log.GDP falls below the 5-year moving average for each country. Due to the fact that the latter was only available for the 2006-2017 time period, I had only 300 country-year observations. The information about the extent of political competition comes from Comparative Politics Dataset Armingeon et al. (2018).

2.4.1.2 Analysis and Results

We consider two ways of measuring the outcome, y_{it}: as the government expenditures on R&D as a share of GDP, and as the government expenditures on R&D as a share of the budget. For each, we can consider three models suggested by the three adjustment sets determined above. A first estimate of the total effect (adjustment set 1) is given by β_4 in

$$\begin{aligned} y_{it} =& \alpha_{1t} + \beta_1 \texttt{GDP} + \beta_2 \texttt{approval}_{it-1} + \beta_3 \texttt{political.competition}_{it} \\ &+ \beta_4 \texttt{R\&D}_{it-1} + \beta_5 \texttt{Country}_i + \epsilon_{it} \end{aligned}$$

The second estimate of the total effect (adjustment set 2) is given by β_4 in

$$\begin{aligned} y_{it} =& \alpha_{1t} + \beta_1 \texttt{GDP} + \beta_2 \texttt{approval}_{it-1} + \beta_3 \texttt{political.competition}_{it} \\ &+ \beta_4 \texttt{R\&D}_{it-1} + \beta_5 \texttt{Country}_i + \epsilon_{it} \end{aligned}$$

Finally, the estimate of interest is given by β_4 in adjustment set 3:

$$\begin{aligned} y_{it} =& \alpha_{1t} + \beta_1 \texttt{GDP} + \beta_2 \texttt{approval}_{it-1} + \beta_3 \texttt{political.competition}_{it} \\ &+ \beta_4 \texttt{R\&D}_{it-1} + \beta_5 \texttt{Country}_i + \epsilon_{it} \end{aligned}$$

In addition, I repeat the models for government expenditures on education as a share of GDP and government expenditures on education as a share of budget to put the results of government expenditures on R&D in context.

Note that under the set of assumptions presented in the DAG, the coefficients on variables other than the treatment are not interpretable, so I do not report them.

	Dependent variable:		
	Government approval		
	(1)	(2)	(3)
	Adjustment Set 1	Adjustment Set 2	Adjustment Set 3
R&D (%GDP)	24.011* (13.940)	24.011* (13.940)	14.221 (9.777)
Observations	194	194	206
R^2	0.613	0.613	0.713
Adjusted R^2	0.507	0.507	0.637
Residual Std. Error	8.308 (df = 92)	8.308 (df = 92)	8.210 (df = 101)
Partial $R^2_{Y=D\|X}$	0.036	0.36	0.018
Robustness Value	0.175	0.175	0.129
F Statistic	12.838*** (df = 28; 165)	12.838*** (df = 28; 165)	16.148*** (df = 31;174)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 2.2: Effect of R&D Expenditures (% GDP) on Government Approval

While Table 2.2 captures the effect of government R&D expenditures as a percentage of GDP on government approval, it does not illustrate the trade-offs of budget allocations across different policies. That is, voters can value greater government expenditures overall, and the increase in government approval could reflect these preferences. Thus, we additionally measure government R&D expenditures as a a percentage of the budget. This new measure captures the fact that growth in government R&D expenditures comes at the expense of other government policies. Results are presented in Table 3.

While we have captured the effect of government R&D expenditures on government approval, it is important to put our findings into context. To do that, we run a similar set of models substituting government R&D expenditures with government education expenditures (see Table 4). This comparison was chosen for several reasons. First, government expenditures on education also have a long-run effect on the economy. However, they tend to be more observable by citizens and are less risky than R&D expenditures. We rely on the same set of assumptions as in case of R&D expenditures, thus making the models fully comparable. One must note that the treatment coefficients vary significantly between models. This is explained by the fact that the baseline level of government expenditures on education is much higher: around 6%, compared to the 2% average of government expenditures on R&D. The results of the models are similar for logged versions of the treatment variables and are available upon request.

Similarly, we can explore the effect of government expenditures on education as a percentage of budget on government approval (see Table 2.4). In this case, the comparison of trade-offs of budget allocation to R&D versus Education is especially striking—1% of additional budget spending on the former can increase government approval by 23%, but the same increase in the latter increases government approval by 2%.

	Dependent variable:		
	Government.approval		
	(1)	(2)	(3)
	Adjustment Set 1	Adjustment Set 2	Adjustment Set 3
R&D(%Budget)	15.156 (10.102)	15.021 (9.992)	6.938 (7.458)
Observations	118	118	129
R^2	0.613	0.613	0.713
Adjusted R^2	0.507	0.507	0.637
Residual Std. Error	8.308 (df = 92)	8.308 (df = 92)	8.210 (df = 101)
Partial $R^2_{Y=D\|X}$	0.057	0.057	0.026
Robustness Value	0.217	0.217	0.153
F Statistic	5.821*** (df = 25; 92)	5.821*** (df = 25; 92)	9.301*** (df = 27; 101)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 2.3: Effect of R&D Expenditures (% Budget) on Government Approval

2.4.1.3 Sensitivity to Confounders

Omitted variable bias can seriously impact any analysis of social phenomena. This concern is especially severe for cross-country observational studies. I presented the structure of assumptions that guides the model specification, but there is a strong possibility of unobserved confounders not reflected in the DAG affecting both government R&D expenditures and the approval citizens bestow on the

	Dependent variable:		
	Government.approval		
	(1)	(2)	(3)
	Adjustment Set 1	Adjustment Set 2	Adjustment Set 3
Education(%GDP)	1.308 (1.237)	1.308 (1.237)	1.273 (1.259)
Observations	142	142	143
R^2	0.767	0.767	0.747
Adjusted R^2	0.707	0.707	0.685
Residual Std. Error	7.835 (df = 112)	7.835 (df = 112)	8.090 (df = 114)
Partial $R^2_{Y=D\|X}$	0.031	0.031	0.037
Robustness Vlaue	0.164	0.164	0.177
F Statistic	12.709*** (df = 29; 112)	12.709*** (df = 29; 112)	12.031*** (df = 28; 114)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 2.4: Effect of Education Expenditures (% GDP) on Government Approval

government.

Sensitivity analysis allows us to quantify the threat posed by unobserved confounding. In this section, I adopt the approach presented in Cinelli and Hazlett (2020) to quantify the confounding that would be required to nullify the observed regression results. To do so, I report two measures of the sensitivity of linear regression coefficients. First, the "robustness value" (RV) illustrates the overall

	Dependent variable:		
	Government.approval		
	(1)	(2)	(3)
	Adjustment Set 1	Adjustment Set 2	Adjustment Set 3
Education(%Budget)	1.415 (2.878)	1.415 (2.878)	−2.260 (2.453)
Observations	142	142	143
R^2	0.761	0.761	0.739
Adjusted R^2	0.699	0.699	0.676
Residual Std. Error	7.936 (df = 112)	7.936 (df = 112)	8.212 (df = 114)
Partial $R^2_{Y=D\|X}$	0.006	0.006	0.007
Robustness Vlaue	0.075	0.075	0.084
F Statistic	12.288*** (df = 29; 112)	12.288*** (df = 29; 112)	11.557*** (df = 28; 114)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 2.5: Effect of Education Expenditures (% Budget) on Government Approval

robustness of a coefficient to unobserved confounding. If the confounders' association to the treatment and to the outcome (measured in terms of partial R^2) are both assumed to be less than the robustness value, then such confounders cannot "explain away" the observed effect. Second, I report the proportion of variation in the outcome explained uniquely by the treatment, $R^2_{Y\sim D|X}$, which reveals how strongly confounders that explain 100% of the residual variance of the outcome would have to be associated with the treatment in order to eliminate the effect. Both measures are a function of the estimate's t-value and the degrees of freedom.

Cinelli and Hazlett (2020) present the following decomposition of omitted variable bias:

$$|\hat{bias}| = se(\hat{\alpha})\sqrt{\frac{R^2_{Y\sim Z|X,D}R^2_{D\sim Z|X}}{1-R^2_{D\sim Z|X}}(df)}$$

where $se(\hat{\alpha})$ is the standard error of the main coefficient of interest $\hat{\alpha}$, Y is the outcome of interest, D is the main explanatory variable, X is a vector of covariates, Z is the omitted variable, and df is degrees of freedom of the regression.

The absolute value of the bias thus depends upon the strength of association of the outcome with the omitted variable (measured by the partial R^2:$R^2_{Y\sim Z|X,D}$), and the strength of association of the main explanatory variable with the omitted variable ($R^2_{D\sim Z|X}$).

One way to interpret results is by comparison to observed variables. Formally, we can form a working assumption that confounding is "no worse than" a particular observed variable, meaning that confounding is assumed to explain less of the residual variation in treatment and in the outcome than that observed covariate. Guriev and Treisman (2016) suggests that the strongest predictor of government popularity is GDP. Cinelli and Hazlett (2020) provide the means to turn such assumptions into bounds on the degree of confounding that is permissible.

For present purposes, we will choose whatever observable was empirically the strongest predictor of the outcome to make these comparisons. For instance, the Total Effect models for government R&D expenditures have log.GDP as the strongest (conditional) predictor of government approval. This fact does not come as a surprise, as it is widely accepted in the literature that economic performance affects government approval and reelection prospects. The Direct Effect models for government R&D expenditures have economic volatility as the main predictor of government approval. All models of the effect of government expenditures on education have political competition as a main predictor. With this in mind, we can explore the sensitivity of our models to unobserved confounders using these variables for comparison..

Tables 2-5 report the partial R^2 of the treatment with outcome and robustness values. For instance, Total Effect 1 in Table 1 has a robustness value of 17.6%. That suggests that unobserved confounders (orthogonal to the covariates) that explain more than 0.176 of the residual variance of both the treatment and the outcome are enough to reduce the absolute value of the effect size by 100%. Conversely, unobserved confounders that do not explain more than 17.6% of the residual variance of both the treatment and the outcome are not strong enough to reduce the absolute value of the effect size by 100%.

In addition, the proportion of variation in the outcome explained uniquely by the treatment, $R^2_{Y\sim D|X}$, is 3.6\5. This implies that an extreme confounder (orthogonal to the covariates) that explains 100% of the residual variance of the outcome would need to explain at least 3.6% of the residual variance of the treatment to fully account for the observed estimated effect.

We can also examine how big the unobserved confounder would have to be compared to the biggest observed covariate to nullify the effect of government R&D spending (as a percentage of GDP). Figure 4 presents a bias contour of t-value plot for three models of the effect of R&D expenditures (as a share of the budget) on popular approval of the government.

The horizontal axis shows hypothetical values of the partial R^2 of the unobserved confounder(s) with the treatment, interpreted as the percentage of the residual variance of the treatment explained by the confounder. The vertical axis shows hypothetical values of the partial R^2 of the unobserved confounder(s) with the outcome, interpreted as the percentage of the residual variance of the outcome explained by the confounder. The bias contour levels represent the adjusted estimates of the treatment effect. The reference points (in red) are bounds on the partial R^2 of the unobserved confounder if it were k times "as strong" as the observed covariate GDP (for total effects of R&D expenditures), volatility (for direct effect of R&D expenditures) and political competition (for all models of education expenditures). They show what would be the maximum bias caused by orthogonal unobserved confounder(s) if it (they) had the same or less predictive power than R&D expenditures (Education expenditures), with both the treatment and the outcome. Figure 4 suggests that the effect of an unobserved confounder on both treatment and outcome should capture at least 6 times the variance of both treatment and outcome as explained by the most important covariate in the regression—GDP. While $R^2_{Y\sim D|X}$ seems fairly low, it is worth remembering that GDP is seen as a good predictor of government popularity by the literature. For the direct effect, the main predictor was volatility, so the plot features it as a comparison variable for R&D expenditures. For all models of the impact of government expenditures on education, the main predictor was political competition, so the figures feature it as the comparison.

We can see that highest robustness values and partial R^2s are obtained for models with government R&D expenditures as a percentage of budget on government approval. The lowest robustness values and partial R^2s are obtained for models with government education expenditures as a percentage of budget on government approval.

2.5 Survey experiment design

The cross-country regression evidence above cannot entirely rule out concerns such as confounding, but is consistent with the claim that governments can utilize R& D policy to signal their competence. In this Section, we consider an additional form of evidence in which confounding is not a concern, using survey experiments conducted in the US and Russia.[6] These experiments are designed to test whether government pro-R& D policy can build a greater perception of an incumbent's competence, compared to pro-education, pro-infrastructure, or pro-short-term-innovation policy. Repeating the experiment in two countries serves several purposes. First, it allows me to test the proposed theory in two very different settings. Second, it may illuminate the difference between policy choice effects in a setting where the competence of the incumbent can argued to have less effect on the economic performance of a country with a functional system of checks and balances (US) than in a country where this system is lacking (Russia). Third, the Russian economy and foreign policy are more susceptible to shocks, which can generate a higher preference among voters for incumbent competence. Further, the difference in political regimes (democracy and autocracy, respectively) and the level of corruption can generate different gains from holding office for the incumbent, which, in turn, can influence voters' updating about politicians' competence after observing a policy choice. Finally, while both countries engage in substantial government R&D policy, Russia started its efforts to promote innovation fairly recently—from 2007—so voters may have different expectations about the economic outcomes of such efforts.

[6] This experiment was preregistered. EGAP identification number is 20180529AC. IRB approval numbers: Russian version: 18-000765, US version: 18-000587

2.5.1 Survey experiment design

Data Collection. Surveys were openly posted on MTurk (2200 respondents) and Yandex.Toloka (1300 respondents) in the United States and Russia, respectively. Respondents were free to drop out at any time. Several steps were taken to ensure the validity of the results. First, there are many foreign workers on MTurk and Yandex.Toloka. In addition to requiring respondents to confirm their US residency on the consent form, I also had Amazon show the survey only to workers who had US addresses. Similar measures were taken on the Yandex.Toloka platform. All respondents were 18 years old or older. Next, respondents were told that payment would be contingent on completing the survey and providing a password visible only at completion. In addition, I administered a pre-treatment attention check. Respondents that failed the test encountered a pop-up prompting them to read tasks attentively. I excluded inattentive respondents from the main analysis, but the results for the full sample were calculated as a robustness check and they are not significantly different. I collected the following demographic information: gender, education, income level, employment status, political affiliation (Unites States only), and zip-code. Both MTurk and Yandex.Toloka provide convenience samples and so are not fully representative of their respective populations. Moreover, the two platforms are designed for similar purposes and attract similar demographics, and so both MTurkers and Yandex.Toloka users tend to be younger and relatively better educated than the average of their respective countries. The core assumption I rely on in this experiment is that MTurk and Yandex.Toloka populations do not differ from the general population in terms of their preference for policy choice.[7]

[7] Despite being a convenience sample, the MTurk population can help us to answer research questions: recent meta-analyses of experimental studies conducted on both Mechanical Turk and US national probability samples suggests high replication rates (Coppock, Leeper and Mullinix, 2018; Coppock, 2018; Mullinix et al., 2015). On the other hand, MTurk samples are

Treatment. In general, the goal of the information treatments was to provide respondents with a paired vignette featuring two similar politicians, one of them favouring pro-R&D policy and another favouring one of three control treatments: pro-education policy, pro-infrastructure policy, or policy focusing on bringing existing technologies to the market. Each description featured a short note discussing the long-run effect for the economy in general and for the competitiveness of companies. I present the samples of treatment vignettes employed in Appendix E, where, for the sake of brevity, I show only the first version of the Treatment (Smith-T, Meyerson-C) for R&D vs Education, R&D vs Infrastructure, and R&D vs Short-term Innovation comparisons. The vignettes were designed as broad statements and did not feature specific numbers, so that the treatment would not be conflated with deviations of specific numbers from those expected by respondents. In all cases, the order of treatment and control vignettes, as well as biographies of politicians, was randomized. In the US sample, I employed block randomization by political affiliation. In the Russian sample, I refrained from asking respondents about their political affiliation due to the sensitivity of this question in the Russian setting; hence, no block randomization by political affiliation was possible. I employed the Qualtrics randomization tool to perform block randomization for both surveys using "complete" randomization.

Thus, I employed a paired vignette design that has been shown to closely mimic data obtained by observing actual behavior in a natural experiment setting Hainmueller, Hangartner and Yamamoto (2015). Table A.2 of the Appendix presents the block structure for the Yandex.Toloka Survey.

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especially susceptible to social desirability bias and provide biased results when experiments in which subjects compensation depends on their answers, which is likely not the case for this study.

Dependent variables. All respondents were invited to answer a series of questions, with the order of the questions randomized to minimize priming effect. I also hoped to elicit more robust results by employing two different response types: score comparison and a forced choice. The score comparison analysis focused on the differences of scores obtained for each politician on three dimensions: competence, economic expectations of policy, and probability of reelection. The score differences are calculated along each of the dimensions by subtracting the competitor's score from that of the incumbent politician, where the score choices are described below. In this setup, it was possible for respondents to assign equal scores to treatment and control politicians. The questions that were used for the score comparisons for the United States sample are presented below. [8]

Thus, calculating the differences between evaluation of the treatment and control politicians allowed me to assess each participant's preference of treatment over the control politician. Since within each treatment block the order of the politicians' biographies and the biographies themselves were randomized, I can regard the average difference of their scores within a block as solely attributable to the politicians' differences with respect to policy preferences.

The forced choice setup instead focuses on the mean scores the pro-R&D (i.e., the treatment) politician obtained relative to the pro-education, pro-infrastructure, or pro-short-term-innovation politicians (Control). In the survey experiment, I forced respondents to choose between politicians, since I did not allow politicians to be ranked equivalently but rather asked to what degree the respondents preferred one politician over another. To this end, I asked the respondents to choose between two candidates based on whether they were more likely to support A. Smith than R. Myerson for a second term; whose competence they rated as higher; and whose policy they expected to be more effective in promoting

[8] Questions that were used for the score comparisons can be found in Appendix

How likely are you to support A. Smith (R. Myerson) for a second term?					
6: Very Likely	5: Moderately Likely	4: Slightly Likely	3: Slightly Unlikely	2: Moderately Unlikely	1: Very Unlikely
Do you think that A. Smith's (R.Myerson's) policy will lead to greater prosperity for the American people?					
6: Strongly Agree	5: Agree	4: Somewhat Agree	3: Somewhat Disagree	2: Disagree	1: Strongly Disagree
Evaluate A. Smith's (R.Myerson's) competence on the following six-point Likert scale					
6: Far Above Average	5: Moderately Above Average	4: Slightly Above Average	3: Slightly Below Average	2: Moderately Below Average	1: Far Below Average

Table 2.6: Questions for score comparison, US survey

economic growth. These choices were on a -3 to 3 scale lacking a 0. Employing forced choice questions allowed me to juxtapose the results where respondents were forced to state their preferences for one politician over another with those of the previously described setup.

Analysis : Since we observed the scores each respondent assigned to both the treatment and control politicians, we can use paired t-test to access the sample average treatment effect within each block for both the United States and Russian samples. Thus, for score difference I employ the paired t-statistic

$$T = \frac{\bar{d}}{SE(\bar{d})}$$

where $d_i = score.treatment_i - score.control_i$. In the case of forced choice, we observe 1 score per respondent per dimension (competence, economic expectations, and reelection) that shows by how much the respondent prefers one politician over the other. I normalize the scores, so that scores in favor of the treatment politician are positive, and scores in favor of the control politician are negative. I perform the t-test within each block:

$$T = \frac{\bar{d}}{SE(\bar{d})}$$

where $\bar{d}$ is the average score the treatment policy receives. Moreover, I employed Welch's difference-in-means t-test to compare the results of the US and Russian samples:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

where country 1 is USA and country 2 is Russia. As an additional exercise, we will assess whether a politician's average reelection scores were positively correlated with his competence and economic expectation scores.

2.5.2 Results

2.5.2.1 Results for the Attentive US Sample

The US sample consisted of 2286 respondents, 2246 of whom successfully passed the attention check administered at the beginning of the survey.

Figure 2.4 presents the mean differences between the scores respondents assigned to the pro-R&D politician and the pro-education, pro-infrastructure, and pro-short-term-innovation politicians. For those respondents who passed the attention check, the top half of the figure show results for the score comparison analysis, whereas the bottom shows the forced choice results. Confidence intervals presented in the graphs are unadjusted for the familywise error rate due to multiple hypothesis testing, while the label shows FDR-unadjusted p-values. Among attentive respondents, a politician that chose the long-term pro-R&D policy was always regarded as more competent, whereas his scores for probability of reelection and economic expectations of his policy remained statistically indistinguishable from those of the control politicians. The results do not change if we look at Democrats and Republicans separately.

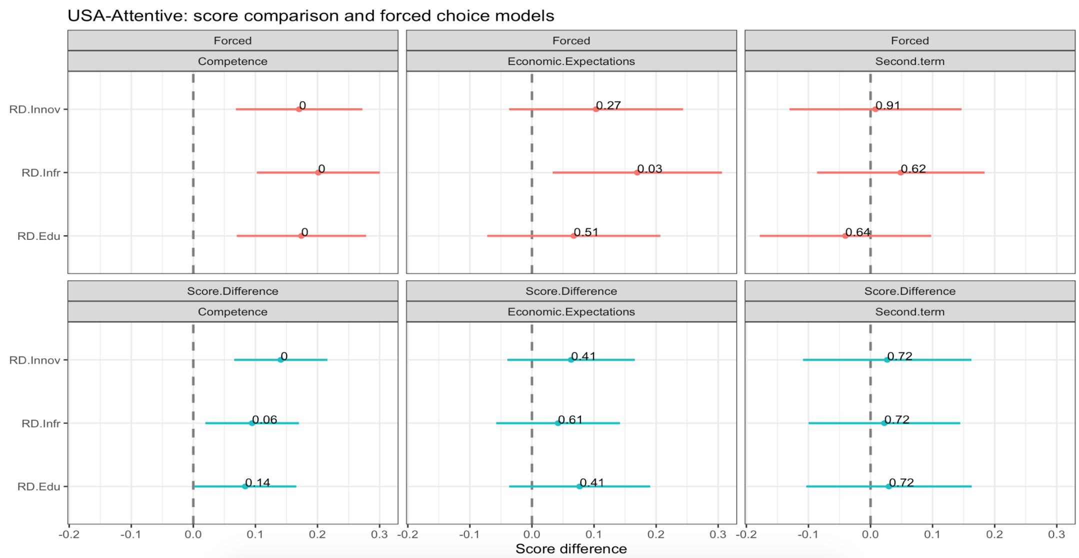


Figure 2.4: Score Comparison for Attentive MTurkers

Survey results for the whole sample of US respondents (including inattentive ones) are presented in Figure A.3 of Appendix A.5. Note that there is no difference in most instances between pro-R&D and pro-short-term-innovation politicians, signaling that US respondents neither rewarded nor penalized short-term versus long-term policies directed at innovation. However, when compared to a pro-infrastructure politician, the pro-R&D politician was seen as more competent and his policy as generating higher economic expectations. Consequently, respondents indicated a greater willingness to vote for him, and these results did not change if Democrats and Republicans were analyzed separately.

2.5.2.2 Results for the Attentive Russian Sample

The full Russian sample consisted of 1252 respondents, 1013 of whom passed the initial attention check. Figure 2.5 displays the results of t-tests for both the score comparison and forced choice analyses showcasing the mean differences in scores respondents assigned to a pro-R&D politician and those assigned to pro-education, pro-infrastructure, and pro-short-term-innovation politicians. The confidence intervals shown are unadjusted for multiple hypothesis testing while the label shows false discovery rate (FDR)-adjusted p-values. The respondents in the Russian sample strongly preferred long-run investment in R&D over investment in commercialization of existing technologies. The survey results for the full Russian sample (including inattentive respondents) are presented in Figure A.4 of Appendix A.5.

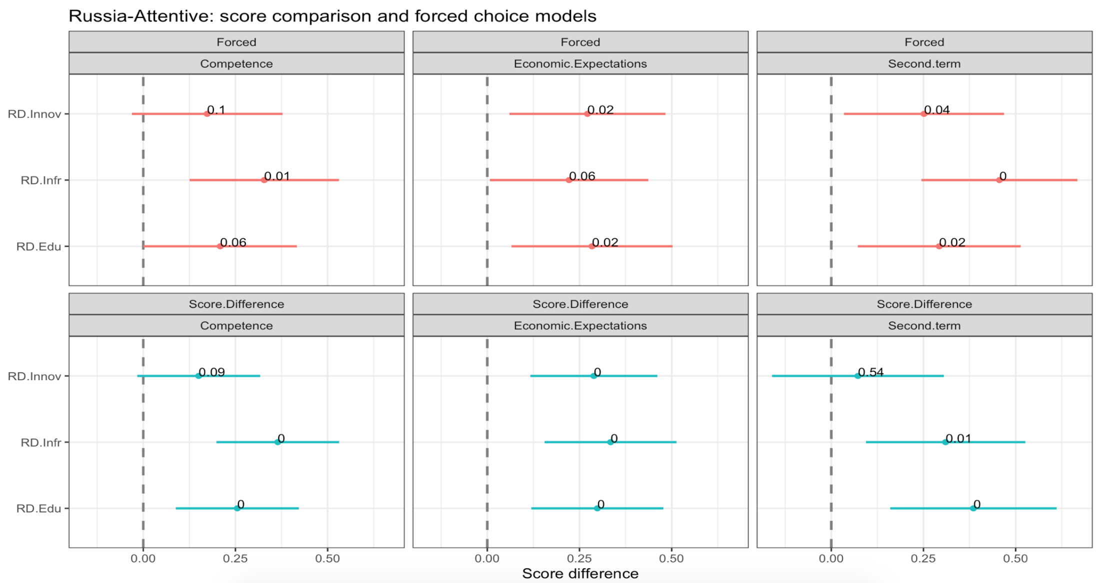


Figure 2.5: Score Comparison and Forced Choice for Attentive Respondents

As in the US sample, Russian respondents viewed the pro-R&D politician as more competent in all dimensions than the politicians favoring other forms of investment. Unlike the US sample, however, the pro-R&D policy was also seen as generating greater expected economic returns, and the politician advocating this policy was more likely to be reelected. This difference could reflect a difference in skill preference in the Russian and US settings.

Appendix A.6 presents score distributions for each policy comparison for the attentive US and Russian samples; since there are three times as many observations for pro-R&D politicians as for non-R&D politicians, I did not aggregate pro-R&D scores across all comparisons. Figures A.7 and A.6 shed some light on the puzzling results presented in Section 2.5.2.1, i.e., that in the US sample a pro-R&D incumbent failed to score higher on the reelection-prospects dimension than a non-R&D incumbent, despite the fact that he did not perform worse than the control politician on the economic expectations dimension and performed better on the competence dimension. The economic expectation scores of pro-R&D politicians are skewed to the right, indicating that the score distribution of economic expectations from R&D policy is wider for both US and Russian samples than the scores from pro-education policy. This can be regarded as a reflection of the risky nature of R&D policies.

Since I employ convenience samples in both the USA and Russia that are not fully representative of the general population of these countries, it is interesting to investigate if there is tangible difference in preferences over treatment and control politicians at different levels of education (cutoff educational achievement is "some college") and wealth (cutoff wealth is 40,000 USD a year in the USA and 30,000 RUR a month in Russia). These cutoffs are median values in both samples. Appendix A.7 presents the results for attentive respondents in both countries.[9]

[9]In the forced choice setting, we do not see a difference in choices made by more educated and less educated respondents in either the USA or Russia. In score comparison settings, more educated US respondents rate the pro-R&D politician higher than the pro-Education

2.5.2.3 Comparison of US and Russian Results for Attentive Respondents

In this section, I compare experimental results for the attentive Russian and US samples, employing Welch's t-test with unequal variances to test for equality of means for the US and Russian pro-R&D versus policy differences for each of the three dimensions, and the results are presented in Figure 2.6. Here, we can see that a US pro-R&D politician competing with a pro-short-term-innovation politician has a lower score advantage than the Russian politician on all dimensions. With respect to a pro-infrastructure politician, there was no statistically significant difference in US and Russian performance with a pro-R&D politician. These comparisons hold for both the score-difference and forced-choice analyses. As we compare the performances of a pro-R&D politician with that of a pro-education politician for the two countries, the framing of the question seems to matter. Whereas the score-difference results exhibit no statistically significant difference between the US and Russian samples, based on the forced-choice analysis, US respondents awarded a lower score premium than the Russian respondents did to a pro-R&D politician competing against a pro-education politician.

The directions of effects for incumbents' policy choices were inspected for both the US and Russia individually and relative to one another. The directions of effects are the same for choosing R&D policy over short-term commercialization (i.e., innovation), infrastructure investment, or education investment, as shown in Section 2.5.2.1 and Section 2.5.2.2, but the magnitudes differ significantly.

politician, but rate both equally on economic expectations and reelection prospects A.12. In Russia, the score difference setup reveals that more educated respondents rate the pro-R&D politician lower on all three dimensions than pro-Education politician A.13. Exploring the comparison between scores assigned by more and less wealthy respondents, in the USA, we do not detect any difference between the two subsamples A.14. In the Russian sample, the pro-R&D politician obtains lower scores from wealthier respondents on reelection prospects compared to the pro-education politician and lower scores on economic expectations in the forced choice setup A.15.

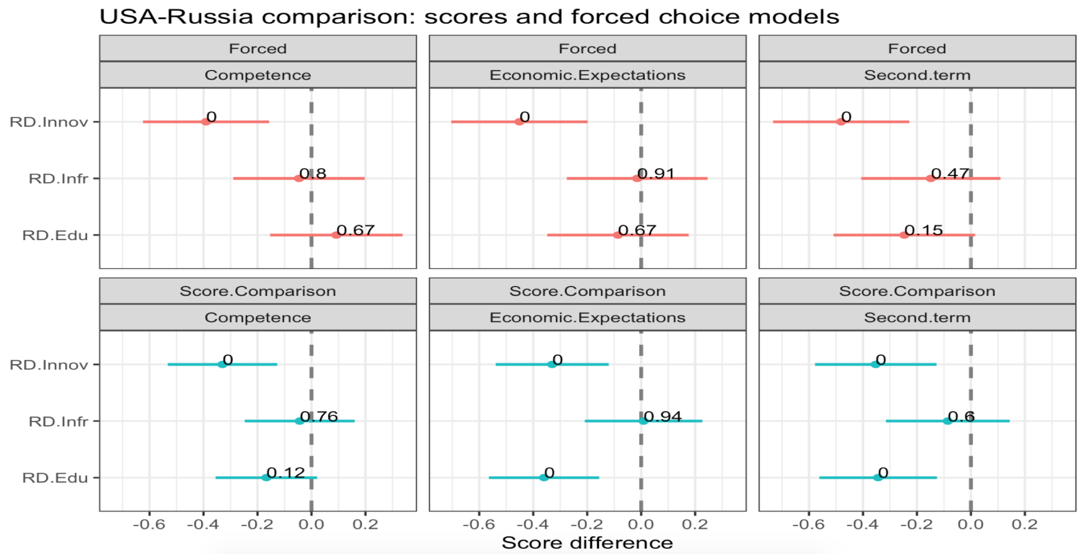


Figure 2.6: Difference in Scores for Attentive Respondents

Overall, Russian respondents tended to value R&D policy more than US citizens did. Respondents from both countries updated their beliefs about an incumbent's competence based on his policy choice. The comparison of survey results for the full US and Russian samples is presented in Figure A.5 of Appendix A.5 and is similar to those of the attentive sample.

2.5.3 Associations between reelection, perceived competence, and economic expectations

As we have explored the role of a politician's policy choice in forming perceptions about his competence and the economic expectations related to this policy choice, we can now explore the associations between the decision to reelect a politician and these two factors and compare the differences we observed between US and Russian responses. For purposes of illustration, I tested whether voting for a pro-R&D politician was positively correlated with perceptions of his competence and with economic expectations. The results do not establish a causal claim but rather validate previous findings, i.e., that both channels move in the same direction as the respondents' stated voting decisions. To accomplish this, I employed linear regressions based on results derived from both the forced choice and score comparison analyses. The simple OLS regression models to explore the associations in score differences were as follows:

$$\begin{aligned}\texttt{Score.Diff.Reelection} =& \alpha + \beta_1 \texttt{Score.Diff.Competence} \\ &+ \beta_2 \texttt{Score.Diff.Economics} + \epsilon\end{aligned}$$

The model employed to explore the forced choice analysis was as follows:

$$\begin{aligned}\texttt{Choice.Reelection} =& \alpha + \beta_1 \texttt{Choice.Competence} \\ &+ \beta_2 \texttt{Choice.Economics} + \epsilon\end{aligned}$$

The results of the analyses are presented in Table 7. In the score comparison analysis, the variables were the differences between perception of a politician's competence or policy and those of his competitor. Similarly, the reelection prospect was measured as the difference in prospects of a politician and his rival. Thus, the maximum value each variable could take was 5 (if the politician was rated highest on the scale and his rival was rated lowest), and the minimum possible value was 0 (if they were rated to be the same). The order in which the questions appeared to a respondent was randomized. In the forced choice analysis, the results were on a scale running from -3 (prefer much less) to +3 (prefer much more), with the 0 score omitted to facilitate forced choice. The results presented below are restricted to respondents that successfully passed the attention check administered at the beginning of the survey but are robust to inclusion of the whole sample of users.

Table 7 presents the results for the pooled Russian and US sample, inattentive

	Dependent variable : Reelection score	
	Score.difference	Forced.choice
	(1)	(2)
Economic_perceptions	0.622*** (0.018)	
Competence	0.461*** (0.022)	
Choice.Economic_perceptions		0.588*** (0.014)
Choice.Competence		0.235*** (0.018)
Constant	−0.041* (0.024)	−0.038 (0.025)
Observations	3.259	3.259
R^2	0.510	0.494
Adjusted R^2	0.510	0.494
Residual Std. Error (df = 3256)	1.353	1.403
F Statistic (df = 2; 3256)	1,696.703***	1,588.785***

Note: *p<0.1; **p<0.05; ***p<0.01

Table 2.7: Predicting reelection scores with perceived competence and economic expectations

respondents excluded.[10] However, when presented with the forced choice, US

[10] Results are very similar when restricting to the attentive sample, and when adding country-fixed effects.

respondents valued competence more and economic expectations less than did the Russian respondents. Overall, the difference in importance between competence perceptions and economic expectations in predicting reelection prospects was rather small within both the US and Russian samples.

Thus, the results suggest that both competence signaling and expectation of future economic performance are plausible determinants of incumbents' reelection prospects. One might argue that the survey respondents responded to questions in the same directions due to rationalization. Although I am not able to eliminate this concern, randomization of order of the questions and employing the two different scales (i.e., score comparison and forced choice) should have helped to alleviate this issue to some degree.

Whether voters can anticipate the long-run effects of government investment in innovation so that they can reward an incumbent with their support is an important question. Unlike other long-term government investments (such as education or infrastructure), the results of government investment in R&D are not directly observable by the population until the time needed to develop the technology and bring it to market has elapsed. Furthermore, the survey results provide insight into whether support for an incumbent changes due to changes in perception of the incumbent's competence or due to the anticipated effects of the policy itself.

A battery of tests was performed to test various hypotheses, specifically whether investment in R&D (1) had any positive effect on an incumbent's reelection prospects compared to investment in short-term innovation, infrastructure, and education; (2) generated greater expectations for the economy; (3) was associated with respondent perceptions of increased competence of the incumbent politician; and (4) caused the politician to be ranked higher than the control politician on reelection prospects.

2.6 A case study: Medvedev and nano-technology

In Section 2.3 I have shown that the incumbent can reap benefits from investing in R&D, contrary to the specific traits of such a policy as outlined in Section 2.1. Section 2.4 provides some evidence on this point, although it cannot be regarded as conclusive due to possible confounding effects. Experimental evidence suggests that citizens regard a pro-R&D politician as more competent than pro-infrastructure, pro-education or pro-short-term-innovation politicians. In what follows, I briefly illustrate that politicians not only invest in R&D policy but also actively broadcast their policy choice. Russia provides a modern example of showcasing government efforts to boost innovation. When Dmitry Medvedev succeeded Vladimir Putin as president in 2008, he put "technological modernization" at the forefront of his agenda and drastically increased funding of nanotechnology. In a statement representative of his agenda, he said, "Instead of the primitive raw material economy, we will create a smart economy generating unique knowledge, new useful things and technologies." As Treisman (2012) shows, this strategy worked initially, and Medvedev's approval was consequently high.

Figure 2.7 shows mentions of the word "nanotechnology" by itself and in combination with the name "Medvedev" in the Russian media over the 2004-2016 period, as well as government approval among the citizenry. As can be seen, nanotechnology mentions (blue line) began to rise sharply in 2007 (the leftmost dashed line) when Medvedev's election campaign began. Medvedev centered his agenda on the idea of promotion of new technologies and "modernization," resulting in a rise of combined mentions of "Medvedev" and "nanotechnology," and, for a substantial period of time, he enjoyed high approval ratings (bottom figure). In contrast to the Autobahn construction, however, Russian citizens did not see tangible results of Medvedev's investments. Although in part this could be due to the long period of time such investments took to yield a return, it could also be attributable to the large-scale rent-seeking that these projects enabled.

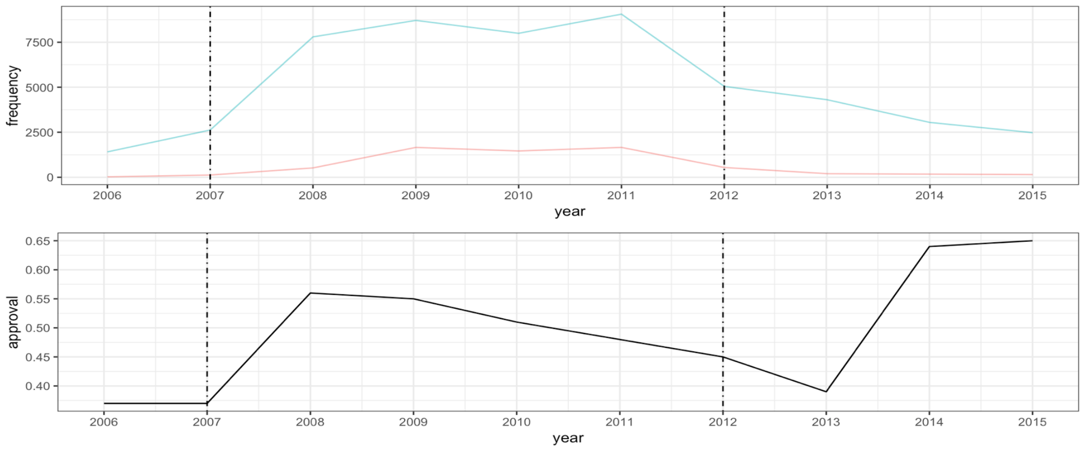


Figure 2.7: Mentions of Dmitry Medvedev and his technology-pPromoting efforts in Russian media. *Source:* Integrum Database

In June 2018, I conducted a semi-structured interview with Yuriy Simachev, a deputy CEO of the Interdepartmental Analytical Center. The Center was founded in 1992 by the Russian government as a consulting body for government industrial policy. Later on it took on the tasks of preparing government R&D policy efforts and monitoring ongoing government R&D projects.[11] Simachev highlighted that the Russian government was interested in "active R&D policy," where the projects that received support were selected by the official body. He noted that government support for innovation was aimed to have a demonstrative effect, as the government could claim to be aiming for a "proriv" ("breakthrough") —a slogan widely used in times of the USSR planned economy. He also suggested that it helps officials to form an image of the strong "derzhava" ("country").

The Russian example is not the only case of showcasing government R&D

[11] The Interdepartmental Analytical Center was transformed from a government body to a joint stock company in 2003.

policy. In 2011 State of the Union address, President Obama focused his speech on the importance of innovation. He campaigned focused on research and innovation in his campaign in one of the key swing states - Philadepphia. Figure 2.8 presents mentions of the keywords "government," "technology," "President," and "research" in the News section of Lexis Uni (Public Administration topic only), approval ratings of the US government, and government R&D expenditures as a share of GDP. Amid the 2013 budget cuts R&D funding was significantly cut as well. In 2016, his widely-discussed attempt to boost government expenditures on R&D by relying on mandatory funding (approved by Congress) failed.

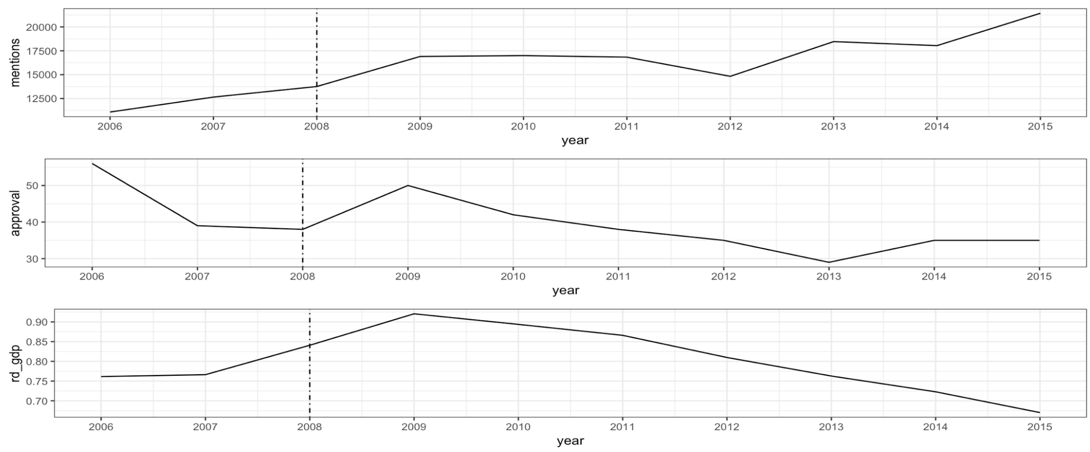


Figure 2.8: R&D mentions, government approval, and government R&D expenditures in the USA over time

In these examples, we can see that both mentions of R&D and actual government R&D spending increase in the first year of the new incumbent's term. At the same time, R&D spending is rarely close to the bliss point of the median voter. For example, Eurobarometer (2018) respondents answering the question "And on which of the following would you like EU budget to be spent? (Max 4 answers),"scientific research was mentioned by one in five Europeans, compared to "public health" and "employment and social affairs," mentioned by 40% of respondents; "economic growth" and "education, training, culture and the media," mentioned by one-third of respondents; and "climate change and environmental protection" and "defense and security," mentioned by a quarter of respondents.

2.7 Conclusion

In this paper, I have explored a political economy puzzle: why do we observe substantial government R&D investment, which carries significant cost and risk and does not provide politicians with apparent short-term results that can boost their reelection chances? This paper focused on a particular mechanism — the ability of politicians to signal their competence by engaging in highly risky and complex policy — and provided a theoretical model showcasing this mechanism. I have tested it using a survey experiment in two countries that actively engage in R&D policy and have found that citizens do indeed exhibit higher perceptions of competence of pro-R&D politicians compared to pro-infrastructure politicians, while the results for pro-short-term-innovation and pro-education politicians differ across countries. At the same time, I failed to establish that the higher competence perception boosts a politician's reelection prospects. In addition, I performed a cross-country analysis and found suggestive (supposing the structure of assumptions was correctly specified) evidence that government R&D investment boosts government approval among the citizenry. Overall, my empirical findings are consistent with the theorized model and suggest that incumbents can indeed engage in competence signaling via pro-R&D policy. In some cases, it can lead to overinvestment in R&D, since even less competent politicians can choose pro-R&D policy in equilibrium.

CHAPTER 3

The Puzzling Politics of R&D: Growing "Lemons" in the Market for Technology

3.1 Introduction

Government investment in research and development (R&D) is a vital input into creation of new technologies (Savrul and Incekara, 2015), an important determinant of sustained economic growth (Romer, 1990; Aghion and Howitt, 1990; Aghion et al., 1998). Positive externalities from the development of new technologies justify government support for innovation from the normative perspective. Non-surprisingly, governments worldwide spend a large sums of money on promoting R&D.[1]

Yet, what are the political incentives to invest in long-term and risky policy that might take decades to bear fruit, and so cannot be helpful by the time a politician stands for reelection? Government investments in R&D seem especially puzzling from the perspective of studies of economic voting. Scholars (Cohen and Noll, 1991; Duch and Stevenson, 2006; Fiorina, 1978; Lewis-Beck, 1986; Huber, Hill and Lenz, 2012; **?**) emphasize that voters care only about recent policy benefits, which provokes inefficient public policy due to the respon-

[1]In 2010, the EU outlined five main long-run goals for the 2020 Strategy and pledged to devote 3% of GDP to R&D support. In the US, the government spent $39.9 billion on R&D in 2017 (Sargent, 2018), comparable to the $44.3 billion budgeted for elementary and secondary education

siveness of government policies to citizens' preferences (Page and Shapiro, 1983). If electoral rewards for beneficial policy decay quickly, then reelection pressures induce policymakers to underinvest in welfare-enhancing policies with benefits that materialize in the long run (Achen and Bartels, 2008; Keech, 1980; Sobel and Leeson, 2006).

In this paper, I show that under rent-seeking, politicians can design and support R&D investment to their immediate and certain benefit. However, this is not a model of government stealing: if the only goal that politician maximizes would be the total amount of bribes, why would they take bribes rather than steal all of the money in their disposal? Equally important is the market response: if buyers of patented technology know that all patents are "lemons", why would they pay a price to buy a technology? The model explains how the opportunity to take bribes granting patents for "lemons" leads to the following empirical observation: an increase in government funding does lead to an increase in the number of patents, yet, in the presence of a corrupt motive, is accompanied by the proliferation of "lemon" patents.

Unlike many other types of government investment, the success of government support for R&D is hard to evaluate in the short-term. First, the creation of new technology can be a process that takes decades. The lag between technology creation and its first implementation can also be very long. The interim step - patenting of the new technology - should, in principle, inform the public of the efficiency of government policy in fostering innovation. Patent expertise should ensure that the new technology is novel, useful, and nonobvious, since it is difficult for non-experts to access its quality. Yet patent expertise often fails, and, in many cases, is non-functional in general.

Given that the success of government R&D policy is hard to evaluate in the short term, investment in R&D is an attractive vehicle for rent-seeking. In the absence of independent expertise and anti-corruption policy, strong incentives for innovation such as patent prizes or state grants allows bureaucrats to extract bribes for awarding patents with little, if any, quality control. This in turn incentives agents to file low-quality patents with the sole aim of getting government grants. The presence of low-quality patents reduces the market price for patents in general, further crowding out high-quality research. Instead of investing in strengthening institutions, even a benevolent government relies on KPIs such as the number of new patents or the *efficiency of government R&D expenditures* measured by the patent to expenditures ratio. I rely on the literature on adverse selection and market unraveling (Akerlof, 1978; Wilson, 1991) to model the effect of proliferation of low-quality patents on the economy.

Russia is an excellent field laboratory to study the impact of government R&D policy in the presence of weak institutional constraints. Starting in 2008, Russia has dramatically increased government support for R&D in the field of nanotechnology. Using difference-in-difference approach, I compare changes in quality of patents (as measured by citations) in the field of nanotechnology to changes in other fields. This allows me to establish a causal link between availability of government R&D support and the quality of patents in the affected field under assumption of common trends. I find that the drop in probability of being cited for nanotechnology-related patents filed after the onset of the policy was 4.5% compared to patents filed before and after policy onset in other fields. This is a large decrease, since only 2% of all Russian patents are cited. [2]

While difference-in-difference approach mitigates the potential omitted variable problem, the estimated ATT can still be biased if there exists an omitted variable (or a group of variables) that varies by time and patent type and af-

[2]A different measure of patent citations suggests a decrease of 1%. They are also less likely to obtain 10 or more citations by 1%.

fects patent citations. I perform sensitivity analysis to assess the vulnerability of the ATT to omitted variable bias and find the robustness value to be rather low - in most specifications, the unobserved confounders (orthogonal to the covariates) that explain more at least around one percent of the residual variance of both the treatment and the outcome to reduce the absolute value of the effect size by 100. Hence, I supplement my difference-in-difference analysis with additional comparison of the quality of Russian patents to quality of US patents. This triple-difference approach eliminates the potential impact of omitted variable (or a group of such variables) that could vary by time and patent class and affect patent citations that could occur due to natural trends in technological development and that is equally biasing US and Russian case. The results of triple-difference estimation are consistent with conclusion that the average quality of nanotechnology patents decreased after the rise of government funding for this technological field. I provide illustrative evidence that purchase of nanotechnology patents (measured by number of licences) filed after the onset of program declined compared to other fields.

This paper contributes, first, to our understanding of effects of rent-seeking and corruption on economic growth. In their book Rowley, Tollison and Tullock (2013) outline the different facets of rent-seeking and its effect on the economy and politics. They argue that an incumbent maximizes his or her chances to stay in power, as well as the amount of collected rents, in the spirit of Downs (1957); Buchanan and Tullock (1962); Peltzman (1972) and other Public Choice literature. Appelbaum and Katz (1987) presents an outlook where regulators endogenously set the rents and firms and consumers respond to rent-setting in a self-motivated manner. Grundler and Potrafke (2019) investigate the effect of corruption on growth and find that real per capita GDP decreased by around 17% when the reversed CPI increased by one standard deviation. Treisman (2007) shows that reported corruption experiences correlate with lower development, and possibly with dependence on fuel exports, lower trade openness, and more intrusive regulations. This paper illustrates how the rent-seeking in associated with distribution of government R&D grants can have a detrimental effect on the market for technology transfer. The model developed here implies that, under low government accountability and the value of grant set independently of the price of the patent, politicians would choose to set rents that lead to creation of patents with no technological or market value, crowding out high-quality innovation.

Second, this paper contributes to the literature on the innovative activities of private firms. There is an ongoing discussion of whether government R&D investment crowd-out (Atanassov and Nanda, 2018; David and Hall, 2000; David, Hall and Toole, 2000) or promote (Takalo and Tanayama, 2010) R&D investment of private companies. For example, Ngo and Stanfield (2016) show that government-dependent firms expand R&D investment whereas industry-peer firms contract. The net result is a reduction in industry-level R&D investment. At the same time, Acemoglu and Linn (2004) show that public investments target research areas with the highest potential for follow-on innovation, for example those where disease burden is rising or scientific opportunities are increasing (Potterie and Lichtenberg, 2001). In short, there is no consensus in the literature on whether government R&D efforts in fact contribute to economic growth (Mathieu and van Pottelsberghe de la Potterie, 2008).

The theoretical models yields a set of conditions that ensure that government R&D policy would be beneficial for technological development. The failure of one or more of these conditions results in a detrimental effect of government R&D grants of creation of new technology.

This work is also related to the investigation of the broader effects of government pro-R&D policies on the economic development of countries. (Azoulay et al., 2019) show that NIH funding spurs the development of private-sector patents: A \$10 million boost in National Institutes of Health (NIH) funding spurs the development of private-sector patents. A \$10 million boost in NIH funding led to a net increase of 2.7 patents, citing NIH-funded research. Investigating data drawn from Italy Akcigit, Baslandze and Lotti (2017) found that government R&D subsidies led to greater profits for politically-connected firms with no change in their efforts to produce new technologies. They interpret this finding as a substitution between a legal monopoly on new technology derived from patents and protection from competition due to political connections.

This paper relies heavily on the body of literature focusing on corporate patenting activity. Patents are a main measure of output of innovative activity,[3] as they are the most important form in which industrial innovation is protected. Schmookler (1953) pioneered the use of patent statistics for the assessment of the rate of American inventing. This approach was criticised by Gilfillan (1960), as it makes an assumption that all patents are of equal quality and contribute equally to technological development. Griliches (1979) conducted the first large sample work using computerized United States Patent and Trademark Office (USPTO) data. His work emphasized the varied quality of patents, and stressed the use of patent citations as an important adjustment criterion. Kwon, Lee and Lee (2017) provide a discussion of varying qualities of patents registered at the USPTO in different countries, as well as the overview of the literature on this topic. There are costs of obtaining even a low-quality patent associated with filing fees and the cost of filing the paperwork.

Next, it illustrates how political institutions can impact the result of government policy toward innovation. It provides a theoretical framework to explain

[3] Patents are strongly related to R&D across firms, with elasticity close to one, but controlling for unobserved differences across firms, the elasticity is lower (about 0.3)

large discrepancies in the effectiveness of such a policy in different countries widely discussed in the literature. This paper illustrates the implications of the model with data on Russian patents.

This paper is organized as follows: Section 3.2 provides a cross-country motivation for the current projects by investigating the conditional correlation between efficiency of government policy in production of patents and public corruption and government accountability. Section 3.3 provides a game-theoretic model that shows how rent-seeking in the distribution of government grants can lead to a reduction in patent quality with implications for the market for innovation under week institutions. Section 4.3.1 introduces a background information for government R&D policy that provides an identification for empirical investigation, an empirical analysis of the impact of Russian R&D policy with regard to nanotechnology, as well as alternative explanations of observed results. Section 3.5 concludes.

3.2 Cross-country motivation

This section provides an observational illustration that inspires the puzzle that I will then probe in the Section 3.3. Not all patents are created equal (Griliches, 1979; Zaller, 1992). While some represent superstar technologies responsible for substantial technological breakthroughs, most go unutilized or uncited (Hall, Jaffe and Trajtenberg, 2005). Countries differ widely in the average quality of patents, with some of them being more efficient in producing the number of patents per dollars of government R&D expenditures. However, patenting efficiency does not necessarily translate to technological development.

Table 3.1 illustrates that in countries with low government accountability the efficiency of government investments in R&D in patent production has no significant relationship with Total Factor Productivity. Total Factor Productivity refers to how efficiently and intensely inputs are used in the production process. It is a common measure of level of technology or knowledge. The measure was obtained from Total Economy Database. Countries are denoted as having low government accountability if Accountability Transparency Index introduced in (Williams, 2015) is below the median. The Informational Transparency Index is comprised of three parts: the quantum of information released by governments; the quality of that information; and the information infrastructure of countries that enables dissemination of that information. The Accountability Transparency Index (ATI) is comprised of the existence of free and independent media, fiscal (budgetary) transparency, and political constraints. The Transparency Index takes both indexes into account. This is surprising, as one expects that the efficiency in production of new technologies (measured by patents) spills over to the level of technology employed in production in all economies, and not just those with high level of government accountability.

In addition, government R&D efficiency is positively related to Public Corruption variable, as measured by Quality of Government Data (Teorell et al., 2019), where the indicator variable is set to 1 if public corruption exceeds 0.6.

Conditional correlations provided in Table 3.2 suggest that R&D efficiency, as measured by the number of patents produced by government R&D expenditures (standardized at 2010 USD), is negatively correlated with accountability transparency and the transparency index introduced by Williams (2015). This is surprising as it suggests that countries with high public corruption or low accountability are more efficient in production of new technologies per dollar of government investment. The alternative explanation is that these countries have low initial level of technological development, and thus are able to catch up by investing in low-hanging fruit. But this would contradict the relationship found

	Dependent variable:		
	'Total Factor Productivity'		
	(1)	(2)	(3)
R&D efficiency	0.549*** (0.199)	0.554*** (0.200)	1.331*** (0.436)
Low ATI		−0.129 (0.317)	0.610 (0.486)
R&D efficiency × Low ATI			−0.880** (0.439)
Constant	0.530 (0.605)	0.655 (0.680)	−0.019 (0.756)
Observations	491	491	491
R^2	0.155	0.156	0.163
Adjusted R^2	0.092	0.091	0.097
Residual Std. Error	2.367 (df = 456)	2.369 (df = 455)	2.361 (df = 454)

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3.1: Total Factor Productivity, Government Patenting Efficiency and Low Accountability

in Table 3.1, as the impact of such technologies is still expected to improve Total Factor Productivity.

	Dependent variable:			
	Government R&D efficiency in patenting			
	(1)	(2)	(3)	(4)
Public Corruption (I=1)	1.512***			
	(0.311)			
Information Transparency		−0.037***		
		(0.006)		
Transparency Index			−0.064***	
			(0.009)	
Accountability Index				−0.034***
				(0.008)
GDP	0.019**	0.015*	0.018**	0.022***
	(0.008)	(0.008)	(0.008)	(0.008)
Constant	0.587***	3.054***	4.467***	2.372***
	(0.136)	(0.405)	(0.558)	(0.435)
Country FE	+	+	+	+
Observations	491	491	491	491
R^2	0.952	0.954	0.955	0.952
Adjusted R^2	0.948	0.950	0.951	0.948
Residual Std. Error (df = 455)	0.539	0.529	0.524	0.542

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3.2: Public Corruption, Information Transparency and Accountability and Patenting Efficiency

While these regressions do not provide causally identified relations, they demonstrate the surprising correlation between government accountability or transparency and the efficiency of government R&D funding in producing patents. In the next section I will employ a game-theoretic model that suggests that, under rent-seeking and low government accountability, creation of patents becomes a poor indicator of creation of functional technology, and, under certain conditions, can stifle technological development.

3.3 Model

This section introduces a model that demonstrates the effect of political rent-seeking on markets of technology and the incentives rent-seeking creates to file cheap but empty patents. It describes the mechanism that illustrates how government support for innovation can lead to the deterioration of patent quality with negative implications for the technology market.

There are two types of strategic players in the game, a politician and researchers, and non-strategic profit-maximizing firms. Researchers, in turn, differ in their talent: there are $\overline{R}$ of talented researchers that can either produce a valuable innovation at cost c and produce a high-quality patent, or choose to do nothing. There is also a pool of size 1 of non-talented researchers that can imitate research; the idiosyncratic cost of producing a "lemon" for non-talented researcher i is a_i, $a_i \in [0, 1]$. These researchers could also choose to do nothing at all.

As it is standard in the literature, the politician cares about both the economic benefits from creation of a new technology, and rents he is able to collect from sub-par patents. The controlling policy parameter that the politician is choosing is the level of bribe b to be paid by an author of a "lemon." In equilibrium, the policy determines the market price for a patent, and thus the incentives of talented researchers to produce a valuable innovation.

Making their individual decisions, all researchers observe the levels of bribe, b, and available research grants, π. If a talented researcher engages in patent production, her utility is $U^T(P) = \pi + p - c$, where π is the award, p is the market-determined price that she can get for selling a patent, and c is the cost of research. Otherwise, she gets 0.

If a non-talented researcher engages in patent production, he has to pay the bribe b, after which he can pass the expertise with probability $1-\theta$,where θ represents the quality of institutions. High θ corresponds to strong institutions, while low θ proxies the weak ones. In this case, the utility of non-talented researcher i is $U^{NT}(P) = (\pi + p)(1 - \theta) - a_i$, otherwise, he gets 0.

Let λ be the share of high-quality patents in the market. Companies purchasing patents do not observe the quality of patents *ex ante*. Their expected value for high-quality patents is $H > 0$, and low-quality patents at 0. The company purchases the patent if $\lambda H - p \geq 0$, so the market for technology clears, as in the simplest version of the Akerlof's "lemons" model (Akerlof, 1978), at price $p = \lambda H$.

Now, the utility function of the politician that cares both about the public welfare (amount of innovation) and rents he extracts, can be written as follows:

$$U^P = \alpha R H^S + (1 - \alpha)B,$$

where R is the total amount of research produced, H^S is the value of new technology for society ($H^S > H$ due to positive spillovers), α is the weight of economic development in politician's utility, and B is the amount of bribes collected from non-talented researchers.

In our analysis, we will focus on the case $0 < c - \pi < H$. The case $\pi > c$ describes the situation, in which the government prize is so big that it alone induces talented researchers to innovate; they are interested in high efforts even without selling their patents on the market. Similarly, when the costs of efforts, c, are prohibitively high, innovation cannot by incentivized by any policy.

3.3.1 Analysis

Suppose that b is the politician's policy choice, the size of the bribe. Then, the number of talented researchers R who engage in innovation is determined as follows:

$$R = \begin{cases} 0 & \text{if } \pi + p(b) < c \\ \overline{R} & \text{if } \pi + p(b) \geq c \end{cases} \tag{3.1}$$

If $R = 0$, $p = 0$ as there are no good patents in the market. Then the number of low-quality patents on the market of technology is

$$\Pr(\pi(1-\theta) - a_i) > b) = (\pi(1-\theta) - b)\,,$$

and the total amount of bribes is

$$B = b\,(\pi(1-\theta) - b)$$

Then the politician's utility is $U^P = (1-\alpha)b(\pi(1-\theta) - b)$, which is maximized at $b = \frac{1}{2}\pi(1-\theta)$, and the politician's utility is equal to $U^P = \frac{1}{4}(1-\alpha)\pi^2(1-\theta)^2$. In this case, the sole purpose of paying a bribe is receiving the award π.

Suppose that $R = \overline{R}$, i.e. talented researchers innovate. Then the price of the patent in the market is determined by

$$p = H\frac{\overline{R}}{\overline{R} + ((\pi + p)(1-\theta) - b)}. \tag{3.2}$$

Let $p(b)$ be a unique solution of (3.2) given the politician's choice of b; the existence and uniqueness of the equilibrium price follows from the fact that LHS of

(3.2) is an increasing function of p, and RHS of (3.2) is decreasing in p. Then the number of low-quality patents in the market is

$$\Pr((\pi+p)(1-\theta)-a_i)>b)=((\pi+p)(1-\theta)-b)\,,$$

and the total amount of bribes is

$$B=b\left(\pi+p\left(b\right)\left(1-\theta\right)-b\right).$$

Naturally, the function $p(b)$ depends positively on b : the higher is the bribe that non-innovators pay for the opportunity to get a patent, the lower is the share of false patents, and, consequently, the higher is the price the market is ready to pay for a patented innovation.

Note that for a certain natural range of parameters α, $\overline{R}$, θ, and H^S there exists a b^* such that $\pi+p\left(b^*\right)\geq c$ and $U^P\left(b^*\right)>U^P\left(\frac{1}{2}\pi(1-\theta)\right)$, i.e., the politician in equilibrium prefers innovation by talented people.

Suppose that the bribe is set at the level $\widehat{b}=(\pi+H)(1-\theta)$. Then $p\left(\widehat{b}\right)=H$, $\pi+p\geq c$ by assumption, and the politician's utility is $U^P\left(\widehat{b}\right)=\alpha\overline{R}H^S$. When parameters α, $\overline{R}$, θ, and H^S exceed certain thresholds (a threshold for each individual parameter),

$$U^P\left(\widehat{b}\right)=\alpha\overline{R}H^S>\frac{1}{4}(1-\alpha)\pi^2(1-\theta)^2.$$

Define b^* as

$$b^*=\arg\max_{b\geq0}\left\{\alpha\overline{R}H^S+(1-\alpha)b((\pi+p\left(b\right))(1-\theta)-b)\right\}.$$

As $U^P\left(b^*\right)\geq U^P\left(\widehat{b}\right)$ by the definition of b^*, the following Proposition is proven.

Proposition 3 *When parameters α, $\overline{R}$, θ, and H^S are sufficiently large (exceed certain thresholds), the politician prefers to set the optimal bribe at the level that makes, via the impact on the price for patented innovation, the talented researchers to innovate.*

The results of the Proposition are very intuitive. Strong incentives for innovation depend positively on politician's interest in growth, α, the total number of talented researchers, $\overline{R}$, the quality of institutions that make it more difficult to patent a false invention, and the extent of spillovers H^S. If the prize that is independent of the market, π, is high, then the optimal choice is to have the bribe level at $\frac{1}{2}\pi(1-\theta)$, the market price of patents at 0, and no innovation produced. One can note that absent government grants, market price for patents would be $p = H\frac{\overline{R}}{\overline{R}} = H$, as only high-quality patents would be produced. The quantity of patents produced would thus be $p - c$. If, on the other hand, $\pi > 0$, the quantity of patents produced would be $\pi(1-\theta)$. So for $\pi > p - c$, the number of patents produced would be greater than in absence of government grants. In the next section I illustrate the implications of the model in the case of Russia, given its low level of accountability θ.

3.4 Empirical Evidence

3.4.1 Background: Government R&D policy in Russia

Russia presents an interesting case for investigating government policy on supporting innovation. Initially, after the collapse of the USSR, policy toward supporting innovation was largely absent until 2008. After 2007, government efforts to support innovation were largely targeted. Government investments and grant programs targeted specific areas of research, with other areas being affected to a smaller degree. For example, various grant programs prioritized research in spheres of nanotechnology and, more recently, age-related medical research. In 2007, the Russian government created a government-owned joint-stock \$10 billion Private Equity and Venture Capital Evergreen Fund called Rusnano aimed at commercializing developments in nanotechnology. Another conglomerate established in 2007, called Rostec, also specializes in strategically important companies, mainly in the defense industry. Other sources of government funding, such as the Russian Fund for Basic Research, also prioritizes nanotechnology. As Dmitry Medvedev took the presidential office, additional resources in the form of government grants poured into supporting researchers in the field of nanotechnology. In many cases, just obtaining a patent was sufficient to claim the successful completion of a project undertaken with government funding. Thus, researchers in the field of nanotechnology were incentivized to produce more patents. I argue that this has led to a disproportionate decline in patent quality and value when compared to other fields.

3.4.2 Background: Russian Patent System

While there is a substantial number of unworkable patents in every patent office, the main distinction between Russian patents and the infamous US patents US 6368227 ("Method of swinging a swing") and US 604596 ("On the method of applying a peanut butter and jelly sandwich") lies in their quasi-scientific nature; they appear to be valid to nonspecialists. Some examples of patent names and associated technological problems are summarized by Arutyunov (2008), and presented in Appendix A.8. Yet, filing even an empty patent is costly. Quotes from the Russian patenting agency patentum.ru [4] suggests that performing a patent search and filing an actual claim amounts to 145 thousand rubles (roughly $2500) excluding the mandatory filing fee. This is about five times the average monthly wage in Russia.

Nonetheless, 98% of Russian patents filed after 1996 were never cited, and only 0.02% of Russian patents have 10 citations or more. The time lag between

[4] https://patentus.ru/sroki-i-tzeny/patentovanie-izobreteniy/

patent publication and its first citation is uncommonly high even for those patents that were cited (six years) compared to usual lag in OECD patents (three years). The market of technology transfer using patents is virtually absent, and more than 90% of Russian patents are held by individuals, and not companies. Why would a researcher file a patent that is likely never be licensed or sold, but looks scientific-like to a non-specialist?

One potential use of such patents is to signal the researcher's competence. Government scientific agencies (RFBR, etc.) decide whether to finance innovative projects with a grant based on several factors. Often the most important of them is the number of patents and publications submitted by the researcher. While it is costly to establish the quality of a complex research, governments often rely on patenting criteria: novelty, inventive step and applicability. A research that satisfies these criteria is worthy of support. The existence of a patent does not guarantee that these criteria are met. Still, the researcher is evaluated not on the basis of true patent quality, but by the mere quantity of obtained patents.

Indeed, the relative importance of patents and publications obtained by the researcher in the process of applying for a grant is very high, accounting for 45% of the score a researcher receives during project evaluation. Thus, the costs of increasing one's chances of receiving a government grant decline as the sum of costs of patenting and the costs of research converge to merely the costs of patenting. This gives researchers the incentive to file low-quality patents and, hence, increases the share of low-quality patents in the pool of Russian patents. Indeed, vast majority of Russian patents are only filed in Russian Patent Office, as shown in Appendix A.12 (WIPO, 2018), as they are only intended for domestic use, as they are never filed in any other patent office, which is surprising given relatively small size of Russian market for technology. For example, 50% of Swedish patents are filed in two offices or more. Such patents can be used as a main result of the research financed by the government grants, providing the researchers with an opportunity to forgo the actual innovative activity.

3.4.3 Data and Methods

I use the complete data of Russian patents for the 1996-2015 time period, including patent classification, year of patent application and patent grant, and number of forward-citations. Unfortunately, there is no readily-available indicator denoting whether the patent covers nanotechnology-related technology. Thus, I rely on two approaches to detect such patents. First, I compile a dictionary of "nanotechnology"-related terms. I then identify the presence of such words in the name of a patent. I denote the dummy variable *nano_text* as equal to 1 if patent name contains at least one nanotechnology-related term and 0 otherwise. I complement this approach with another measure based on pre-existing classification of Russian 5-letter patent classes. I denote the dummy variable, taking the value 1 if patent belongs to nanotechnology-related field as nano. [5] Figure A.16 of the Appendix presents the histogram of patent applications in the 1998-2015 time period. Colors represent patent section in International Patent Classification - the broadest definition of patent field.

Figure A.16 shows that the number of patent applications has grown after the announcement of large-scale government R&D funding.[6] This growth was especially large in sections B (performing operations), C (chemistry) and G (physics). These are the sections most likely to contain nanotechnology-related patents,

[5] B82B1/00, B82B3/00, B82B10/00, B82B20/00, B82B30/00, B82B40/00, B82C5/00, B82C15/00, B82C20/00, B82C25/00, B82C30/00, B82C35/00, B82C99/00, B82C, A61K9/51, B05D1/00, C01B31/02, G01B 1/00-15/00, G01N 13/10-13/24, G02F 1/017, G12B 21/00-21/24, H01F 10/32, H01F 41/30, H01L 29/775.

[6] Note that incentives to file nanotechnology-related patents mechanically creates a push to cite existing patents in the same area as part of the filing process

and, therefore, be eligible for additional government support. Similar growth in nanotechnology-related patent applications is noticeable using the dictionary-based approach, as demonstrated in Table A.6 of the Appendix.

Further, I explore the policy change in the provision of R&D funding that occurred in 2008 and provided large grants to researchers in the fields of nanotechnology. Using patent classification, I determine which research-based patent filings were eligible for government support. I then employ a difference-in-difference approach to demonstrate that the average quality of patents eligible for government grants dropped after the onset of government R&D programs compared to patents in fields where government support for innovation was less pronounced. The non-nanotechnology patents serve as a control group, since they are less likely to receive government support. Treatment period $\in 0, 1$ is 0 before the onset of a massive campaign to support innovation in nanotechnology in 2008, and 1 after the onset of a program: Equation 3.3 provides the details of the estimation.

$$Y_{it} = program_{it} + nano_{it} + nano_{it} * program_{it} + patent.class_{it} + \epsilon_{it} \quad (3.3)$$

Treatment variables are as follows: $program_i$ is an indicator variable, denoting whether the government program subsidizing researchers in the field of nanotechnology was in place in the year the patent was obtained; $nano_i$ is an indicator variable that shows whether the patent fell into patent classification of nanotechnology.

Since less than 2% of Russian patents are ever cited, I focus on the following measures of citations: `citations1` is a dummy variable, that takes the value 1 if the patent received at least 1 citation by 2016, 0 otherwise. `citations10` is a dummy variable, that takes the value 1 if the patent received at least 10 citations by 2016, 0 otherwise.

In order to account for the fact that older patents have more time to be cited, I include year of publication as a control variable. I account for the fact that patents in some fields are more likely to be cited than patents in other fields, by including fixed effects of the first 3 letters of patent classification.

As in any difference-in-difference analysis, I rely on a parallel trends assumption. Figure 3.1 presents trends for mean age-adjusted patent citations over the first five years of patent existence and citations based on nanotechnology-related patent classes and dictionary-based approach, respectively.

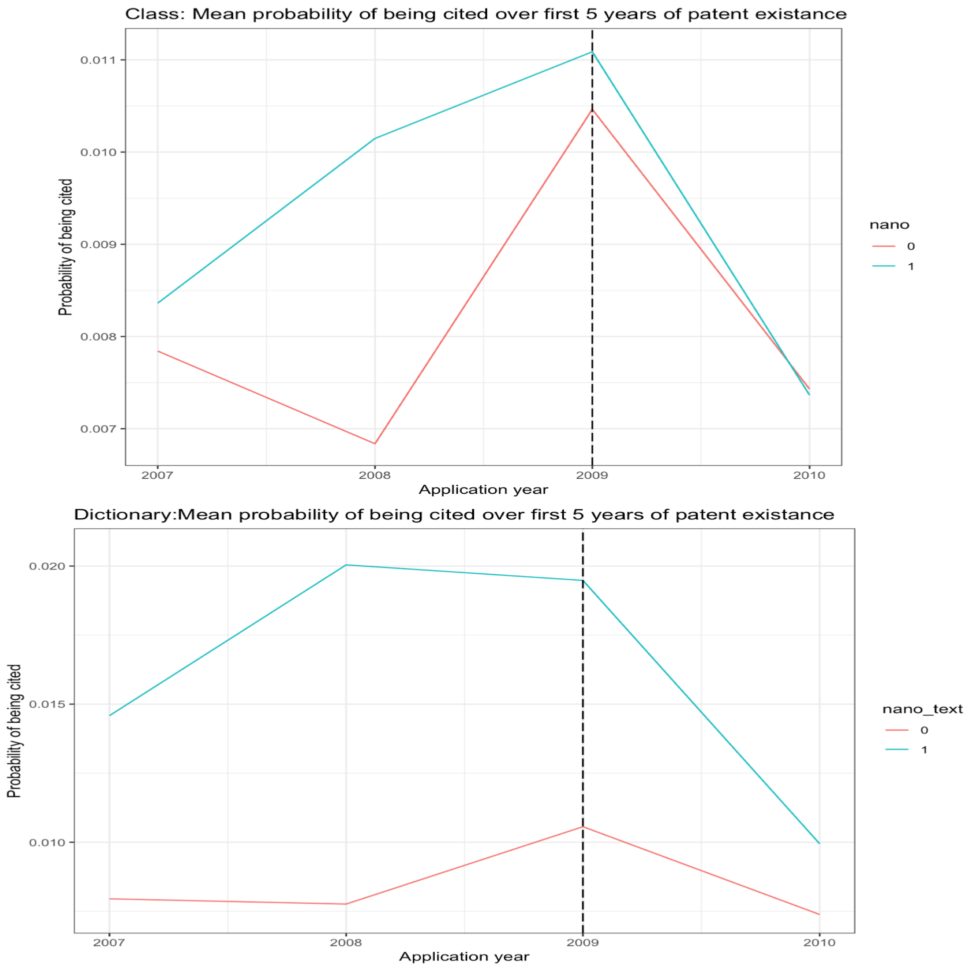


Figure 3.1: Parallel trend assumption

Both figures suggest that the decline in patent citations was more pronounced in classes receiving greater government support in nanotechnology-related classes.

3.4.4 Results

Table 3.3 demonstrates the decline in the probability of being cited for nanotechnology patents during years of additional government support for nanotechnology when compared to other fields. Specifically, a dictionary-based approach suggests a 4.6% decline in the probability of being cited at least once by 2016 for nanotechnology-related patents as a result of increased government support. A classification-based approach suggests a 1% decline in the probability of being cited by 2016. These results are robust for two ways of classifying patents as belonging to nanotechnology with either text analysis of the patent name or the five-letter patent class it belongs to.

Omitted variable bias can seriously impact any analysis of social phenomena. A difference-in-difference approach relies on a parallel trends assumption to mitigate the effects of extraneous factors and selection bias, but it can still be subject to the omitted variable bias.

I adopt the approach presented in Cinelli and Hazlett (2020) to quantify the confounding that would be required to nullify the observed regression results. To do so, I report the "robustness value" measure of sensitivity that illustrates the overall robustness of a coefficient to unobserved confounding. If the confounders' association to the treatment and to the outcome (measured in terms of partial R^2) are both assumed to be less than the robustness value, then such confounders cannot "explain away" the observed effect. This measure is a function of the estimate's t-value and the degrees of freedom.

Omitted variable bias can be decomposed in the following way Cinelli and

	Dependent variable:			
	text: citations1	text: citations10	class: citations1	class: citations10
	(1)	(2)	(3)	(4)
Nanotechnology	0.070***	0.008***	0.023***	−0.0001
	(0.022)	(0.003)	(0.007)	(0.001)
Program	0.059***	0.0001	0.062***	−0.0001
	(0.003)	(0.0004)	(0.004)	(0.0004)
Nanotechnology×Program	−0.046*	−0.009***	−0.010**	0.001
	(0.027)	(0.003)	(0.004)	(0.0005)
Constant	0.550***	0.007***	0.549***	0.007***
	(0.012)	(0.001)	(0.012)	(0.001)
3-letter IPC FE	+	+	+	+
Publication year FE	+	+	+	+
Observations	191,583	191,583	191,583	191,583
R^2	0.125	0.004	0.125	0.004
Adjusted R^2	0.124	0.004	0.124	0.004
Residual Std. Error	0.399	0.047	0.399	0.047
F Statistic	196.05***	6.06***	196.07***	6***
Robustness Value	0.0062	0.0035	0.0048	0.0049

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3.3: Government Policy and Patent Quality

Hazlett (2020):

$$|\hat{bias}| = se(\hat{\alpha})\sqrt{\frac{R^2_{Y\sim Z|X,D}R^2_{D\sim Z|X}}{1-R^2_{D\sim Z|X}}(df)}$$

where $se(\hat{\alpha})$ is the standard error of the main coefficient of interest $\hat{\alpha}$, Y is the outcome of interest, D is the main explanatory variable, X is a vector of covariates, Z is the omitted variable, and df is degrees of freedom of the regression.

The absolute value of the bias thus depends upon the strength of association of the outcome with the omitted variable (measured by the partial R^2:$R^2_{Y\sim Z|X,D}$), and the strength of association of the main explanatory variable with the omitted variable ($R^2_{D\sim Z|X}$).

An intuitive way to interpret the results is by comparing them to observed variables. The core assumption here is that confounding explains less of the residual variation in treatment and in the outcome than the observed covariate.

I choose publication year as the strongest predictor of citations received by the patent since it is widely accepted in the literature that there is a strong positive relationship between the age of the patent and its forward citations. The robustness values for the four main models are reported in Table 3.3.

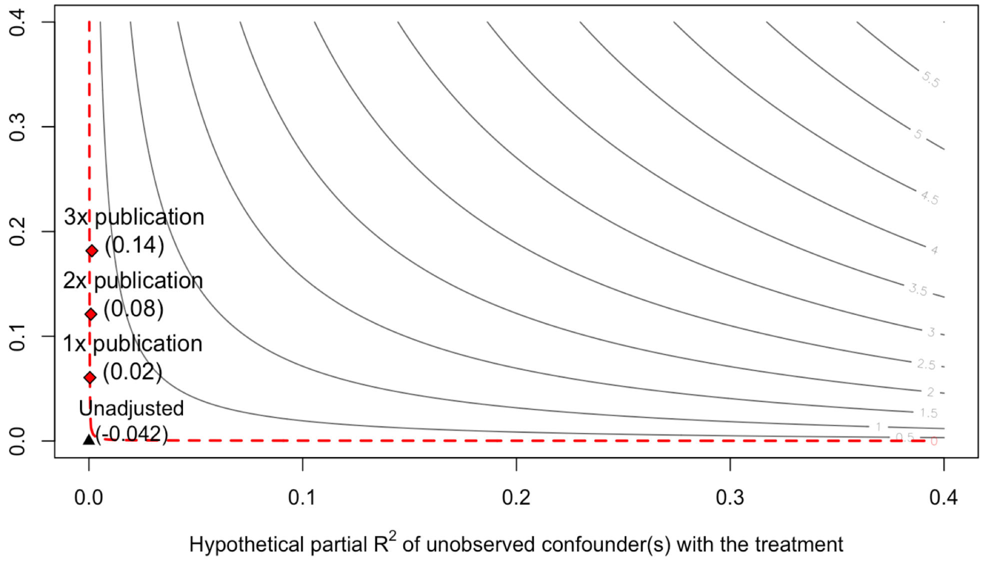


Figure 3.2: Aggregated licenses per patent by aggregated patent class

For model 1, unobserved confounders (orthogonal to the covariates) that explain more than 0.62 % of the residual variance of both the treatment and the outcome are enough to reduce the absolute value of the effect size by 100 %. Conversely, unobserved confounders that do not explain more than 0.62 % of the residual variance of both the treatment and the outcome are not strong enough to reduce the absolute value of the effect size by 100 %. Similarly, unobserved confounders should explain at least 0.36 %, 0.49 % and 0.49 % of the residual variance of both the treatment and the outcome in models 2-4 to reduce the absolute value of the effect size by 100 %. The observed robustness values are rather low, yet the citation data of Russian patents exhibits rare events characteristics, meaning that the predictive power of most variables would be rather low.

Table 3.4 presents similar results for age-adjusted patents. The outcome variable in this case is the number of citations received by patent i by year t, divided by the number of years since patent publication. The results suggest that disproportional government support of nanotechnology-related patents had a negative effect on their quality.

While class-based nanotechnology classification is negative and significant, suggesting 7% decline in probability of being cited (adjusted for patent age) is negative and statistically significant, it is still sensitive to omitted variable bias. Unobserved confounders (orthogonal to the covariates) that explain more than 0.18% of the residual variance of both the treatment and the outcome are enough to reduce the absolute value of the effect size by 100 % at the significance level of alpha = 0.05 . Conversely, unobserved confounders that do not explain more than 0.18 % of the residual variance of both the treatment and the probability of being cited are not strong enough to reduce the absolute value of the effect size by 100 % at the significance level of alpha = 0.05 . Benchmarking the effect of the difference-in-difference coefficient against the publication year suggests that omitted variable at least as influential is it will reduce the effect to zero.

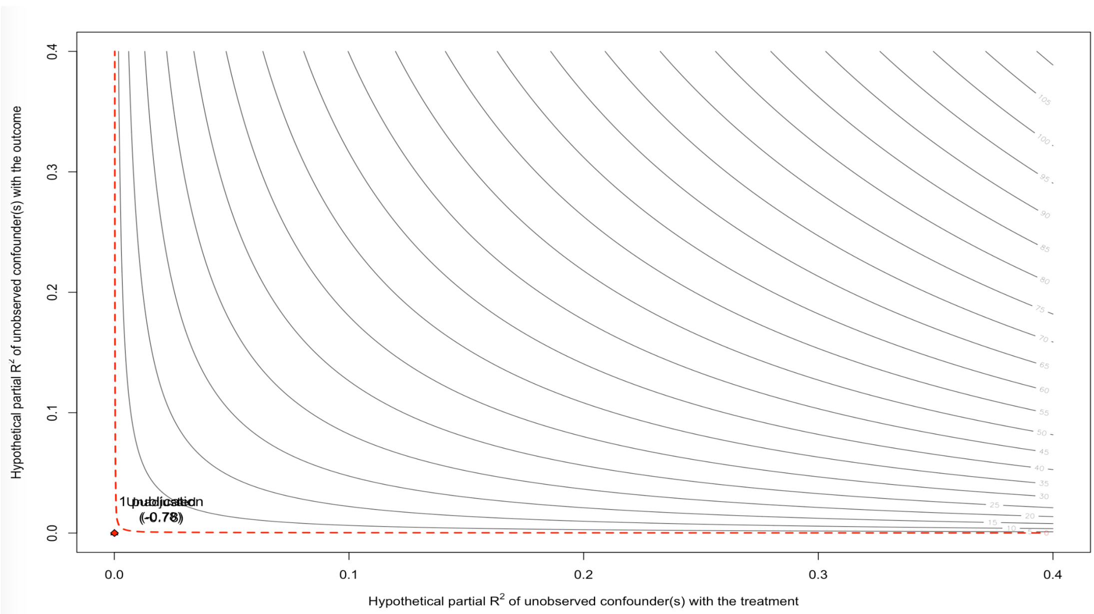


Figure 3.3: Aggregated licenses per patent by aggregated patent class

	Dependent variable:	
	citations per age	
	(1)	(2)
Nanotechnology (text)	0.105 (0.795)	
Nanotechnology (class)		0.118 (0.251)
Program	0.358*** (0.092)	0.591*** (0.110)
Nanotechnology (text) × Program	−0.596 (1.150)	
Nanotechnology (class) × Program		−0.787*** (0.199)
Constant	0.440 (0.394)	0.434 (0.394)
Observations	1,194,924	1,194,924
R^2	0.0001	0.0001
Adjusted R^2	−0.00005	−0.00003
Residual Std. Error (df = 1194799)	37.585	37.585
F Statistic (df = 124; 1194799)	0.562	0.685
Robustness Value	0.00053	0.0036

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3.4: Age-adjusted patent citations

3.4.5 Triple-difference approach

The difference-in-differences approach employed in subsection 3.4.4 measures the effect of government funding on patent citations in the treated group (nanotechnology), relative to changes in the patent citations in the control group (other patents). However, it suffers from high sensitivity to omitted variable bias. In this section, I employ US patent data to pursue the triple difference approach by comparing the double differences in nanotechnology citations with the double difference in non-nanotechnology citations, allowing the control of more factors that could bias the average treatment effect. It is possible that there exists an omitted variable (or a group of variables) that varies by time and patent type and affects patent citations. The double-difference approach eliminates the effect of such a variable if both nanotechnology patents and non-nanotechnology patents experience the same change in it. The differential advances in the technology can be such a factor. Yet it is hard to measure and therefore cannot be easily controlled. Thus, I remove the effect of such an omitted variable with a triple-differencing strategy, allowing an additional comparison between Russian and US patent citations.

New and growing fields, such as nanotechnology, can exhibit different patterns of development, compared to more established fields[7]. Thus, one might suggest the presence of a time-varying confounder that changes differently across nanotechnology and non-nanotechnology patent fields. A time-varying confounder that is not class-invariant violates the common trend assumption of difference-in-difference. I address the problem with a DDD design, using Russian and US patent data. The assumption is that nanotechnology patents in both countries are

[7]Nanotechnology became a specialized field in the 1980s after two major breakthroughs: the invention of the scanning tunneling microscope in 1981 which provided unprecedented visualization of individual atoms and bonds, and the discovery of fullerenes in 1985. Nanotechnology-related patent classification - Class 977 - was created in January 2011.

exposed to time-varying counfounders related to the relative novelty of the field. However, US patents are not influenced by Russian policy aimed at nanotechnology funding. Thus, I aim to remove the bias from the confounder and isolate the treatment effect by estimating the triple difference model of the following form:

$$Y = program + nano + rus + nano * program + nano * rus + \\ + program * rus + nano * program * rus + broad.patent.class + publication + \epsilon$$

$$Y = \text{program} + \text{nano} + \text{rus} + nano * program + nano * rus + \\ + program * rus + nano * program * rus + broad.patent.class + publication + \epsilon$$

where the outcome variable are `citations` - a count of citations received by the patent by 2016; `citations1` - a dummy variable that takes the value 1 if the patent received at least one citation by 2016, and 0 otherwise and `citations10` - a dummy variable, that takes the value 1 if the patent received at least 10 citation by 2016, 0 otherwise.

As before, in order to account for the fact that older patents have more time to be cited, I include the year of patent publication. In order to account for the fact that patents in some fields are more likely to be cited than patents in other fields, I include the fixed effects of the first 3 letters of patent classification.

I rely on pre-existing classification of patent classes that are more likely to include nanotechnology patents for construction of my explanatory variable. I denote the dummy variable, taking the value 1 if the patent belongs to nanotechnology related field as `nano`. The results of triple-difference estimation are presented in Table 3.5.

	Dependent variable:		
	`citations1`	`citations10`	`citations`
	(1)	(2)	(3)
Russia	-0.549^{***} (0.002)	-0.312^{***} (0.001)	-19.529^{***} (0.226)
Program	-0.903^{***} (0.262)	-0.471^{**} (0.211)	-14.675 (32.214)
Nanotechnology	0.006 (0.004)	0.003 (0.004)	1.083^{**} (0.539)
Russia × Program	0.249^{***} (0.004)	0.304^{***} (0.003)	19.211^{***} (0.452)
Russia × Nanotechnology	0.044^{***} (0.005)	0.035^{***} (0.004)	2.200^{***} (0.623)
Program × Nanotechnology	-0.032^{***} (0.006)	0.015^{***} (0.005)	1.210^{*} (0.717)
Program × Russia × Nanotechnology	0.028^{***} (0.007)	-0.013^{**} (0.006)	-2.117^{**} (0.851)
Constant	-26.045^{***} (0.649)	7.290^{***} (0.521)	296.379^{***} (79.705)
Observations	853,974	853,974	853,974
R^2	0.444	0.227	0.049
Adjusted R^2	0.444	0.227	0.048
Residual Std. Error (df = 853548)	0.371	0.298	45.547
F Statistic (df = 425; 853548)	$1,602.422^{***}$	589.407^{***}	102.957^{***}
Robustness value	0.0168	0.0101	0.00261

Note: *p<0.1; **p<0.05; ***p<0.01

Table 3.5: Triple-Difference Approach

The results of models 2 and 3 suggest that after the implementation of government support for nanotechnology in Russia, the patents in this area received fewer total citations, and fewer of them reached at least 10 citations. At the same time, the probability of Russian nanotechnology patents receiving at least one citation increased compared to US patents. This may reflect the fact that when applying for a patent, researchers are expected to cite existing relevant patents when producing patents that have few citations.

3.4.6 Government R&D support and licensing

Next, I investigate whether the decline in patent quality as measured by patent citations led to a reduction in technology purchases (measured by licenses). Licensing is one of the most common ways of technology transfer, and thus reflects the changes in the market for patents. Since licensing data is not readily available for Russian patents, I rely on government-compiled reports, which provide the total number of licenses of nanotechnology patents, as well as non-nanotechnology patents. This data has several limitations. One cannot observe exact patent class or any other unit-level information. In addition, I was able to collect data only for a limited span of time, from 2000 to 2011. Thus, these results can only serve as illustrative evidence.

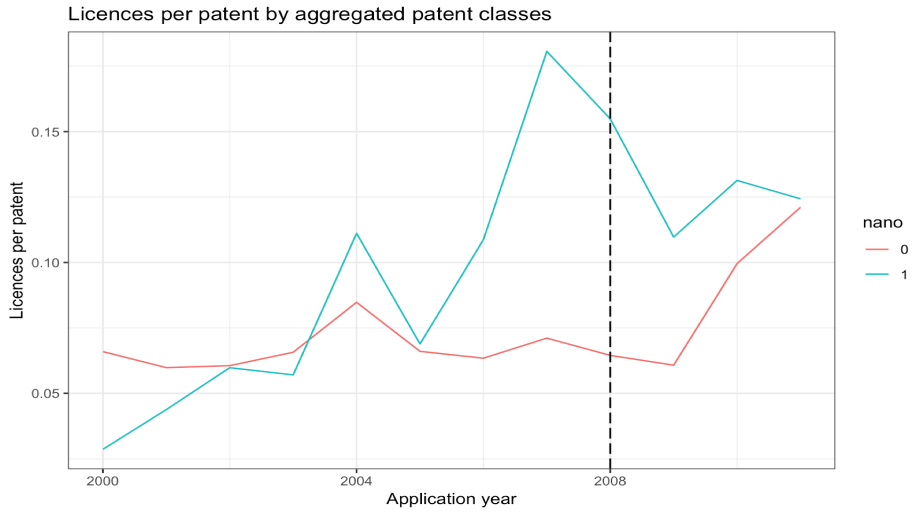


Figure 3.4: Aggregated licenses per patent by aggregated patent class

Figure 1 suggests that nanotechnology patents affected by government policy receive fewer licences when compared to post-policy implementation, and this decline is especially pronounced when compared to the increase in licensing of non-nanotechnology patents.

3.4.7 Alternative explanations

Section 3.4.4 demonstrated that both quality (as measured by citations) and market attractiveness (as measured by licenses) of nanotechnology-related patents have declined in the aftermath of government support for innovation in this field.

There are possible alternative explanations for these results. First, if government support triggers growth in fundamental research, companies may become interested in resulting technologies later on, while the present-day positive impact on licensing could be negative. Yet this hypothesis would fail to explain the fall of patent quality, as measured by citations, since the comparison is drawn between patents of the same publication year. If anything, government support for R&D

should prompt the increase in citations since patenting requires citing relevant research. Thus, citations in the affected fields should not decline, especially if government agencies highlight the importance of patenting for both selection of grantees and successful completion of the grant contract. For example, Azoulay et al. (2019) show that NIH funding by the United States government spurs the development of private-sector patents that cite NIH-funded research.

A second alternative explanation is that government funding of nanotechnology patents became effective at a time when nanotechnology research experienced a decline, and the patents in the field became less cited. This conjecture is unlikely to hold since an examination of citation trends of nanotechnology and other patent citations suggest that parallel trend assumption was true for the pre-treatment period. Still, one might suspect that there was some fundamental change in the year when government policy took effect, but was independent of this policy. Yet the analysis of the triple-difference model, including US patents, does suggest that no such change took place or that it was Russia-specific.

3.5 Conclusions

As government support for R&D renders results in a very long-term horizon and is very risky compared to other policies, the fact that we observe massive government R&D investment, poses a puzzle. Moreover, even the effectiveness of these investments on growth remains in doubt. In this paper, I show that, due to difficulty of accessing welfare implications of government support for R&D, such investments can be used as a vehicle for rent-seeking. I document the wide discrepancies in the impact of government funding on the creation of patented technologies and show that countries with higher levels of corruption have a greater patenting efficiency, but that does not translate into actual technological development. Using a game-theoretical approach, I suggest a mechanism that explains how corruption in the public sector creates incentives for polluting the technology market with fake patents and leading to the creation of “Lemons” problem in the market for technology. I further employ a difference-in-difference approach in context of Russian policy to support nanotechnology. I show how government support for innovation can reduce the overall quality of patents in the field that is eligible for such support. These findings help to reconcile various findings regarding the efficiency of government innovation policies in different countries by incorporating political incentives and institutional quality into policy analysis. Furthermore, they provide a theoretical background for evaluating the impact of political incentives for investing in the creation of new technologies in the technological development of countries.

CHAPTER 4

The Puzzling Politics of R&D: Political Connections and Innovation in Russia

4.1 Introduction

Innovation is key to long run economic development (Romer, 1990; Aghion and Howitt, 1990; Aghion et al., 1998), but often causes painful shifts in economic structure, displacing workers and reducing the value of capital sunk in old technologies.[1]. It can create "superstar firms" (Autor et al., 2020) with abnormal returns, while rendering others obsolete(Bloom, Schankerman and Van Reenen, 2013) Banerjee and Duflo (2019) compare these effects to those of international trade: increasing technological development benefits society on the whole, but can have negative effects on the groups and industries left behind. While important to considerations of equity versus growth, for political leaders these highly uneven returns to new technologies can also threaten to shift the balance of power in the economy, reducing the wealth of key supporters while generating a wealthy and powerful group that may challenge the regime. Politicians may thus appear to have incentives to stifle the development of new technologies, just as they sometimes do to impose trade barriers (Acemoglu and Robinson, 2006*a*; Mokyr, 1992*b*,*a*).

[1](Berman, Bound and Machin, 1998; Caselli, 1999; Galor and Savitskiy, 2017; Salomons et al., 2018; Acemoglu and Restrepo, 2018, 2019)

As a result, politicians face a trade-off between limiting economic growth—a costly action since most political regimes depend on positive economic growth—and facing a threat of technological displacement of their supporters. Yet, instead of suppressing innovation, governments have historically played a large role in fostering it via different policy tools: intellectual property rights regulations (Hu and Jaffe, 2007; Acemoglu and Akcigit, 2012; Moser, 2013; Moser and Nicholas, 2013; Moser, 2005; Moser, Voena and Waldinger, 2013; Lerner, 2009), tax credits (Akcigit, Ates and Impullitti, 2018; Guceri and Liu, 2017; Dechezleprêtre et al., 2020) and direct grants (Bronzini and Iachini, 2014; Azoulay et al., 2019; Ganguli, 2017*b*; Lach, Neeman and Schankerman, 2017).[2]

How can this apparent contradiction be reconciled? This paper proposes an explanation: the government's incentive is not to block technological change altogether, but rather to channel it so as to firms and industries allied to the regime can retain or even improve upon their position in the economy. In the proposed formal model, though government support for innovation flows to companies whether they are politically connected to the incumbent or not, the technological advantage of the allied companies is maintained. Provided that the government values the future higher than these companies, this can stimulate the development of new technologies by both connected and unconnected companies via co-funding the costs of innovation. Unlike models for some types of grants, this strategy requires companies receiving grants to expend effort in order to develop technology and maintain their advantage. However, the incumbent is able to condition additional progress-contingent benefits to connected companies, stimulating and offsetting the cost of that effort.

There are several observable implication of this model. First, it predicts that

[2]The normative grounds for this stem from observation that the value of the new technology is not fully appropriable by its creator (Arrow, 1962)

governments will provide co-investment in corporate R&D projects to both connected and unconnected companies. Second, such R&D grants should have higher impact on the economic performance of connected companies. Third, connected companies that engage in government-sponsored R&D project are expected to receive higher levels of other types of government funding, but only after the assessment of the progress of their R&D project. Finally, unconnected companies should expect no changes in other types of government funding after receiving government R&D grant.

In order to test these observable implications, I investigate a program of R&D support implemented by the Russian government since 2010 (the Decree 218 Program). This program provides government grants to Russian companies that purchase the creation of new technologies from Russian universities. Under the terms of the grant, the company has to co-invest an amount equal to or greater than the size of the government grant, which the university cannot spend for other purposes.

Using a variety of data sources I find, first, that indeed grants go to both connected and unconnected companies, consistent with the first prediction. Consistent with the second prediction, connected companies appear to benefit more than unconnected ones from winning these grant, as shown using both atriple difference-in-difference and a synthetic control approach called trajectory balancing. Specifically, while winning a grant had only insignificant effects on outcomes for unconnected companies, connected companies showed heightened profits and returns on assets. Third, in keeping with the final prediction, connected companies who won grants showed a higher volume of government contracts two years later during the R&D assessment period, while unconnected companies showed no difference.

This paper contributes to several strands of literature. First, it is related to the literature on the value of political connections. Many studies show that they are value-enhancing (see, for example, Fisman (2001); Faccio (2006); Voth and Ferguson (2008); Faccio and Parsley (2009); Ovtchinnikov and Pantaleoni (2012); Akey (2015); Ang, Ding and Thong (2013); Acemoglu et al. (2016). Political connections can help companies in different ways. They allow companies to gain better access to external funding (Claessens, Feijen and Laeven, 2008; Cull et al., 2015; Khwaja and Mian, 2008) and government help in times of crises (Faccio, 2006; Duchin and Sosyura, 2012). Connected companies are more likely to obtain government support in the form of contracts or subsidies (Tahoun, 2014; Goldman, Rocholl and So, 2008; Johnson and Mitton, 2003). Such companies can enjoy better protection from government expropriation (Batta, Sucre Heredia and Weidenmier, 2014) or law enforcement (Correia, 2014; Wu, Johan and Rui, 2016). Political connections can bend government policy to favor certain firms (Agrawal and Knoeber, 2001; Claessens, Feijen and Laeven, 2008). Fifth, political connections can provide a Pwith relevant information that allows it to optimize its strategy (Cohen and Malloy, 2014; Ovtchinnikov, Reza and Wu, 2019).[3] This paper suggests that connected companies benefit from government R&D investment more then unconnected ones.

Next, it contributes to the literature on the effect of government R&D policy on technological development (see, for example, Akcigit, Ates and Impullitti (2018); Guceri and Liu (2017); Dechezleprêtre et al. (2020)). In particular, Bronzini and Iachini (2014); Azoulay et al. (2019); Ganguli (2017*b*) and Lach, Neeman and Schankerman (2017) look at the effect of government grants on company R&D effort and resulting innovation.

Finally, it speaks to emerging literature on the role of political connection in

[3]There is evidence of political connection being value-destroying Aggarwal, Meschke and Wang (2012); Coates (2012). They can keep a company afloat even if it lacks efficiency (Okazaki and Sawada, 2017)

firm innovation. The role of political connections seems to depend on the context of the country in which the company operates. For example, Akcigit, Ates and Impullitti (2018) find that in Italy, politically connected companies make less R&D investment and produce fewer patents than unconnected ones. By contrast, Su, Xiao and Yu (2019) find that in China, politically connected companies generate more innovation compared to unconnected ones, with government subsidies being the mediator in this relationship. Ovtchinnikov, Reza and Wu (2019) find that US companies engaging in political activism (campaign contributions) obtain additional information, thus reducing political risks. Consequently, they invest in R&D more and produce more patents. This paper presents an alternative explanation. Rather then focusing on firm's access to information, I suggest that it's the government's willingness to act on the information about the success of the R&D project implemented by the connected companies that drives the latter to invest extra effort into innovation compared to unconnected ones.

This paper is organized as follows: Section 4.2 provides a model of choice of government R&D policy. Section 4.3.1 provides information about the state of government R&D policy and Decree 218 in particular. The sample is presented in Section 4.3.3. Section 4.4 analyzes the relation between political connections and winning a grant. Section 4.5 investigates the role of winning a grant on firms' performance. Section 4.5.1 employs trajectory balancing to draw causal inference about the effect of grant and connections on corporate economic outcomes. Section 4.6 presents evidence of a potential mechanism of compensation provided to connected companies for their R&D effort. Section 4.7 provides the discussion and concluding remarks.

4.2 Game-theoretic model of R&D policy regimes

There are 2 types of players: incumbent and a continuum of companies that differ in their discount factor. Their discount factor is uniformly distributed: $\delta_i \in [0,1]$. The incumbent can choose R&D policy: (A) do nothing, (B) cover part of the cost of innovation, (C) cover part of the cost of innovation and add a bonus to successful companies.

Let us first consider the case where incumbent doesn't engage in R&D policy. Companies can purchase new technology that will be successful with probability $\underline{P}$, or can devote additional effort to monitoring of the technology creation. In this case the technology will be successful with probability $\overline{P}$. Thus, the action space of the firm is as follows: invest in R&D, but not in monitoring; invest in both R&D and monitoring; do nothing.

Let H denote the value of successful technology, i - the cost of innovation, c - the cost of monitoring.

Then the expected utilities of each action:

$U_{RD,NM} = \underline{P}\delta H - i$ for R&D but no monitoring; $U_{RD,M} = \overline{P}\delta H - i - c$ for both R&D and monitoring; $U_0 = 0$ for doing nothing.

Let $d = \overline{P} - \underline{P}$. Then the company invests in R&D and monitoring iff

$$\begin{cases} \delta H d \geq c \ \textit{IC constraint} \\ -c - i + \delta H \overline{P} \geq 0 \ \textit{IR constraint} \end{cases}$$

Then denoting the discount rate required by incentive compatibility constraint by δ^{IC} and the discount rate required by individual rationality constraint by δ^{IR} we can find the cost of monitoring c under which incentive compatibility constraint becomes binding: $c \geq \frac{d*i}{\underline{P}}$. In what follows, I assume that this condition holds. Then for the firm to invest in both R&D and monitoring the following condition should hold: $\delta \geq \frac{c}{dH}$.

Conversely, firm invests in R&D but not in monitoring iff

$$\begin{cases} \delta H d \leq c \\ -i + \delta H \underline{P} \geq 0 \end{cases}$$

.

Then the company invests in R&D but not in monitoring if $\frac{i}{HP} \leq \delta \leq \frac{c}{dH}$.

The incumbent can choose policy B and stimulate R&D investment by covering half of the cost of innovation. Then corresponding firm utilities are as follows: $U_{RD,NM} = \underline{P}\delta(H) - i/2$ for R&D but no monitoring; $U_{RD,M} = \overline{P}\delta(H) - i/2 - c$ for both R&D and monitoring; $U_0 = 0$ for doing nothing. In this case, the condition for investing both in R&D and in monitoring remains the same: $\delta \geq \frac{c}{dH}$.

However, the conditions under which firm invests in R&D but not in monitoring change so that more more firms that previously did nothing choose to invest in R&D: $\frac{i}{2H\underline{P}} \leq \delta \leq \frac{c}{dH}$.

Finally, the incumbent can choose policy C and cover half of the cost of innovation. In addition, he can add a bonus B for successful implementation of the innovation. Then firm utilities are then as follows: $U_{RD,NM} = \underline{P}\delta(H+B) - i/2$ for R&D but no monitoring; $U_{RD,M} = \overline{P}\delta(H+B) - i/2 - c$ for both R&D and monitoring; $U_0 = 0$ for doing nothing.

Then the condition under which the company chooses to invest in R&D at all doesn't change: $\frac{i}{2H\underline{P}} \leq \delta$. But the condition under which a company chooses to add monitoring shifts so that more companies engage in it:

$$\delta \geq \frac{c}{d(H+B)}$$

Let's compare the utility of the government from each of the policies, given its $\delta = 1$, and it internalizes the costs payed by the companies. In addition, it covers the costs of bonuses and co-investment in innovation.

Let $e_{RD,NM}$ be the cost the company pays to engage in R&D but not in monitoring, and $e_{RD,M}$ be the cost the company pays to engage in both R&D and in monitoring. Let $g_{RD,NM}$ is the stimulus the government pays to the company that engages in R&D but not in monitoring, and $g_{RD,M}$ the stimulus the government pays to the company pays to engage in both R&D and in monitoring. Then the social utility of each policy can be calculated as follows

$$\lambda_1 H\underline{P} + \lambda_2 H\overline{P} - \lambda_1 e_{RD,NM} - \lambda_2 e_{RD,M} - \lambda_1 g_{RD,NM} - \lambda_2 g_{RD,M} \tag{4.1}$$

It is easy to see that under policy A (no R&D policy) the share of companies that do not engage in R&D is $\lambda_0 = \frac{i}{H\underline{P}}$, the share of companies that invest in both R&D and monitoring is $\lambda_1 = (1 - \frac{c}{dH})$, and the share of companies that invest in R&D but not in monitoring is $\lambda_2 = \frac{c}{dH} - \frac{i}{H\underline{P}}$, and $1 = \lambda_0 + \lambda_1 + \lambda_2$.

Then the social utility of choosing option A is the sum of firm utilities under assumption that $\delta = 1$:

$$(\frac{c}{dH} - \frac{i}{H\underline{P}})(H\underline{P} - i) + (1 - \frac{c}{dH})(\overline{P}\ H - i - c)$$

Recalculating shares of companies engaging in R&D only, or in both R&D and monitoring in accordance with policies B and C, we can find the social utilities under those policies. The the social utility of choosing option B also simplifies to the sum of firm utilities under assumption that $\delta = 1$:

$$(\frac{c}{dH} - \frac{i}{2H\underline{P}})(H\underline{P} - i/2)+$$
$$(1 - \frac{c}{dH})(\overline{P}\ H - i/2 - c)-$$
$$(\frac{c}{d(H} - \frac{i}{2H\underline{P}})i/2-$$
$$(1 - \frac{c}{dH})i/2 =$$
$$(\frac{c}{d(H} - \frac{i}{2H\underline{P}})(H\underline{P} - i) + (1 - \frac{c}{dH})(\overline{P}\ H - i - c)$$

Similarly, the the social utility of choosing option C is:

$$(\frac{c}{d(H+B)} - \frac{i}{2H\underline{P}})(H\underline{P} - i/2)+$$
$$(1 - \frac{c}{d(H+B)})(\overline{P}\ H - i/2 - c)-$$
$$(\frac{c}{d(H+B)} - \frac{i}{2H\underline{P}})(i/2 + B)-$$
$$(1 - \frac{c}{d(H+B)})(i/2 + B) =$$
$$(\frac{c}{d(H+B)} - \frac{i}{2H\underline{P}})(H\underline{P} - i) + (1 - \frac{c}{d(H+B)})(\overline{P}\ H - i - c)$$

Comparing three options, we can see that $U_b - U_a = \frac{i}{2H\underline{P}}(\underline{P}H - c)$;

Similarly, $U_c - U_b = \frac{cB}{d(H+B)H}(dH - c)$

Then, assuming $H(\overline{P} - 2\underline{P}) > 0$, the incumbent should choose option C.

Let us now consider the following case: companies can be of two types: Loyal (L) with probability θ and Apolitical (A) with probability $(1-\theta)$. The incumbent can discriminate his policy choice by the observed company type. He wants to maximize the overall social utility U^S of society, yet to make sure that loyal companies have long-run technological advantage $T^L > T^A$:

$$\text{Max } U(Policy)^S$$
$$s.t. T^L > T^A$$

Technological advantage of companies operating under policy A is

$$(\frac{c}{dH} - \frac{i}{H\underline{P}})(H\underline{P}) +$$
$$(1 - \frac{c}{dH})(\overline{P}H)$$

Similarly, technological advantage of companies operating under policy B is

$$(\frac{c}{d(H+B)} - \frac{i}{2H\underline{P}})(H\underline{P}) +$$
$$(1 - \frac{c}{d(H+B)})(\overline{P}H)$$

Finally, technological advantage of companies operating under policy C is

$$(\frac{c}{d(H+B)} - \frac{i}{2H\underline{P}})(H\underline{P}) +$$
$$(1 - \frac{c}{d(H+B)})(\overline{P}H)$$

In this case, he would choose the policy that is a combination of B and C, with companies that are loyal are subject to policy C, but all the companies that are apolitical are subject to policy B.

Then the expected impact of policy on apolitical companies is $(1-\theta)(\frac{c}{d(H} - \frac{i}{2H\underline{P}})(H\underline{P} - i) + (1 - \frac{c}{dH})(\overline{P}\ H - i - c)$,

Similarly, the expected impact of policy on loyal companies is $\theta(\frac{c}{d(H+B)} - \frac{i}{2H\underline{P}})(H\underline{P} - i) + (1 - \frac{c}{d(H+B)})(\overline{P}\ H - i - c)$.

Assuming that costs of monitoring are relatively high: $c \geq \frac{d*i}{\underline{P}}$, and that the difference in success rates of R&D investment with and without monitoring is sufficient, $H(\overline{P} - 2\underline{P}) > 0$, we expect to see that the government provides co-investment in innovation for all companies. In addition, it provides bonuses for successful implementation of R&D project to loyal companies.

4.2.1 Discussion and Observable Implications

Note that the parameter δ, presented in this model, can have several interpretations. First, it can be interpreted as a discount factor. Given this interpretation, the government has a longer time-horizon and does not discount the future, while the companies have varying time horizons. A different and non-contradictory interpretation of δ is the firm's ability to appropriate the value created by the new technology. The society on the whole always reaps the full social value of innovation, while the companies that created it vary in their ability to reap profits from it. To some degree, this ability depends on the strength and length of intellectual property right protection. Yet the speed of technological change in the industry, the degree of competition and the ease of patenting around the protected technology also impacts the degree to which the company can appropriate the full value of innovation.

Finally, there are several observable implications of this model that facilitate empirical testing. First, as long as the costs of innovation are smaller than expected benefits, the government is better off providing cost-reducing R&D grant to all companies since it benefits from the overall economic growth. Thus, we should expect to see such grants awarded to both connected and unconnected companies. The second implication of the model is greater success of politically connected companies in implementation of their R&D projects compared to unconnected companies. This difference stems from the difference in the R&D policy regime available for connected and unconnected companies. Thus, the third observable implication of the model is the provision of additional bonuses to connected companies, but conditional on the success of their R&D project, and provision of cost-reducing grants to both connected and unconnected companies. Section 4.3 tests these observable implications using the case of Russian Decree 218 grant that provides government co-financing of R&D projects.

4.3 Background and Data: Russia's Decree 218 Program

In what follows I first provide relevant background on the Russian R&D policy landscape, then details of Decree 218, followed by details of the data collection for the empirical test case.

4.3.1 Russian R&D Policy

Before the collapse of the USSR, the Soviet/Eastern European scientific community accounted for close to one-third of the world's scientists and engineers as well as R&D expenditures (Sagasti, Salomon et al., 1994; Graham and Dezhina, 2008). In 1991, it was pauperized overnight.

With severe economic crisis hitting Russia, no money was available to continue R&D funding, leading to shortages of lab supplies and months of unpaid wages (Ganguli, 2017*a*). Many scientists chose to to continue their careers in the United States, Israel, or Europe. By 1993, the Russian government estimated that there was a 35.2 percent decrease in the researchers working in higher education institutions (Graham and Dezhina, 2008).[4] In the early 2000s, with the economy recovering, observers still saw Russia's science and technology as its "major untapped resource" (Sher, 2000). Despite the USSR's scientific legacy, Russia's innovative performance remains astonishingly low, coining the term "Russian innovation paradox" (Gianella and Tompson, 2007). The explanations for such poor performance include the deterioration of human capital (Gaddy and Ickes, 2013), weak intellectual property rights protection (Aleksashenko, 2012), and territorial imbalances in access to world technologies through multinational corporations

[4]Little foreign help was targeted at R&D (Sher, 2000), yet the funding that was available through George Soros' program, which provided grants to over 28,000 Soviet scientists shortly after the end of the USSR, more than doubled publications on the margin, significantly induced scientists to remain in the science sector, and had long-lasting impacts (Ganguli, 2017*a*)

(Crescenzi and Jaax, 2017). Among many determinants of unsatisfactory innovative performance, scholars underscore two: weak demand for R&D in the economy and low government funding for R&D (Alexeev et al., 2013). In 2010, the Russian government decided to tackle both of them with Decree 218, aimed at generating demand for Russian R&D from private companies and relaxing their budget constraints on innovation investments.

4.3.2 Decree 218

In 2010, the Russian government issued Decree 218 called "Measures of state support for development of cooperation between Russian universities, research organizations and companies which implement complex projects for high-tech production." Its mechanism is similar to that of matching grants – one of the broadly used tools of R&D policy. The main feature of this tool is that manufacturing companies that implement projects can be the direct recipients of public funding that has been earmarked for universities. The company that implements the project pays for up to half of the R&D costs using the funds that it received from the government. It then conducts the project jointly with its university partner. The program was deemed as one of the most successful based on interviews with company managers (Simachev, Kuzyk and Feygina, 2014), interviews with universities (Uskov et al., 2018), and the assessment of progress based on the 2010–2013 waves (Dezhina and Simachev, 2013). In short, Decree 218 grants do seem to result in creation of new technologies that are purchased and implemented by winning companies.

Over 2010–2018, the winners of nine rounds were announced and 45.1 billion rubles (around 750 million USD) was allocated to them. The typical grant equaled 210 million rubles in 2010 (around 7 million USD). By the terms of the contract, companies had to co-invest funds matching at least 100% of the government subsidy in R&D. Winners that failed to implement the R&D project in accordance with the grant obligations are obliged to return the funds received from the government, sometimes with a fine. They could deduct the cost of R&D expenses they had already paid in case of force majeure during the R&D phase. Over the observed 2010–2016 time period, 1,946 companies have applied for the grant, and 202 have received it.

4.3.3 Data

The sample consists of companies that applied for a Decree 218 government grant over the 2010–2016 time period. The list of names and addresses of such companies is available on the Decree 218 website, together with the lists of winners of each wave of the grant. Furthermore, using the Kontur-Focus service that searches company details from official registries, I establish registration numbers for each company. Twenty percent of Decree 218 companies return multiple candidates in the Kontur-Focus database. For these, I employ record linkage based on name and address, and later check the industry of the candidate company to verify correct record linkage. Using the company registration number, I collect data about their date of registration, owner, industry, gross profits, returns on assets (ROA), returns on equity (ROE), sales, revenues, and fixed assets over the 2008–2016 time period from the SPARK database. Of 1,946 companies that applied for a grant, I was able to recover economic data for 1,237 companies. The oldest company in the sample was created in 1957, the youngest in 2016. Government procurement data for each company and year is collected through the ClearSpending database,[5] collected by the Civil Society Committee. The composition of Decree 218 applicants by application status and industry is presented in Table 4.1. On average, the company that applied for Decree 218 grant

[5] *ClearSpending* (2020)

at least once had a 17% chance of obtaining it. The majority of applications and winners were concentrated in manufacturing, technology and retail sectors. Yet the chances of winning a grant for companies operating in these industries were smaller then for companies in administration, real estate or agriculture.

Industry	**Loser**	**Winner**	**Share of Winners**
Administration	5	2	0.40
Agriculture	17	4	0.24
Arts & recreation	24	4	0.17
Construction	43	6	0.14
Education	3	0	0
Electricity & gas	8	1	0.12
Finance	1	0	0
Food service	2	0	0
Health	0	0	NA
ICT	42	10	0.24
Manufacturing	463	77	0.17
Mining	37	5	0.14
Other	4	0	0
Public Administration	15	1	0.07
Real Estate	23	8	0.35
Technology	204	39	0.19
Retail	122	20	0.16
Transportation	17	2	0.12
Water and Utilities	5	1	0.20
Total	1,035	180	0.17

Table 4.1: Summary Statistics: Application Decisions by Industry

Summary statistics for the main variables of interest are presented in Table 4.2. There is significant variation in economic outcomes of companies in the sample. Note that many companies in the collected sample have some economic outcomes missing in some years. In cases where I control for pretreatment economic outcomes, I employ a multiple imputation procedure (van Buuren et al., 2015) to fill the gaps in the raw data, together with identifiers of missingness (a dummy variable that is set to 1 if the observation is imputed, 0 otherwise) for each variable. This approach helps me to alleviate the failure of "missing at random" assumption. I do not impute outcome variables of interest, so for the approaches that require the balanced panel (Section 4.5.1), I remove the companies that have at least one missing observation.

Statistic	**N**	**Min**	**Max**	**Mean**	**St. Dev.**
log(Gross Profit)	6,696	6.908	25.725	16.607	2.812
log(Fixed Assets)	5,096	−6.908	23.712	13.607	3.706
ROA	8,118	−46.500	151.033	0.152	2.574
ROE	8,015	−232.500	832.000	0.337	10.953

Table 4.2: Summary Statistics (raw data)

Reassuringly, in the last year before the onset of the Decree 218 program, companies that won a grant in any wave of the program were similar to applicants that never won a grant on many characteristics (Table 4.3). Notably, however, winners had higher level of fixed assets.

	Losers	Winners	p-value
ROA	0.035	0.044	0.69
ROE	0.095	0.2	0.66
Gross Profit	$245 \cdot 10^6$	$97 \cdot 10^6$	0.56
Authorized Capital	$3.89 \cdot 10^9$	$11 \cdot 10^6$	0.63
Fixed Assets	$47 \cdot 10^6$	$311 \cdot 10^6$	0.04

Table 4.3: Winners and Losers Look Similar in 2009

4.3.4 Measuring political connections

Corporate political connections can take many forms and, consequently, require different approaches to measurement. The seminal paper of Fisman (2001) relies on opinions of consultants to detect if a company enjoys political connection to Suharto. Other studies proxy political connections with corporate political activism via contributing to campaigns (Akey, 2015; Claessens, Feijen and Laeven, 2008; Voth and Ferguson, 2008; Jayachandran, 2006), lobbying efforts (Sobel and Leeson, 2006), employing former or current politicians (Akcigit, Ates and Impullitti, 2018; Faccio, 2010; Nee and Opper, 2010; Canayaz, Martinez and Ozsoylev, 2015), having a member of management appointed by government (Cull et al., 2015), or coming from the same town/village/home district (Faccio and Parsley, 2009). Some papers rely on a combination of different measures (Eggers and Hainmueller, 2014; Acemoglu et al., 2016).

The approach presented in this paper is closest to Lamberova and Sonin (2018*a*), where the authors measured social ties as co-occurrence of members of predefined populations in general web pages through the news section of the most popular Russian search engine, Yandex. The populations of interest are owners of companies applying for Decree 218 government grants and members of the dacha cooperative "Ozero" that is comprised of Vladimir Putin's inner circle. I append the list of "Ozero" members with others – university friends, former colleagues, and relatives – whose biographies and connections to Vladimir Putin were featured in Novaya Gazeta, a newspaper famous for its journalistic investigations. The benefit of this approach is in the omission of joint mentions, in which any of the firm owners cited Vladimir Putin, a sitting president of Russia, or refer to him in his official capacity. Connections of Vladimir Putin and "Ozero" members were featured in Forbes Russia, Bloomberg, Novaya Gazeta, etc. All inner circle members formed their relationships with Vladimir Putin before his accession to power. The resulting list is conservative and not exhaustive. However, omission of inner circle members would bias my results downward, since the failure to detect connections to missing inner circle members means that some of the "unconnected" businessmen might in fact be connected to the inner circle member I don't observe. Many sources have noted that Vladimir Putin manages a lot of his business connections through the members of his inner circle (Dawisha, 2015; Morrison, 2019). Thus, it is straightforward to assess the political connection of a company/individual based on the connection to one of such people.

Instead of investigating the whole network of interactions, I focus on direct connections, as they were found to be the most important in previous research (Lamberova and Sonin, 2018*a*). I use both a binary measure of connection (1 if a company owner is connected to at least one of 24 people in the "inner circle" list, 0 otherwise) and the number of "Ozero" members the company owner is connected to.

4.4 Test of Implication 1: Political Connections and Grant Allocation

Though there is evidence that politically connected companies in Russia do typically receive preferential treatment.[6] By contrast, this model predicts that for the type of program analyzed here, the government will not be preferentail in awarding grants to more connected companies. Does this prediction hold up?

As shown in Table 4.4, in the last year before the R&D grant program was implemented (2009), politically connected companies differed were, on average, more profitable and had greater authorized capital and fixed assets.

	Unconnected	**Connected**	**p.value**
ROA	0.035	0.036	0.948
ROE	0.200	-0.588	0.006
Log(Gross Profit)	16.018	16.812	0.001
Authorized capital	14.251	15.279	0.002
Fixed Assets	12.469	13.659	0.002

Table 4.4: Politically Connected Companies were Different in 2009

Yet, the simple tabulation of award and connection statuses of companies in Table 4.5 suggests that, if anything, connected companies are slightly less likely to win the grant: 15.1% of connected applicants win the grant, and 18% of unconnected win a grant.

[6]See Treisman (2012, 2016, 2013); Yakovlev and Zhuravskaya (2004) and Lamberova and Sonin (2018*b*) for some examples.

	Unconnected	Connected
Loser	849	204
Winner	153	31

Table 4.5: Connections and Grant Awards

Nevertheless, the share of connected companies varies by industry. Thus, summarizing data with the inclusion of industry fixed effects suggests that politically connected companies are more likely to win the grant. Further inclusion of 2009 company economic outcomes reduced the magnitude of the effect, but it remains highly significant (Table 4.6).[7]

4.5 Test of Implication 2: Effects of government R&D grants of corporate performance

In this section, I test the second observable implication of the theoretical model, namely that politically connected companies benefit more from implementing R&D projects. I focus on the following outcomes: gross profit, fixed assets, sales, and revenues. Fixed assets are especially important, since purchase of new equipment or patents (behavior that is expected of winners of a 218 grant) should be reflected here. I also look at two indicators of corporate performance – Returns on Assets (ROA) and Returns on Equity (ROE).[8]

[7]Note, that due to missing values in the data the sample changes to those companies for which 2009 economic data is available.

[8]ROA indicates how effectively an organization is taking earnings advantage of its base of assets. ROE indicates how effectively the firm takes advantage of its shareholder equity (Total Assets − Liabilities). That is, if we see high ROE and low ROA, we can conclude that company is taking on a lot of debt

	Dependent variable:	
	Grant Received	
	(1)	(2)
Connected	0.534*** (0.185)	0.215* (0.117)
Constant	−4.388*** (0.586)	−2.113*** (0.402)
Industry FE	+	+
Econ Controls	-	+
Observations	11,925	4,878
Log Likelihood	−713.251	−1,457.744
Akaike Inf. Crit.	1,466.503	2,951.489

Note: *p<0.1; **p<0.05; ***p<0.01

Table 4.6: Political Connections and Grant Allocation

In order to investigate if receiving a government R&D grant results in better economic performance, I first consider a fixed effects model. The most common approach to the estimation of a fixed effects model with varying treatment timing takes the following form:[9]

$$Y_{it} = \alpha_t + w_i + \beta D_{it} + \theta X_i + \epsilon_{it} \tag{4.2}$$

where where Y_{it} is the outcome of interest, α_t is a time-fixed effect, w_i is a "group" fixed effect, D_{it} is a treatment indicator that is equal to one if company i is holds

[9]See Wooldridge (2005); Chernozhukov et al. (2013); Borusyak and Jaravel (2017); Goodman-Bacon (2018) and Athey and Imbens (2018).

a grant at time t and zero otherwise, X_i is a vector of observed characteristics, and ϵ_{it} is an error term.

Differentiating between effects of receiving a grant for connected and unconnected companies would require modifying Equation 4.2 in the following way:

$$Y_{it} = \alpha_t + w_i + c_i + \beta D_{it} + \gamma D_{it} * c_i + \theta X_i + \epsilon_{it} \tag{4.3}$$

where c_i is a "connected" fixed effect. Vector X_i is comprised of firm-level variables, namely, amount of authorized capital in 2009, year of registration, and 2009 economic outcomes: Log(Gross Profit), Fixed Assets, ROA, and ROE. Controlling for pretreatment economic outcomes should attenuate the endogeneity problem that arises from the fact that winning companies are more likely to be systematically different from losing companies.

Table 4.7 suggests that companies that win a government 218 grant at any time during 2010–2016 period, in general, have higher profits and fixed assets. Connected companies tend to have higher profits. Companies that have already won the grant (in the current or previous period) have higher fixed assets. Connected companies that have already won the R&D grant have much higher profits and fixed assets than unconnected winners.

While I control for pretreatment outcomes, this specification is still very vulnerable to omitted variable bias. Table 4.7 reports the robustness value for each specification, following the approach of Cinelli and Hazlett (2020) to sensitivity analysis. The robustness value shows how much of the residual variance the omitted variable would have to explain to reduce the absolute value of the effect by 100%. For example, in specification 1 of Table 4.7, the robustness value equals 0.037, meaning that unobserved confounders (orthogonal to the covariates) that explain more than 3.7% of the residual variance of both the treatment and the outcome are enough to reduce the absolute value of the effect size by 100%.

	Dependent variable:			
	log (Gross Profit)	ROE	ROA	log (Fixed Assets)
	(1)	(2)	(3)	(4)
Ever Won	0.189*** (0.069)	−0.161 (0.351)	0.090 (0.080)	−0.238** (0.106)
Connected	0.151** (0.064)	−0.476 (0.327)	−0.069 (0.075)	−0.093 (0.098)
Grant Received	−0.024 (0.117)	−0.545 (0.564)	−0.110 (0.129)	0.314** (0.158)
Received×Connected	0.718*** (0.236)	0.750 (1.163)	0.085 (0.267)	0.725** (0.312)
Constant	12.803 (8.227)	−62.067 (42.667)	−11.995 (9.744)	−25.719** (12.466)
Industry FE	+	+	+	+
Econ Controls	+	+	+	+
Observations	6,556	7,867	7,967	5,019
R^2	0.510	0.007	0.046	0.459
Adjusted R^2	0.508	0.003	0.042	0.456
Residual Std. Error	1.963	11.037	2.543	2.685
F Statistic	226.690	1.800	12.660	141.187
Robustness Value	0.037	0.0073	0.0036	0.032

Note: *p<0.1; **p<0.05; ***p<0.01

Table 4.7: Political Connections, Government R&D Grant and Economic Performance

Benchmarking the effect of the interaction coefficient of Won and Connected on the logarithm of Gross Profit against the logarithm of Gross Profit in 2008 for this specification suggests that the omitted variable would have to be at least twice as influential in order to reduce the effect to zero.

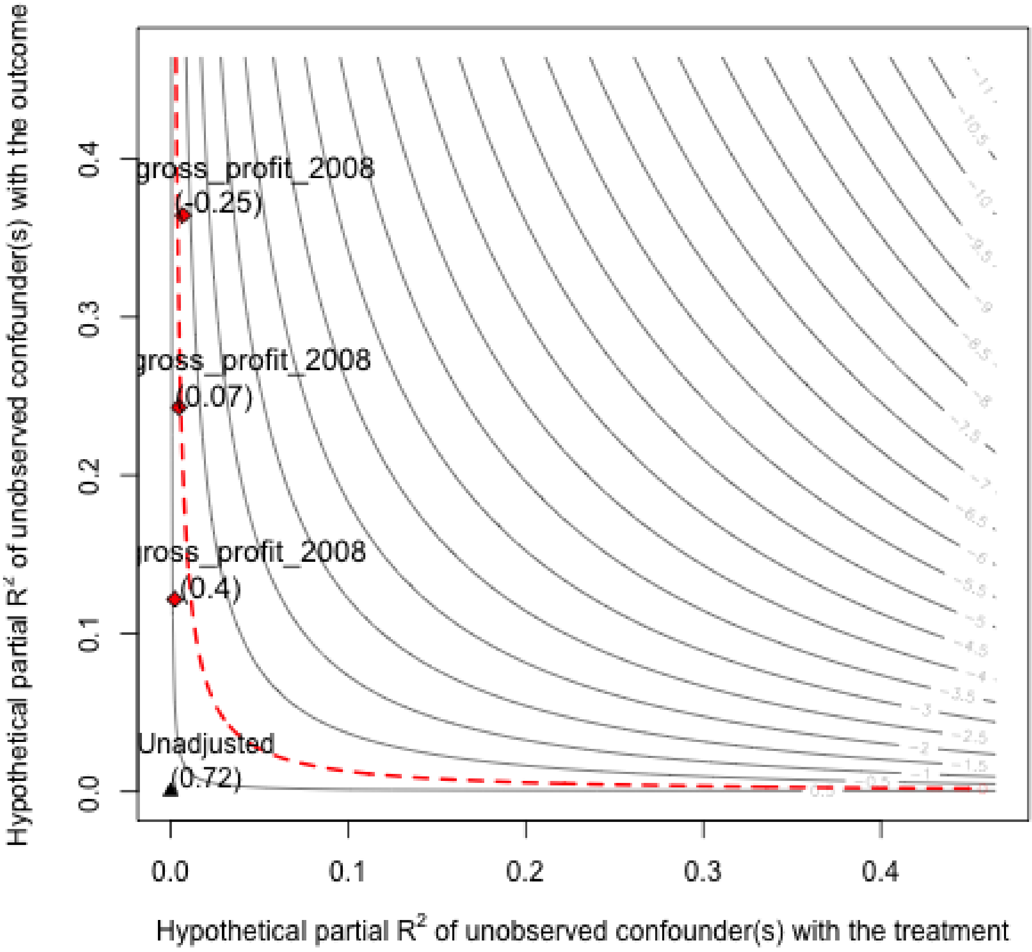


Figure 4.1: Benchmarking coefficient of interest against Log(Gross Profit 2008)

4.5.1 Trajectory balancing

In this section, I employ kernel-based trajectory balancing introduced by Hazlett and Xu (2018) since it tolerates time-varying confounders in order achieve the causal interpretation of the effects of government R&D grants on corporate performance. This method is an approach to the more general Synthetic Control Method (Abadie and Gardeazabal, 2003; Abadie, Diamond and Hainmueller, 2010; Cavallo et al., 2013). The intuition behind the synthetic control can be understood as follows: assume that there exists a set of omitted time-varying confounders and that some time-fixed linear combination of these confounders affects the outcomes of both the treated and control units. These confounders enter control units to different degrees. Then, weighting the control units to make their averaged pretreatment trend match that of the treated units replicates the combination of confounders that must be influencing the treated unit as well. So, with these weights on the control units, the time-varying confounders are differenced out. The Synthetic Control Approach approach relies on the Linearity in Prior Outcomes assumption. Hazlett and Xu (2018) relax this assumption and balance on the high-order "trajectory" of pretreatment outcomes rather than their period-wise average. It ensures that overall distributions of trajectories are similar between the treatment group and the reweighted control group.

The weights put on control units are chosen such that

$$\frac{1}{N_{tr}} \sum_{G_i=1} \phi(Y_{i,pre}) = \sum_{G_i=0} \phi(Y_{i,pre}), \tag{4.4}$$

and $\sum_{G_i=0} w_i = 1, w_i > 0$ for all i in the control group. The choice of ϕ is achieved through a similarity measure: a Gaussian kernel $k(Y_i, Y_j) = exp(-||Y_i - Y_j||^2/h)$. Then, under assumptions of conditional ignorabilty, linearity of pre-treatment outcomes in $\phi(Y_{i,pre})$, and feasibility of weights (the existence of non-negative weights that achieve kernel balancing), the ATT_t is calculated as follows:

$$\widehat{ATT}_t^k = \frac{1}{N_{tr}} \sum_{G_i=1} Y_{it} - \sum_{G_i=0} w_i Y_{it} \tag{4.5}$$

.

Since there are substantial number of pre-treatment outcomes to be balanced, achieving the balance on both level and dynamics proved to be different. Hazlett and Xu (2018) solve this problem by allowing an intercept shift for each unit. Before reweighting, the average outcome from period T1 to period T0 is subtracted from the original outcome for each unit, making the outcome of each treated or control unit mean zero in the pre-treatment period. Thus, we focus on the imbalance in dynamics but not levels. This assumption imposes the parallel trends assumption similar to the one that exists for difference-in-difference model. Figure 4.2 presents the trends of the logarithm of gross profits by connection status and group. Note that companies that won R&D grant at least once did it in different periods. However, we can see that the trends in profits were parallel before the start of the program, i.e. before any company had a chance to win a grant.

Table 4.8 presents the results of trajectory balancing inference for the effect of winning a 218 R&D grant for connected and unconnected companies and the corresponding difference in means. Standard errors are presented in parenthesis, and N is the number of observations used in estimation. As in the baseline model, connected companies benefit more from winning a grant in terms of profits relative to unconnected companies. In addition, they generate higher return on assets. Though the magnitude of the effect of winning a grant on fixed assets is much higher for the connected companies, it is statistically insignificant.

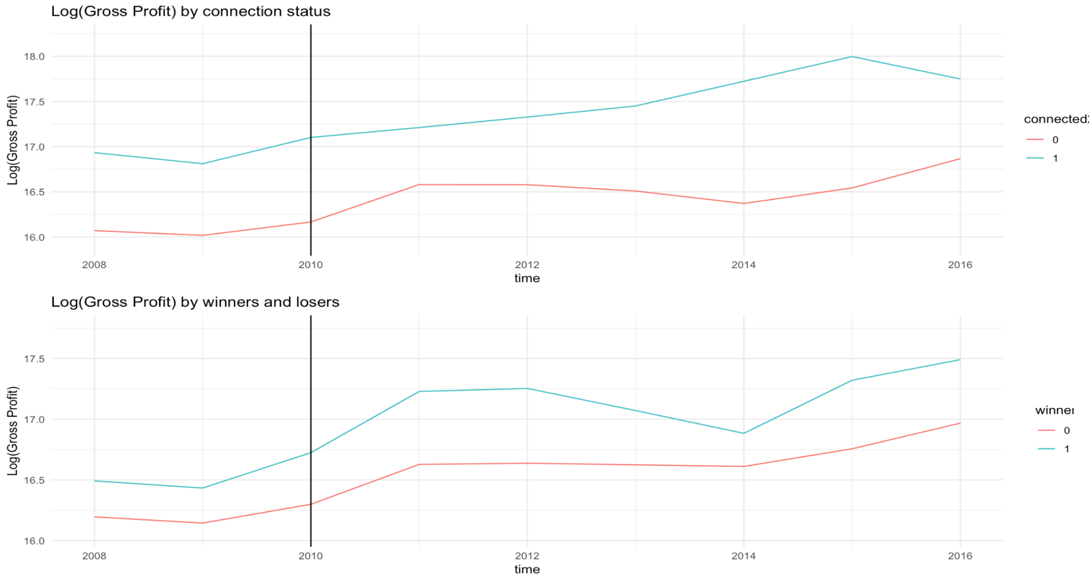


Figure 4.2: Raw Data: Log(Gross Profit) by group and connection status

	Log (Gross Profit)	**Fixed Assets**	**ROA**	**ROE**
Connected	0.53 (0.16); N=522	0.69 (0.66); N=567	0.17 (0.06); N=1071	-0.07 (0.09); N=1035
Unconnected	-0.74 (0.27); N=1908	0.15 (0.48); N=2016	0.01 (0.02); N=3897	-0.3 (0.2); N=3825
Difference	1.27 (0.31)	0.54 (0.82)	0.16 (0.06)	0.23 (0.21)

Table 4.8: Heterogenous treatment effects with trajectory balancing

Figure 4.3 presents the results of winning a 218 R&D grant for connected companies. The figures for fixed assets, ROA, and ROE are presented in Appendix A.14. Connected recipients of the Decree 218 saw sustained growth of thier gross profits relative to connected companies that were not awarded R&D grant.

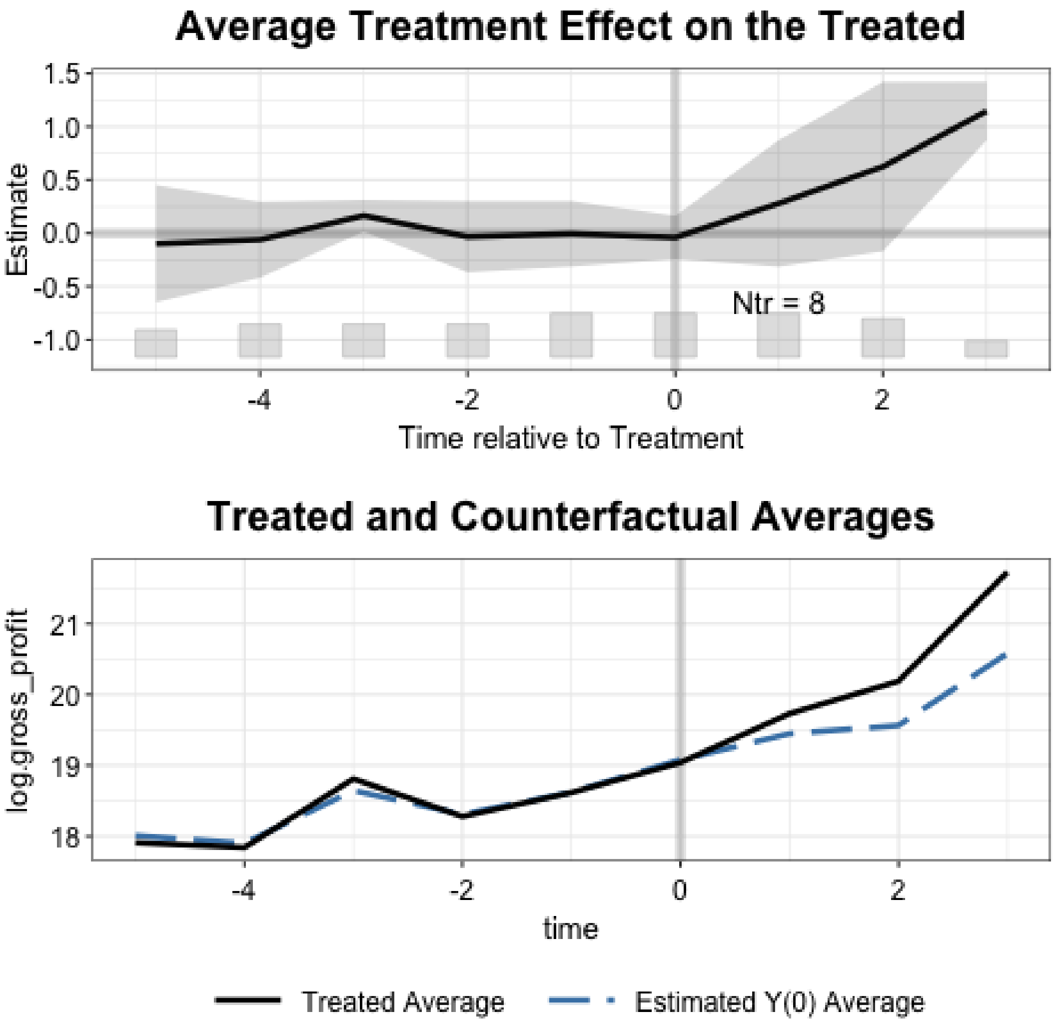


Figure 4.3: Log(Gross Profit) under trajectory balancing (connected firms)

Note that due to the varying time of treatment, there are several treatment groups, depending on the year the R&D grant was received. Figure 4.4 presents the balance on outcomes and the weights put on control units for connected companies that had their last pre-treatment period in 2014. After demeaning, the balance on pre-treatment measured of the outcome variable, log(Gross Profit), has improved for all pre-treatment periods and for the date of company registration. The later was included to account for the differences in corporate performance that are due to company age (and stage of its lifecycle). Note that many companies were effectively excluded from the comparison (the weights on 24 control units is 0) since their pre-treatment gross profits were not comparable to those of treated units.

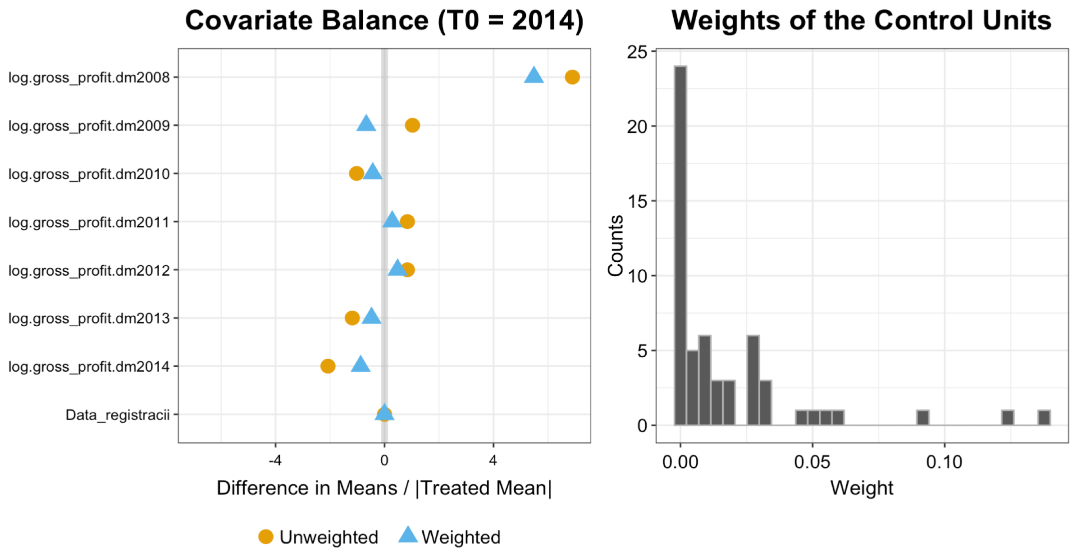


Figure 4.4: Balance for Log(Gross Profit (Connected Firms)

Figure 4.5 presents the results for unconnected firms. It is important to note that the pre-treatment trajectories of average logarithm of gross profit overlap for treated and counterfactual units. There are 33 treated units in the sample of unconnected companies. If anything, there is a (statistically insignificant) reduction in gross profits of companies in the first two years after receiving the R&D grant. The effect of winning it never becomes significantly greater than zero for the subgroup of politically unconnected applicants for the Decree 218 grant.

As before, the balance of the pre-treatment gross profits of treated and counterfactual observations is achieved trough re-weighting of control units. The resulting balance of pre-treatment de-meaned gross profits for companies that

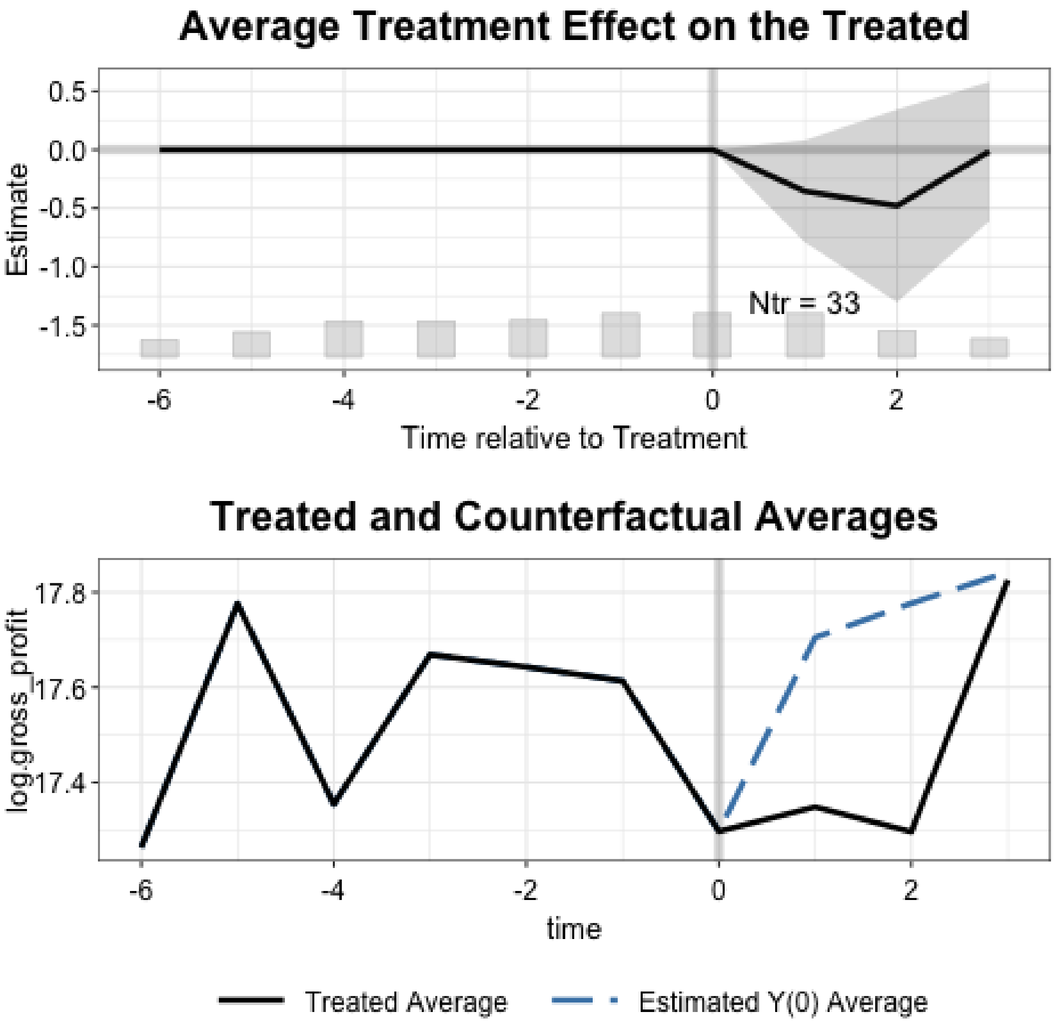


Figure 4.5: Log(Gross Profit) of unconnected companies under trajectory balancing

were first treated in 2015 is presented on Figure 4.6.

One can also examine the balance of treated and counterfactual units for treatment groups that received the grant in different years (see Figure 4.6). Note that the later the grant was received, the longer the trajectory that has to be balanced. For example, companies that received the grant in 2011 have to be

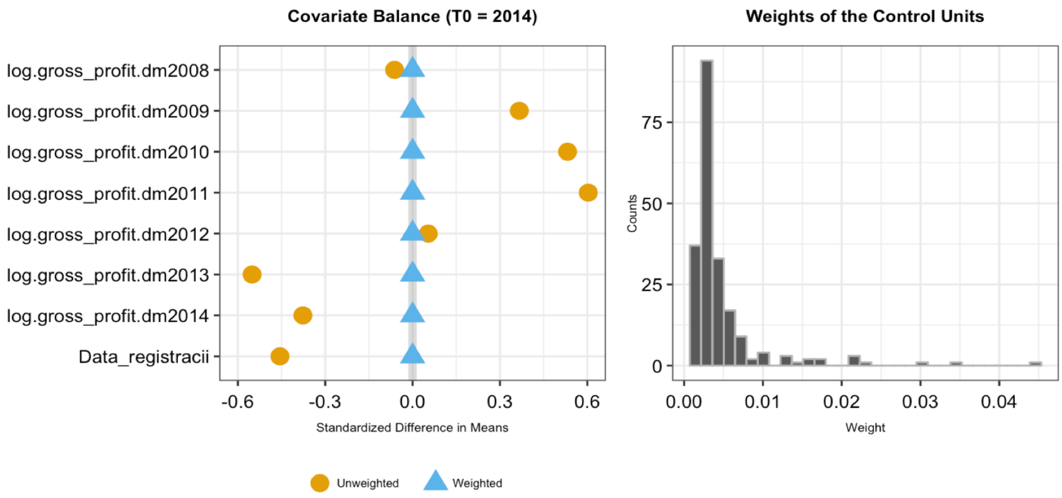


Figure 4.6: Balance and weights for Log(Gross Profit) (unconnected companies treated in 2015)

similar in their trajectories of gross profits to control companies over three years - 2008, 2009 and 2010. However, companies that were first treated in 2015 have to be similar to counterfactual in the trajectory of their gross profit over 2008-2014 time period.

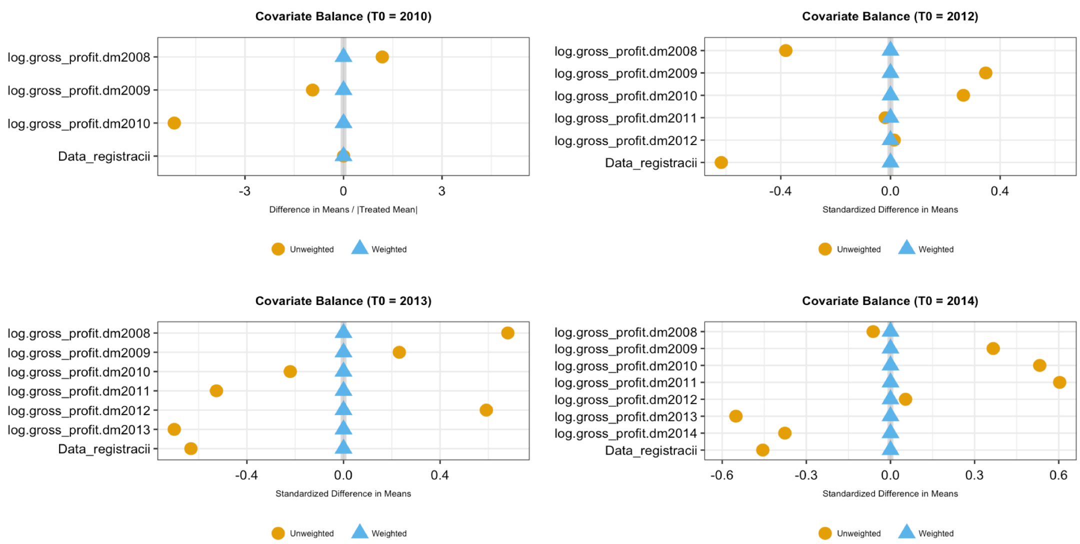


Figure 4.7: Balance for Log(Gross Profit) (unconnected companies)

Winning a grant has a lasting and positive impact on gross profits and returns on assets of connected companies, but not for unconnected ones. Similar heterogeneity of the effect of the grant is observed for the return on assets (see Figure A.27 of the Appendix). While the magnitude of the estimated ATT effect of the R&D grant on the fixed assets on connected companies was much greater than for the unconnected companies, the difference is not statistically significant (see Figures A.25 and A.26, respectively). The model presented in Section 4.2 suggests that connected companies are, indeed, expected to be more successful in implementing their R&D project and suggests a mechanism: providing more benefits to connected companies, conditional on the success of their R&D project. In absence of the data on the direct outcomes of the R&D project, such as information about patents filed or the volume of innovative goods produced, it is hard to test this mechanism directly. Section 4.6 provides indirect evidence by examining whether there is a change in allocation of government contracts to the winners of the Decree 218 grant after the initial assessment of progress on the R&D project.

4.6 Test of Implication 3: Government contracts as incentive

Conventional wisdom suggests that winning a government R&D grant should do little to increase the likelihood of obtaining government contracts, at least during the R&D phase (the first two years after receiving a grant). Figure 4.8 suggests that there is, indeed, no difference in the amount of government contracts received by firms that have won an R&D grant at any point compared to firms that applied for the grant at least once but lost.

By contrast, the theoretical model above predicts that grant winners should

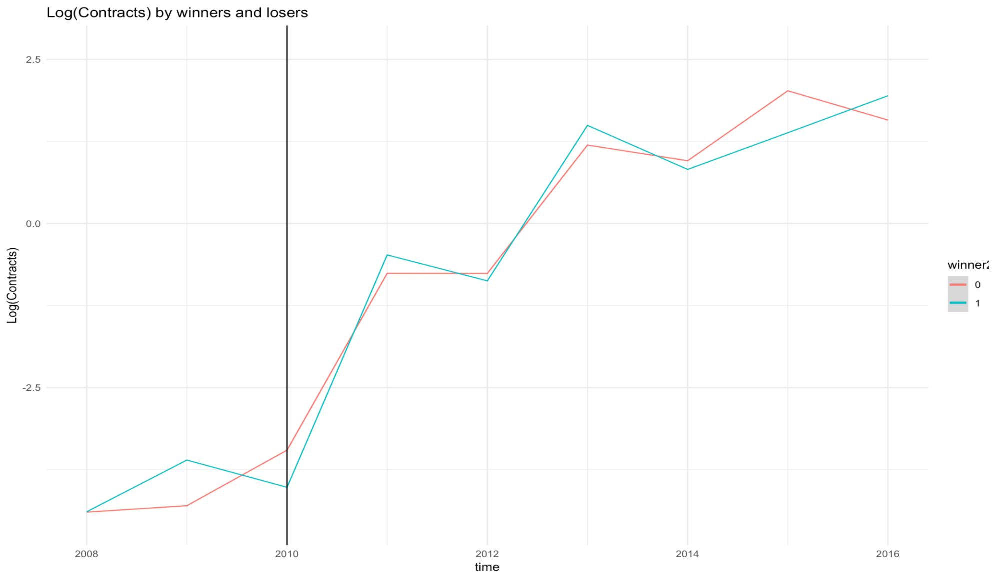


Figure 4.8: Log(Contracts) by group

receive additional government contracts during the assessment phase but only (or preferentially) if they are politically connected, a tool used by incumbents to inventivize connected companies to supply more effort.

To test this, I start with the difference-in-difference type model, described in Equation 4.3, where the outcome variable is logged volume of government contracts received by the company i in year t. Table 4.9 suggests that connected companies do, in general, receive more funds in the form of government contracts. In addition, they receive even more funds after winning a government R&D grant.

The robustness value reported in Table 4.9 suggests that unobserved confounders (orthogonal to the covariates) that explain more than 2.11% of the residual variance of both the treatment and the outcome are enough to reduce the absolute value of the effect size by 100%. Benchmarking the result against the logarithm of gross profit in 2008 suggests that the unobserved confounders should be more than three times more influential than it (Figure 4.9).

Next, I employ trajectory balancing to examine the link between the timing of

	Dependent variable:
	log(contracts)
Ever Won	−0.089 (0.204)
Grant Received	−0.171 (0.349)
Connected	0.497*** (0.189)
Grant Received×Connected	1.628** (0.723)
Constant	76.146*** (23.364)
Industry FE	+
Econ Controls	+
Observations	11,169
R^2	0.121
Adjusted R^2	0.119
Residual Std. Error	7.576 (df = 11138)
F Statistic	51.284*** (df = 30; 11138)
Robustness Value	0.02

Note: *p<0.1; **p<0.05; ***p<0.01

Table 4.9: Government contracts and R&D grant

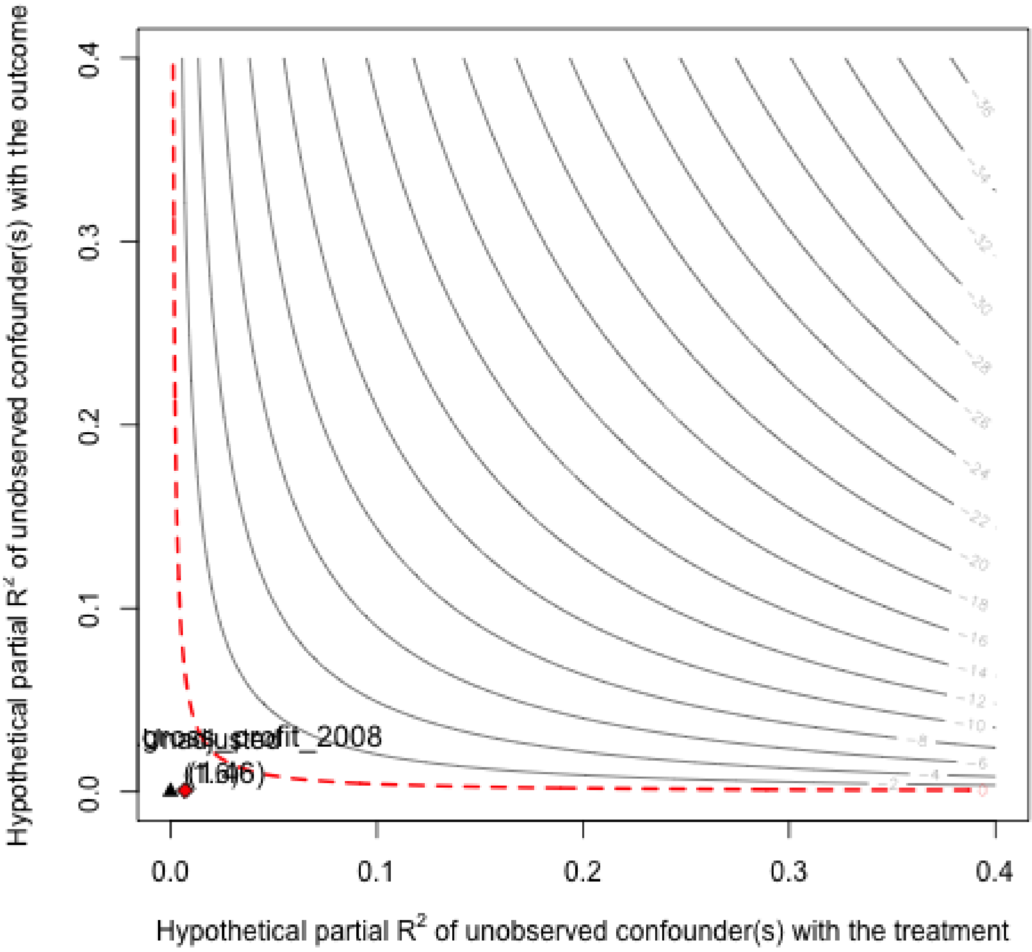


Figure 4.9: Benchmarking the effect of unobserved confounder against pre-program gross profits

the R&D phase of the grant and government contracts received by the company. The specification of trajectory balancing is the same as in Section 4.5.1. First, I examine the effect of winning a grant on the volume of government contracts for unconnected companies. Consistent with the predictions of the model, winning a government 218 R&D grant is not related to the volume of government contracts awarded to the company for unconnected firms (Figure 4.10).

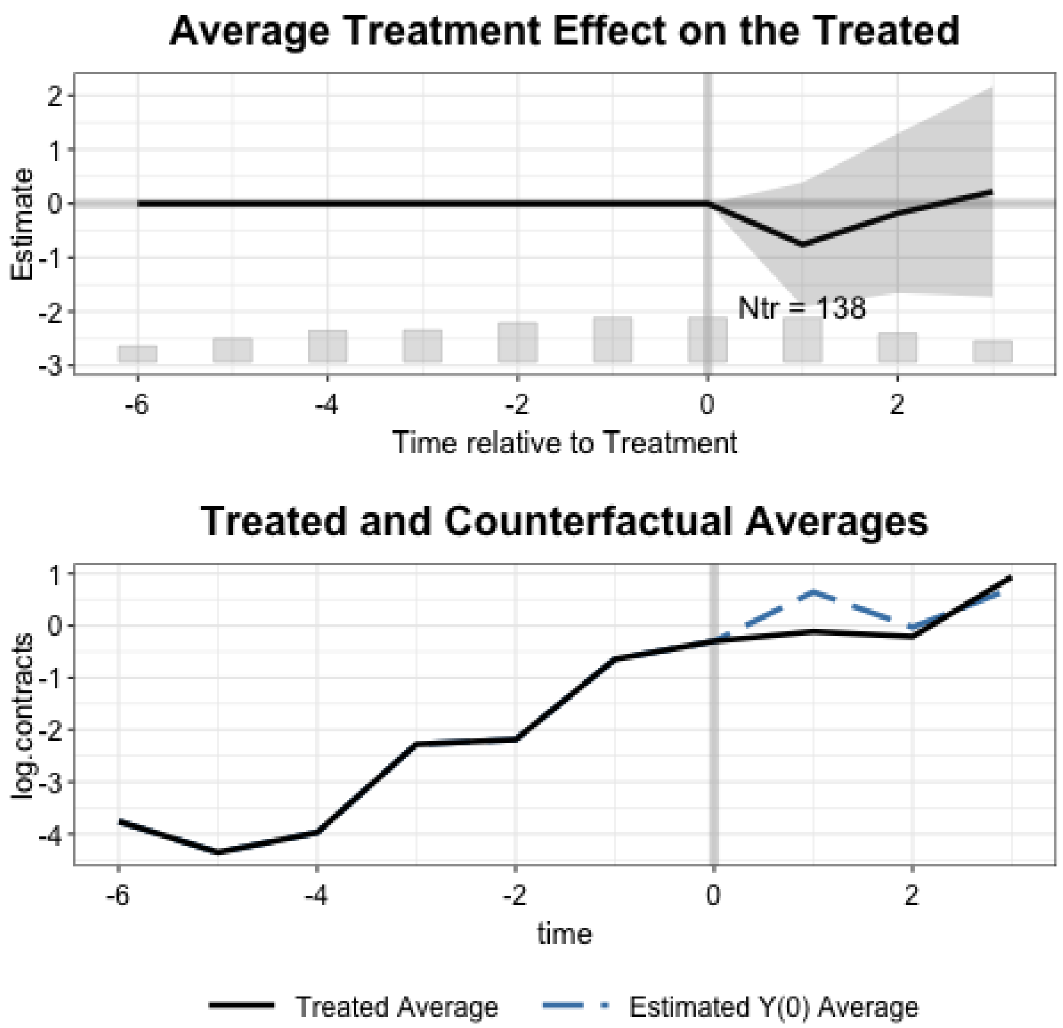


Figure 4.10: The effect of winning a 218 grant on the volume of received government contracts for unconnected firms

For the connected companies, however, the timing of increased government contracts received by the company coincides with assessment of progress of R&D project carried out under Decree 218 grant (Figure 4.11).

The empirical implications implied by the model in Section 4.2 all appear to hold.

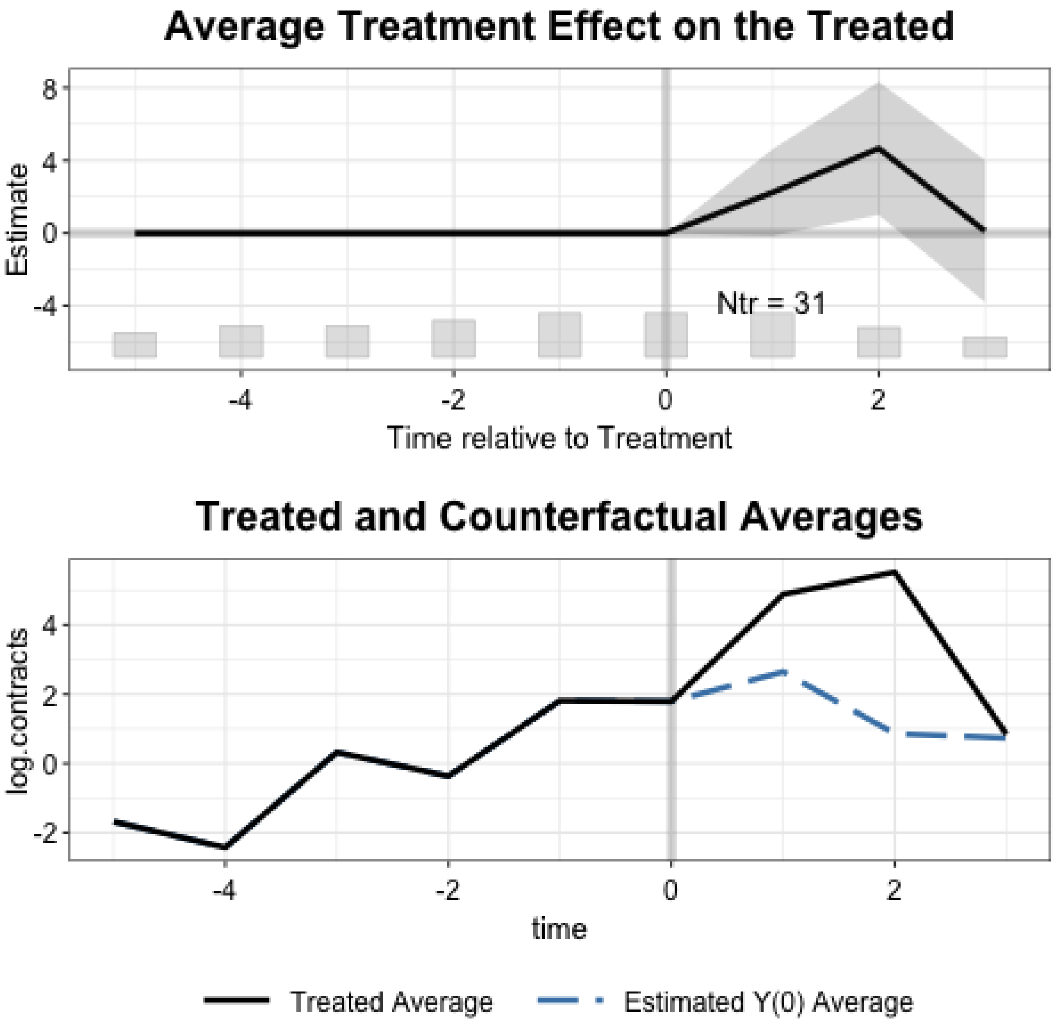


Figure 4.11: The effect of winning a 218 grant on the volume of received government contracts for connected firms

4.7 Discussion

This paper presents a model of regimes of government support for innovation, applied differentially to connected and unconnected companies that could promote technological development of the society and alleviate the threat of technological displacement of companies that belong to the loyal supporters of the incumbent.

The empirical analysis employed in this paper is consistent with the model. Yet it suffers from several important limitations: first, I was not able to obtain the direct measures of innovation - the number of patents files or the volume of innovative goods produced by the companies. Instead, I rely on the measures of corporate performance to assess the outcomes of implementation of R&D projects. Thus, one can suggest a possible alternative explanation: it is the government contracts, available to connected companies that drive better corporate performance than that of unconnected companies. Thus, under this view, the difference in performance is achieved regardless of R&D projects. While I cannot rule out this explanation, it is worth noting the timing of increased government contracts - they are granted in the period of evaluation of the progress of the R&D project. Furthermore, the growth in government contracts awarded to connected companies is a one-time development, and should not be able to explain the consistent growth of return on assets and profit enjoyed by connected recipients of 218 grant after the grant was awarded. The ATT of winning the Decree 218 grant on government contracts over the whole time period is statistically indistinguishable from zero (ATT= 1.824, 1.21). Next, even in the available data many companies have information on their economic outcomes missing for one or more years. Where possible, I employ multiple imputation and indicator variable for missingness to alleviate the problem. Yet this approach is not possible for the trajectory balancing approach, leaving it vulnerable to selection bias. The broad consistency of the trajectory balancing and baseline specifications helps to mitigate this problem.

At the same time, the proposed view helps to reconcile theoretical notion of government incentives to stifle innovation and the observation that many governments devote substantial funds and efforts to its promotion.

Furthermore, this view does not contradict empirical evidence that political connections improve corporate innovation, yet suggests a different mechanism that could explain their findings (Su, Xiao and Yu, 2019; Ovtchinnikov, Reza and Wu, 2019). In particular, Ovtchinnikov, Reza and Wu (2019) suggests that politically connected companies gain access to information that could help them limit the political risks of R&D investment. I hypothesize that it is willingness of the incumbent to act of the information about the success of R&D projects implemented by connected companies that incentivizes them to pour additional investment in R&D.

Such view is very intuitive, if one considers that government has repeated interactions with connected companies, but one-shot interaction with unconnected ones. Then conditioning future grant allocations on the success of the current project for the former provides additional incentives to them, but not to the unconnected companies. Thus, it is the information available to the incumbent that helps to explain the difference in the impact of government R&D grant on the economic outcomes of politically connected and unconnected companies.

4.7.1 Conclusion

Technological progress is an important factor in economic development, yet it can be a destabilizing force, upending the existing balance of power in the economy. Such changes can be unwelcome to the government that would like to preserve the existing status quo. However, blocking technological development is costly as it harms economic growth. In this paper, I show that the incumbent can support technological development of all companies in the economy, while assuring technological advantage of loyal companies.

Unlike pork-barrel forms of favoritism that are often illustrated in the literature, government support of innovation in the form of co-sponsoring corporate R&D project requires some efforts on the part of receiving company so that it actually obtains technological advantage. In order to assure technological advantage of companies that belong to loyal individuals, government can provide additional benefits to such companies conditional on success of realization of their R&D project. For example, it can channel greater volume of government contracts to such firms.

In this paper, I have demonstrated that politically connected companies are more likely to obtain government R&D grants. Furthermore, they benefit more from the grant, generating higher profits and return on assets, compared to unconnected companies. I further find evidence that connected companies that carried out the R&D project under Decree 218 grant obtain greater volume of government contracts during the assessment of progress of the R&D project.

CHAPTER 5

Conclusion

In this dissertation, I attempt to advance the study of the political economy of technological development. I tackle a general question – why do some leaders devote significant funds to fostering innovation even though such investments are risky, less visible to the public than many other options, and typically bear fruit only after the incumbent has already left office? I provide several explanations and explore the economic consequences of political incentives that shape government R&D policy. My dissertation contributes to the scholarly discussion in several ways.

First, it speaks to the literature on the political economy of technological development (Mokyr, 1992*b*,*a*; Acemoglu and Robinson, 2006*b*). Unlike the majority of existing works in this field that focus on political incentives to stifle innovation, I examine incentives that drive political elites to support it: competence signaling, rent seeking, and channeling technological development to loyal supporters.

Second, it speaks to the literature on the effect of government R&D policies (Akcigit, Baslandze and Stantcheva, 2016; Guceri and Liu, 2017; Akcigit, Ates and Impullitti, 2018; Acemoglu et al., 2016; Moser, 2005; Kremer and Williams, 2010; Moser and Nicholas, 2013). Unlike these studies that take government policy as a given, I focus on the set of political incentives that shape the impact of such policy.

Finally, it speaks to the emerging literature on the role of political connection in firm innovation. The role of political connections seems to depend on the context of the country in which the company operates. Unlike Akcigit, Ates and Impullitti (2018), I find that political connections have a positive impact of corporate innovation. While Su, Xiao and Yu (2019) and Ovtchinnikov, Reza and Wu (2019) find that connected companies generate more innovation due to access to government grants and information, respectively, I argue that political connections in Russia have an additional positive impact on recipients of government R&D grants.

APPENDIX A

Additional materials

A.1 Conditional Independencies for Cross-Country Analysis

1.$Approve \perp Approve.l2|Approve.l, RD.l, RD.l2, Volatility$
2.$Approve \perp Approve.l2|Approve.l, Country, GDP, Polcomp, RD.l, Volatility$
3.$Approve \perp Approve.l2|Approve.l, Country, GDP, Polcomp, RD, Volatility$
4.$Approve \perp RD.l|Approve.l, Country, GDP, Polcomp, RD, Volatility$
5.$Approve \perp RD.l2|Approve.l2, Country, GDP, Polcomp, RD.l, Volatility$
6.$Approve \perp RD.l2|Approve.l, Country, GDP, Polcomp, RD.l, Volatility$
7.$Approve \perp RD.l2|Approve.l, Country, GDP, Polcomp, RD, Volatility$
8.$Approve.l \perp GDP|Country, RD.l, RD.l2$
9.$Approve.l \perp GDP|RD.l, RD.l2, Volatility$
10.$Approve.l \perp GDP|Approve.l2, RD.l, Volatility$
11.$Approve.l \perp Polcomp|Country$
12.$Approve.l \perp Polcomp|Volatility$
13.$Approve.l \perp RD.l2|Approve.l2, RD.l, Volatility$
14.$Approve.l2 \perp GDP|Country, RD.l, RD.l2$
15.$Approve.l2 \perp GDP|RD.l, RD.l2, Volatility$
16.$Approve.l2 \perp Polcomp|Country$
17.$Approve.l2 \perp Polcomp|Volatility$
18.$Approve.l2 \perp RD|Approve.l, GDP, Polcomp, RD.l$
19.$Approve.l2 \perp RD|Approve.l, Country, RD.l, RD.l2$
20.$Approve.l2 \perp RD|Approve.l, RD.l, RD.l2, Volatility$
21.$GDP \perp Volatility|Approve.l2, Country, RD.l2$
22.$GDP \perp Volatility|Country, RD.l, RD.l2$
23.$Polcomp \perp RD.l|Approve.l2, RD.l2$
24.$Polcomp \perp RD.l|Volatility$
25.$Polcomp \perp RD.l|Country$
26.$Polcomp \perp RD.l2$
27.$Polcomp \perp Volatility|Country$
28.$RD \perp RD.l2|Approve.l2, GDP, Polcomp, RD.l, Volatility$
29.$RD \perp RD.l2|Approve.l, GDP, Polcomp, RD.l$
30.$RD \perp Volatility|Approve.l, Country, RD.l, RD.l2$
31.$RD \perp Volatility|Approve.l, GDP, Polcomp, RD.l$
32.$RD.l \perp Volatility|Approve.l2, RD.l2$
33.$RD.l2 \perp Volatility$

Figure A.1: List of Conditional Independencies

A.2 Survey Vignettes

- **Treatment 1.**

  A. Smith is 48 years old. He graduated from MIT with a degree in physics and subsequently attended Yale Law School, where he graduated with honors. His budget prioritizes government support for research and development. Some of the prioritized areas include research funding to universities and laboratories, and additional funding to companies involved in creation of new technologies. He believes that, in 10-12 years, these investments would shift American companies to the new technological frontier, and American citizens would enjoy prosperity and a higher quality of life. A. Smith is married and has three children.

  R. Myerson is 45 years old. He studied economics at the University of Chicago and then received his PhD in economics from Harvard. His budget prioritizes education spending. Some of his policies are focused on promoting student achievement and ensuring equal access. He believes that increased investment in education would secure the prosperity, health and security of the American people, and bolster American competitiveness through increased human capital.

- **Treatment 2.**

  A. Smith is 48 years old. He graduated from MIT with a degree in physics and subsequently attended Yale Law School, where he graduated with honors. His budget prioritizes government support for research and development. Some of the prioritized areas include research funding to universities and laboratories, and additional funding to companies involved in creation of new technologies. He believes that, in 10-12 years, these investments would shift American companies to the new technological frontier, and American citizens would enjoy prosperity and a higher quality of life. A. Smith is married and has three children.

R. Myerson is 45 years old. He studied economics at the University of Chicago and received his PhD in economics from Harvard. His budget prioritizes government support for innovation. His main goal is to spur commercialization of ideas by lowering the cost of managing changing technologies and bringing them to market. He believes that in 3-4 years these investments would shift American companies to the new technological frontier, and American citizens would enjoy prosperity and higher life quality.

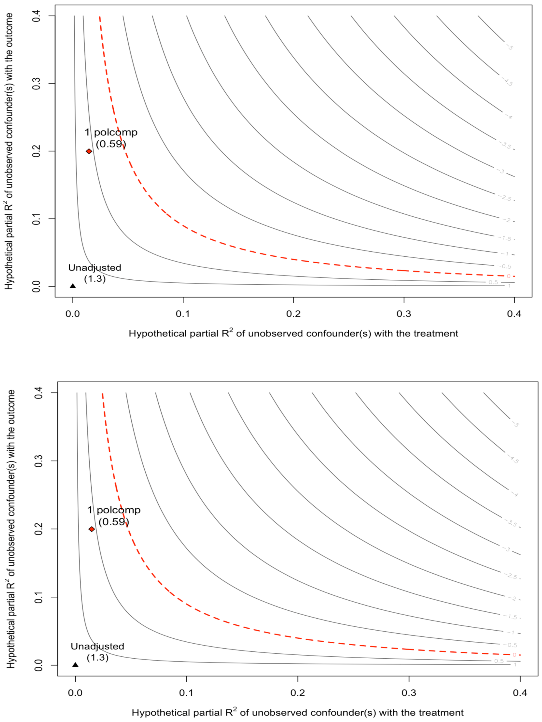
- **Treatment 3.**

A. Smith is 48 years old. He graduated from MIT with a degree in physics and subsequently attended Yale Law School, where he graduated with honors. His budget prioritizes government support for research and development. Some of the prioritized areas include research funding to universities and laboratories, and additional funding to companies involved in creation of new technologies. He believes that, in 10-12 years, these investments would shift American companies to the new technological frontier, and American citizens would enjoy prosperity and a higher quality of life. A. Smith is married and has three children.

R. Myerson is 45 years old. He studied economics at the University of Chicago and then received his PhD in economics from Harvard. His budget prioritizes infrastructure spending. He is committed to repairing and rebuilding aging infrastructure and improving transportation system. He believes that increased investment in infrastructure would secure the prosperity and security of the American people, and that American companies would and bolster American competitiveness.

A.3 Bias contour of t-value plot for three models of effect of R&D expenditures (as a share of budget) on popular approval of the government.

(a) Total Effects of education Expenditures



(b) Direct Effect of education Expenditures

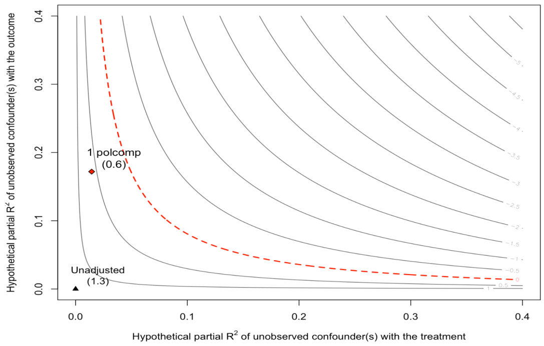


Figure A.2: Bias contours of t-value

A.4 Structure of block randomization

	Democrat	**Republican**	**Independent/ No Answer**
R&D vs Education	Smith-T, Meyerson-C;	Smith-T, Meyerson-C;	Smith-T, Meyerson-C
	Meyerson-C, Smith-T	Meyerson-C, Smith-T	Meyerson-C, Smith-T
	Meyerson-T Smith-C	Meyerson-T, Smith-C	Meyerson-T, Smith-C
	Smith-C, Meyerson-T	Smith-C, Meyerson-T;	Smith-C, Meyerson-T
R&D vs Infrastructure	Smith-T, Meyerson-C	Smith-T, Meyerson-C	Smith-T, Meyerson-C
	Meyerson-C, Smith-T	Meyerson-C, Smith-T	Meyerson-C, Smith-T
	Meyerson-T, Smith-C	Meyerson-T, Smith-C	Meyerson-T, Smith-C
	Smith-C, Meyerson-T	Smith-C, Meyerson-T	Smith-C, Meyerson-T
R&D vs Short-term Innovation	Smith-T, Meyerson-C;	Smith-T, Meyerson-C	Smith-T, Meyerson-C
	Meyerson-C, Smith-T	Meyerson-C, Smith-T	Meyerson-C, Smith-T
	Meyerson-T, Smith-C	Meyerson-T, Smith-C	Meyerson-T, Smith-C
	Smith-C, Meyerson-T	Smith-C, Meyerson-T	Smith-C, Meyerson-T

Table A.1: Blocks in MTurk Survey

	Yandex.Tolokers
	Smith-T, Myerson-C
R&D vs Education	Myerson-C, Smith-T
	Myerson-T, Smith-C
	Smith-C, Myerson-T;
	Smith-T, Myerson-C;
R&D vs Infrastructure	Myerson-C, Smith-T
	Myerson-T, Smith-C
	Smith-C, Myerson-T;
	Smith-T, Myerson-C;
R&D vs Short-term Innovation	Myerson-C, Smith-T
	Myerson-T, Smith-C
	Smith-C, Myerson-T;

Table A.2: Blocks in Yandex.Toloka Survey

A.5 Survey results for Full US and Russian samples

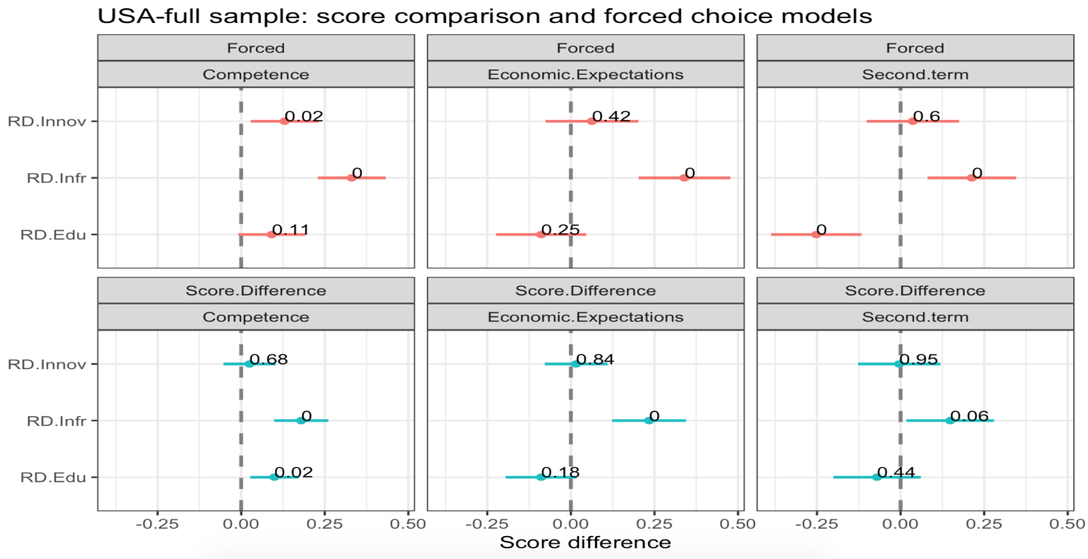


Figure A.3: Survey Results: Full US Sample

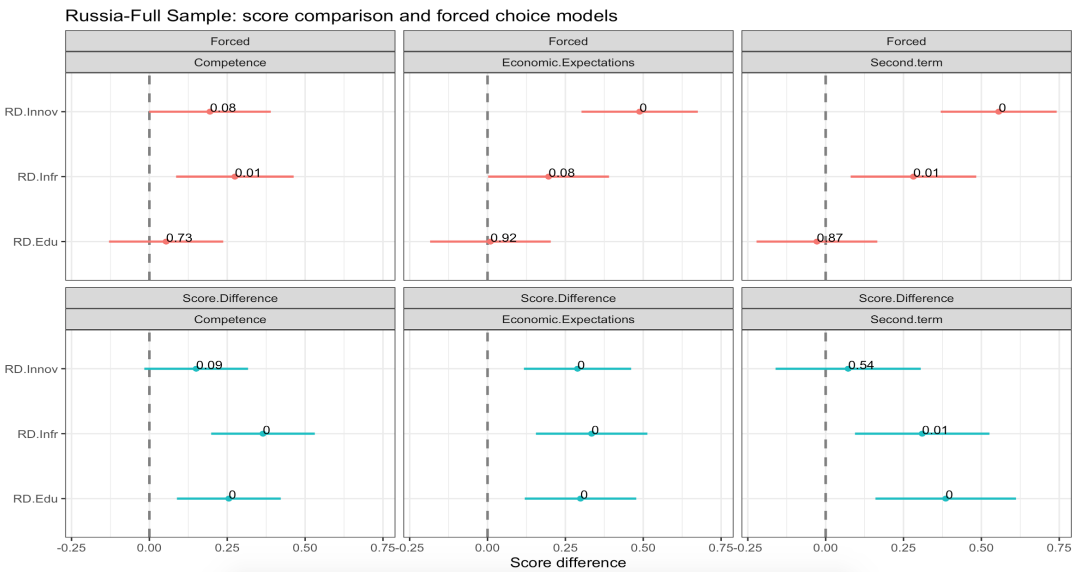


Figure A.4: Score comparison and Forced choice for the full Russian sample

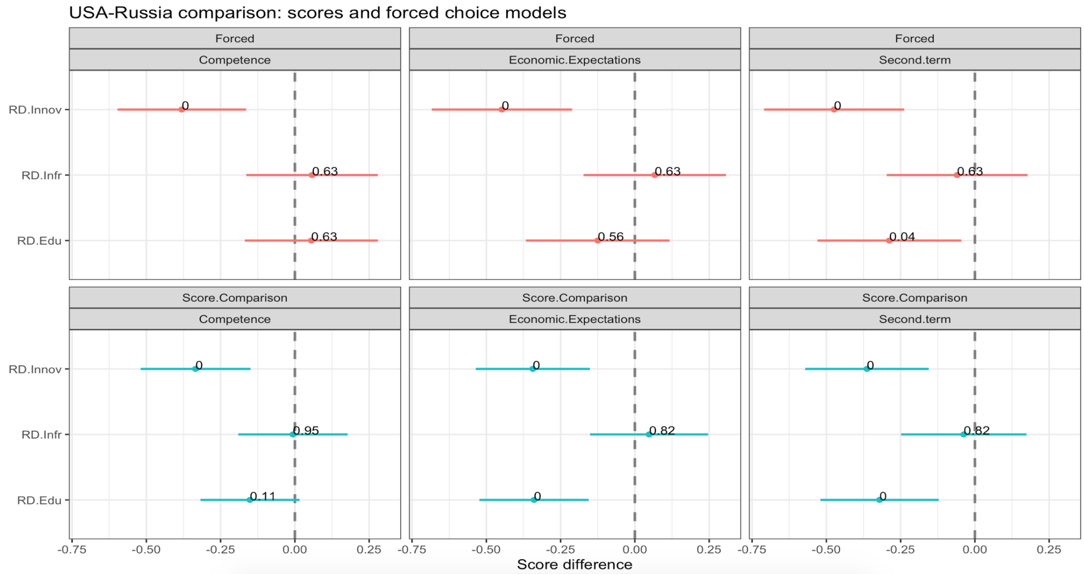


Figure A.5: Forced choice and score difference comparison for US and Russian results: Full sample

A.6 Score Distributions for Attentive samples

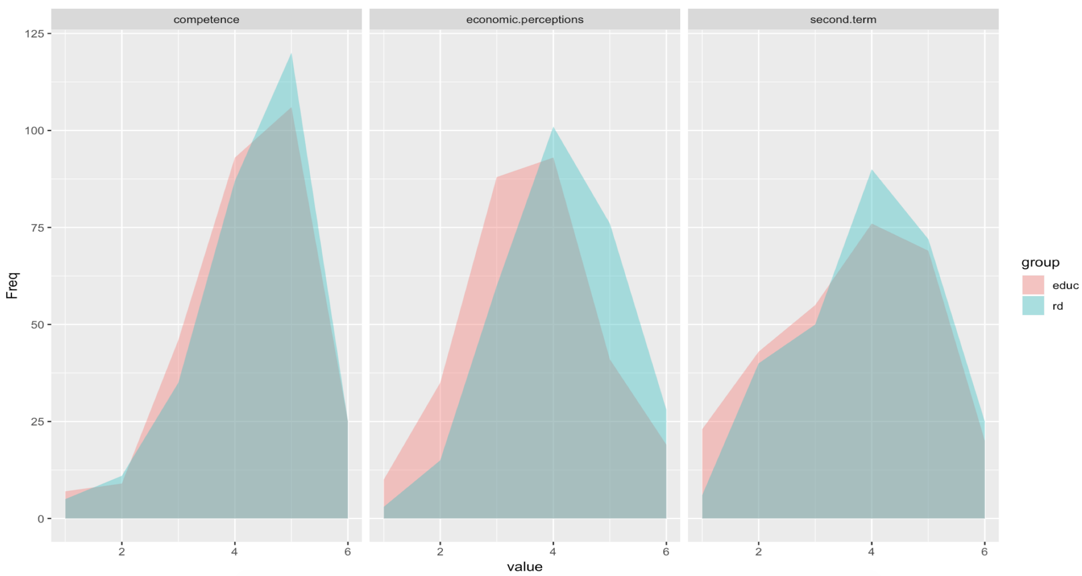


Figure A.6: Russian Attentive sample: pro-R&D vs pro-Education scores

How likely are you to support A. Smith over R. Myerson for a second term?					
6: Very Likely	5: Moderately Likely	4: Slightly Likely	3: Slightly Unlikely	2: Moderately Unlikely	1: Very Unlikely
You have higher expectations from A.Smith's policy compared to R.Myerson's policy					
6: Strongly Agree	5: Agree	4: Somewhat Agree	3: Somewhat Disagree	2: Disagree	1: Strongly Disagree
Comparing the competence of A. Smith and R. Myerson, I find that A. Smith's competence is					
6: Far Above A. Smith's	5: Moderately Above A. Smith's	4: Slightly Above A. Smith's	3: Slightly Below A. Smith's	2: Moderately Below A. Smith's	1: Far Below A. Smith's

Table A.3: Questions for forced choice, US survey

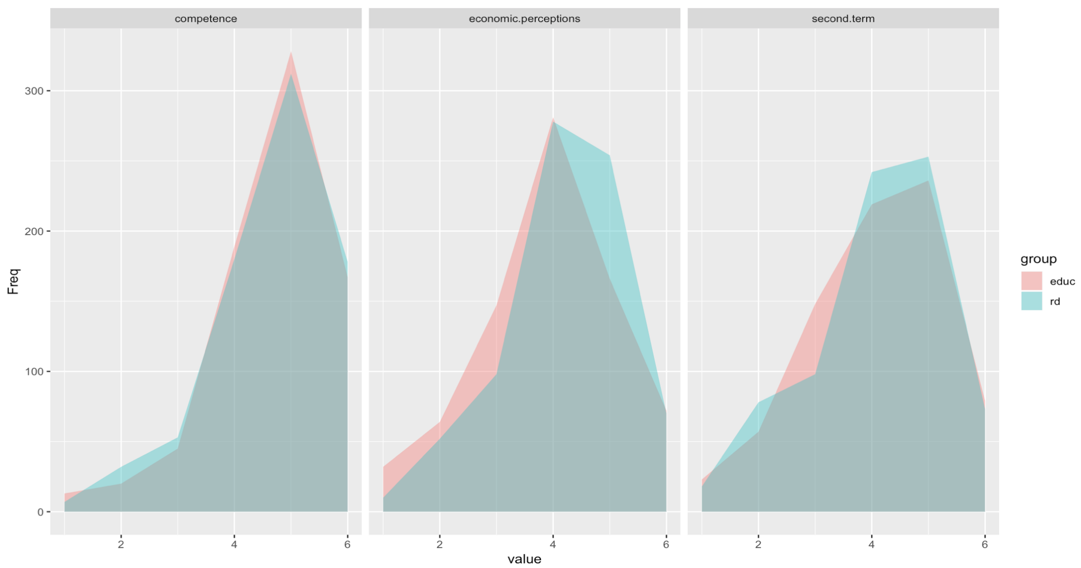


Figure A.7: US Attentive sample: pro-R&D vs pro-Education scores

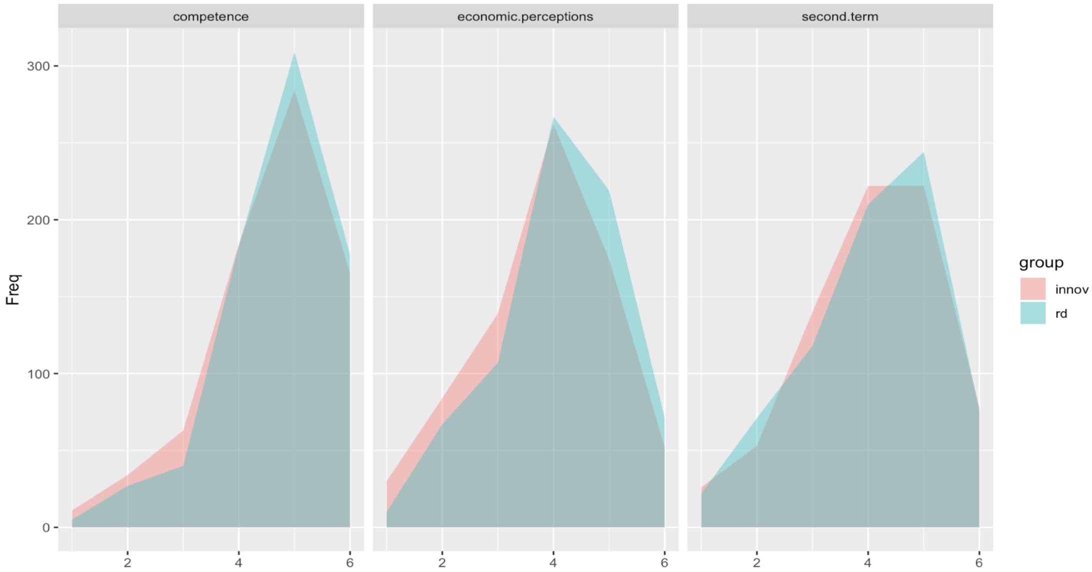


Figure A.8: US Attentive sample: R&D vs Innovation

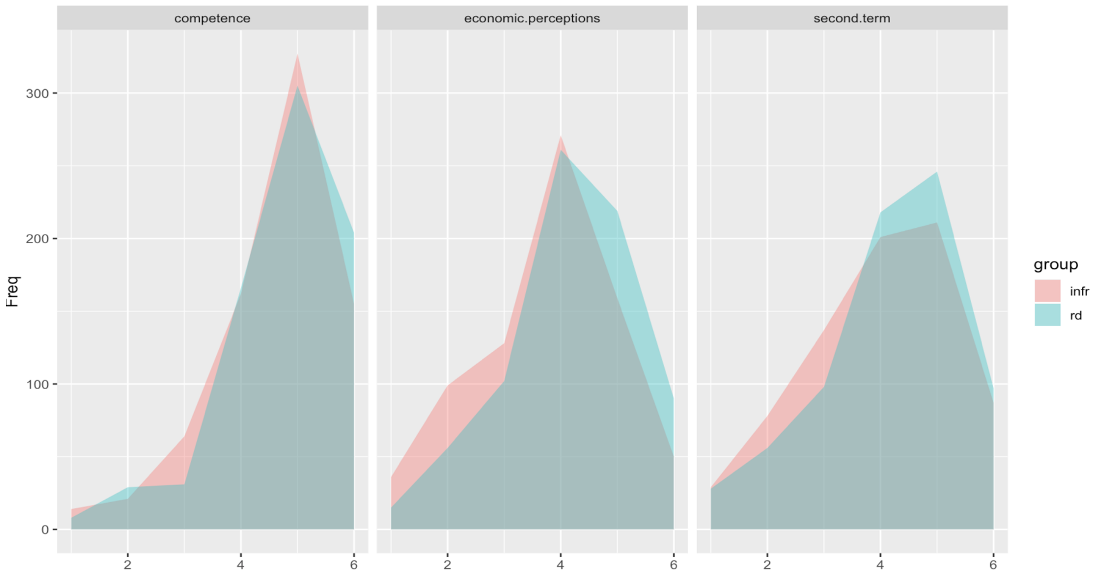


Figure A.9: US Attentive sample: R&D vs Infrastructure

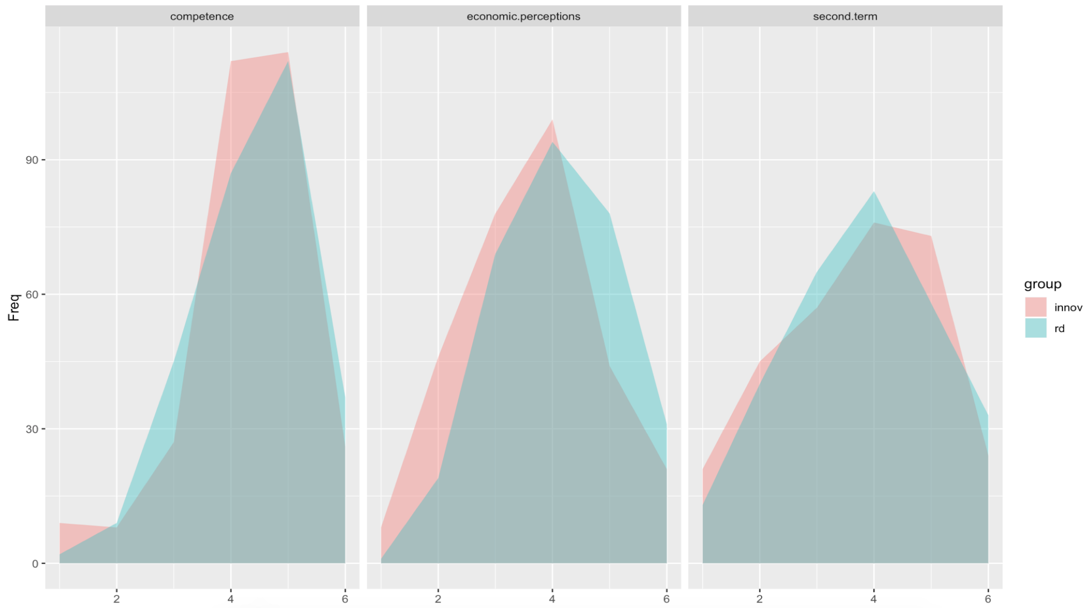


Figure A.10: Russia Attentive sample: R&D vs Innovation

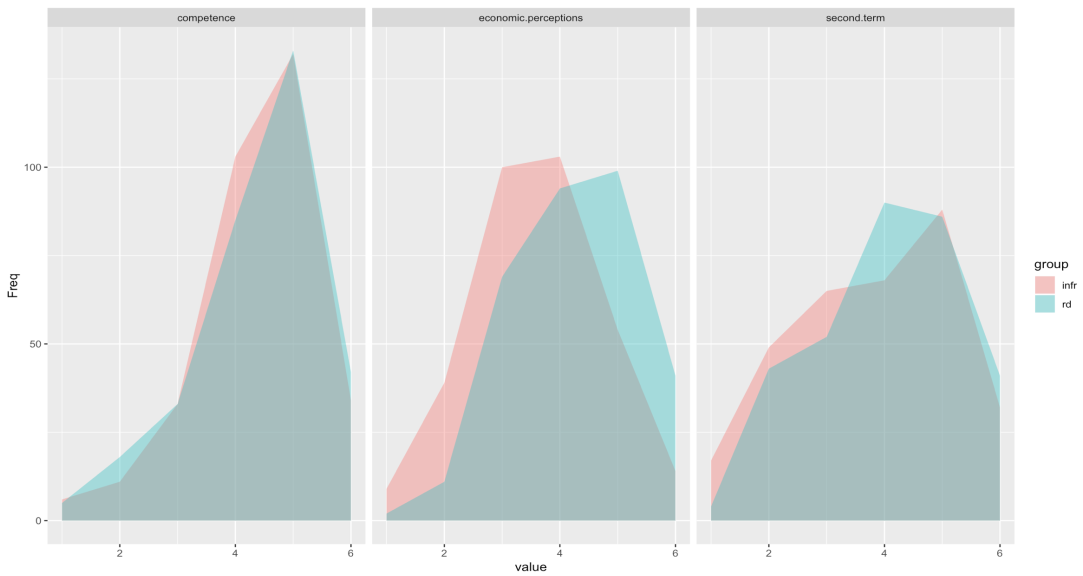


Figure A.11: Russia Attentive sample: R&D vs Infrastructure

A.7 Survey Results in sub-samples

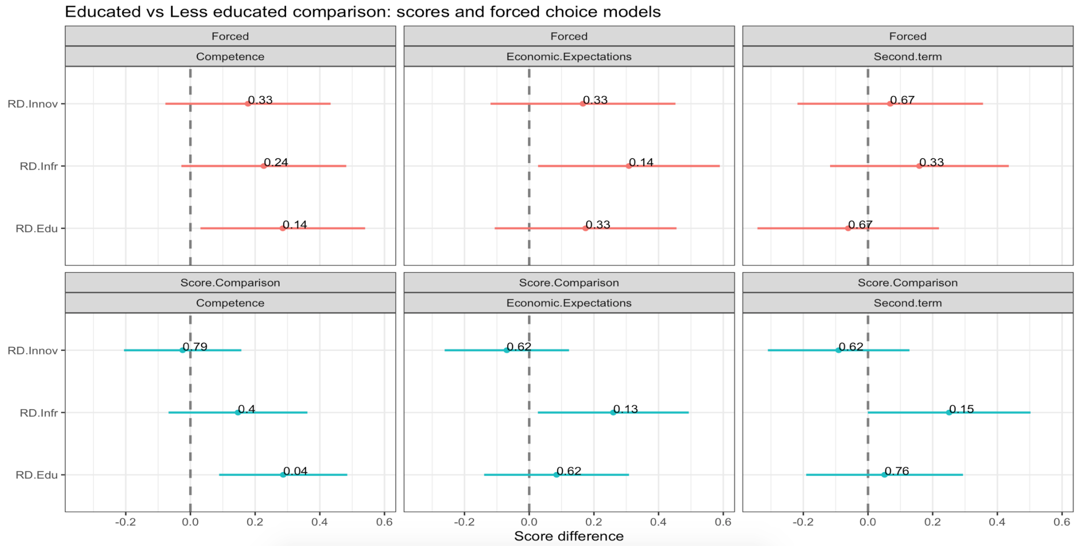


Figure A.12: Difference in scores assigned by more educated and less educated respondents, Attentive US sample

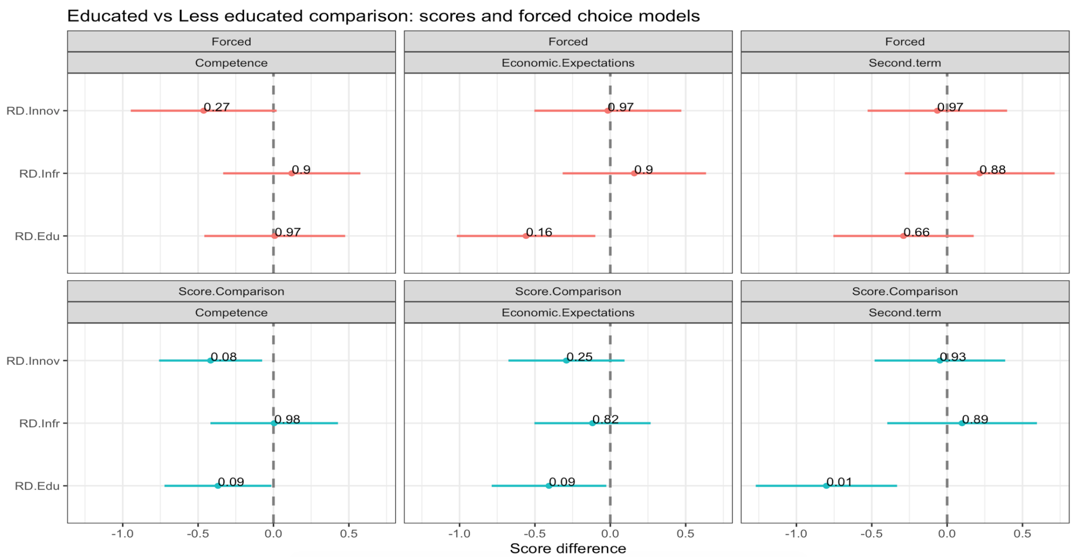


Figure A.13: Difference in scores assigned by more educated and less educated respondents, Attentive Russian sample.

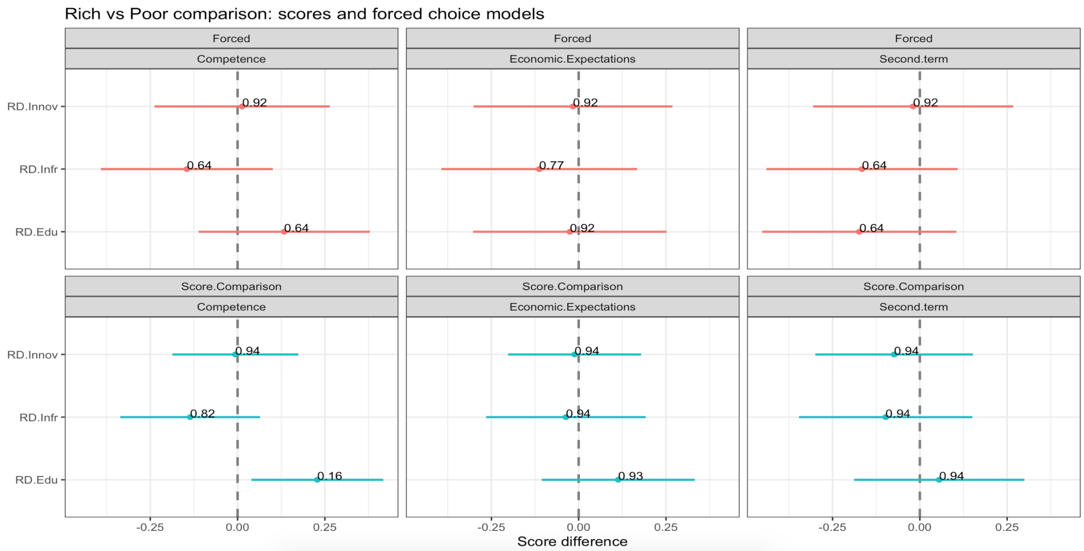


Figure A.14: Difference in scores assigned by more wealthy and less wealthy respondents, Attentive US sample

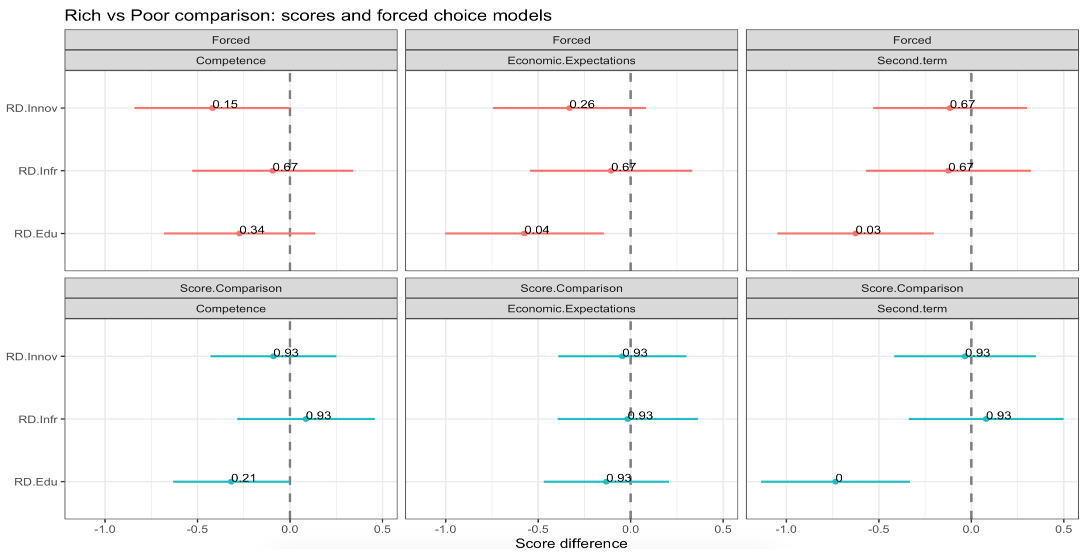


Figure A.15: Difference in scores assigned by more wealthy and less wealthy respondents, Attentive Russian sample.

A.8 Examples of "Signalling" Patents

Patent Num	Patent Name	Technology
RU2062143	A rigging for production of methanol	The application of this technology would lead to destruction of the surrounding area of up to hundreds of square kilometers.
RU2265585	Technology of production of methanol and other aliphatic spirits	The production of methanol and other aliphatic spirits with such method is proved impossible
RU2181622	A method of natural gas oxidation	The description of technology doesn't include any numbers or proportions. Essentially, patent claims only that there exists an unspecified method of natural gas oxidation
RU2282612	The method of production of liquid oxygenates by natural gases conversion and the equipment for its' conduction	Implies a technological reaction that is impossible due to physical parameters of mentioned substances
RU2205172	The method of production of methanol	Describes a technology that allows to achieve parameters 5-7 times worse than mentioned in a patent

Table A.4: Examples of "Signalling" Patents

A.9 Government Accountability and Patenting Efficiency

	Dependent variable:			
	rd_efficiency			
	(1)	(2)	(3)	(4)
pubcorrI	1.216*			
	(0.693)			
IT		0.028*		
		(0.016)		
TI			−0.032*	
			(0.019)	
AT				−0.064***
				(0.014)
GDP	−0.017	−0.009	−0.017	−0.011
	(0.032)	(0.033)	(0.032)	(0.032)
Constant	1.362***	−0.698	3.707***	5.741***
	(0.138)	(1.240)	(1.341)	(0.989)
Observations	491	491	491	491
R^2	0.007	0.006	0.007	0.039
Adjusted R^2	0.003	0.002	0.003	0.035
Residual Std. Error (df = 488)	2.370	2.371	2.370	2.331

Note: *p<0.1; **p<0.05; ***p<0.01

Table A.5: Government Accountability and Patenting Efficiency

A.10 Growing number of nanotechnology-related applications

	Dependent variable:	
	Patent name contains related term	
	logistic (1)	*OLS* (2)
Program in place	0.255**	0.002***
	(0.119)	(0.001)
application year	0.114***	0.0005***
	(0.013)	(0.0001)
Constant	−234.492***	−0.928***
	(25.610)	(0.118)
Observations	191,583	191,583
R^2		0.002
Adjusted R^2		0.002
Log Likelihood	−5,964.383	
Akaike Inf. Crit.	11,934.770	
Residual Std. Error		0.071 (df = 191580)
F Statistic		205.507*** (df = 2; 191580)

Note: *p<0.1; **p<0.05; ***p<0.01

Table A.6: Growing number of nanotechnology-related applications

A.11 Histogram of patent Applications by Patent Section

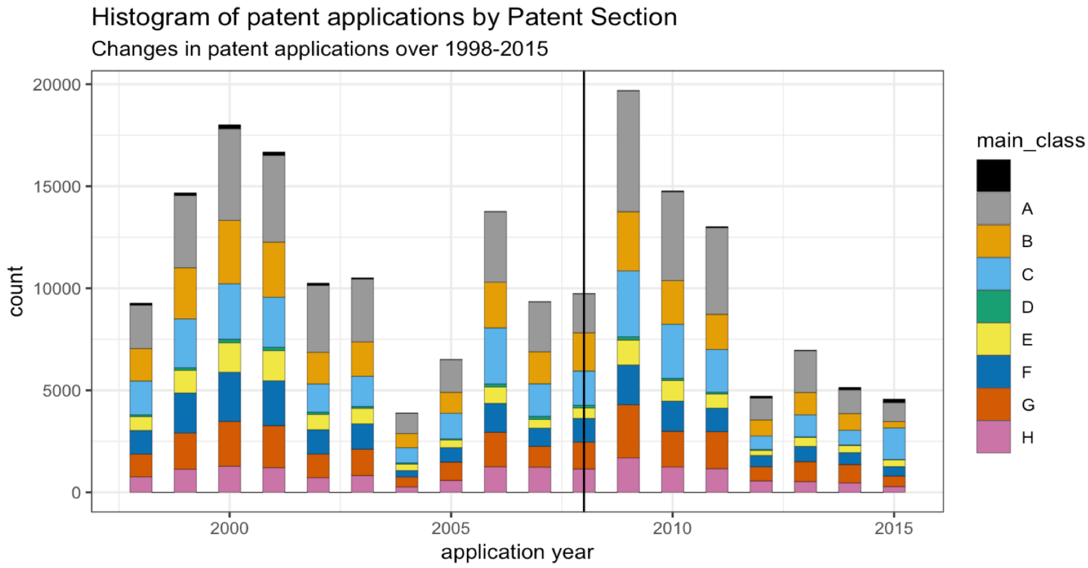


Figure A.16: Number of patents applications per IPC section per year, 2011

A.12 Patenting in multiple offices

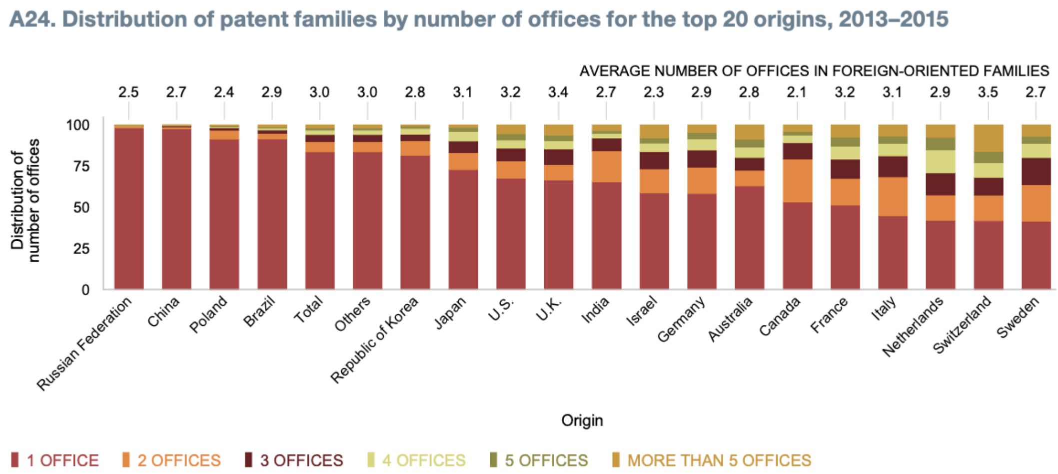


Figure A.17: Source:World Intellectual Property Indicators 2018 - WIPO

A.13 DID with time-varying treatment

The results presented in Table 4.7 pooled ATT effects over time and all treatment groups. We can augment them by applying the method proposed by Callaway and Santanna (2019), computing group-time average treatment effects, $ATT(g,t)$, that are the average treatment effect in period t for the group of companies first treated in period g with the same set of controls X_i included in the estimation of model 4.3. The authors show that under a set of assumptions and $2 \leq g \leq t \leq T$, group-time average treatment effect for group g at time t is given by

$$ATT(g,t) = E[(\frac{G_g}{E[G_g]} - \frac{\frac{p_g(X)C}{1-p_g(X)}}{E[\frac{p_g(X)C}{1-p_g(X)}]})(Y_t - Y_{t-1})], \tag{A.1}$$

where g is the group variable indicating in which year the company won a grant, $p_g(X)$ is a propensity score $p_g(X) = P(G_g = 1|X, G_g + C = 1)$, $P(G = g)$ is the probability that the firm is first treated in period g conditional on not being in a control group or treated in period 1.

Unfortunately, this approach relies on data availability for the complete panel. Since the majority of companies in the sample have missing indicators for at least one year in the 2008–2016 sample period, the sample size for the estimation is reduced, and sample selection bias becomes a greater concern. In addition, data availability precludes the analysis of changes in sales and revenue.

The reliability of the causal interpretation of all aforementioned results relies on the validity of a conditional parallel trends assumption; however, that is fundamentally untestable as adopted by this approach. Callaway and Santanna (2019) strengthen the conditional parallel trends assumption such that it holds in both pretreatment and posttreatment, which can be tested if more than two time periods are available. The null hypothesis can be represented as

$$H0 : E[Y_t - Y_{t-1}|X, G_g = 1] - E[Y_t - Y_{t-1}|X, C = 1] = 0 \text{ a.s. for all } 2 \leq t \leq g \leq T \tag{A.2}$$

Table A.7 presents the number of observations and integrated moments test for conditional common trends holding in all pretreatment time periods across all groups. Unfortunately, we reject the hypothesis of common trends, so the results should be interpreted with caution.

Outcome	**N**	**p-value: conditional common trends**
Log(Gross Profit)	2529	0.008
ROE	5265	0
ROA	5427	0
Log(Fixed Assets)	2880	0

Table A.7: Number of observations and DID pre-trend tests

Group-average treatment effects on profits of the unconnected companies are presented in Figure A.18. As in Table 4.7, winning a grant does not, in general, lead to higher profit.

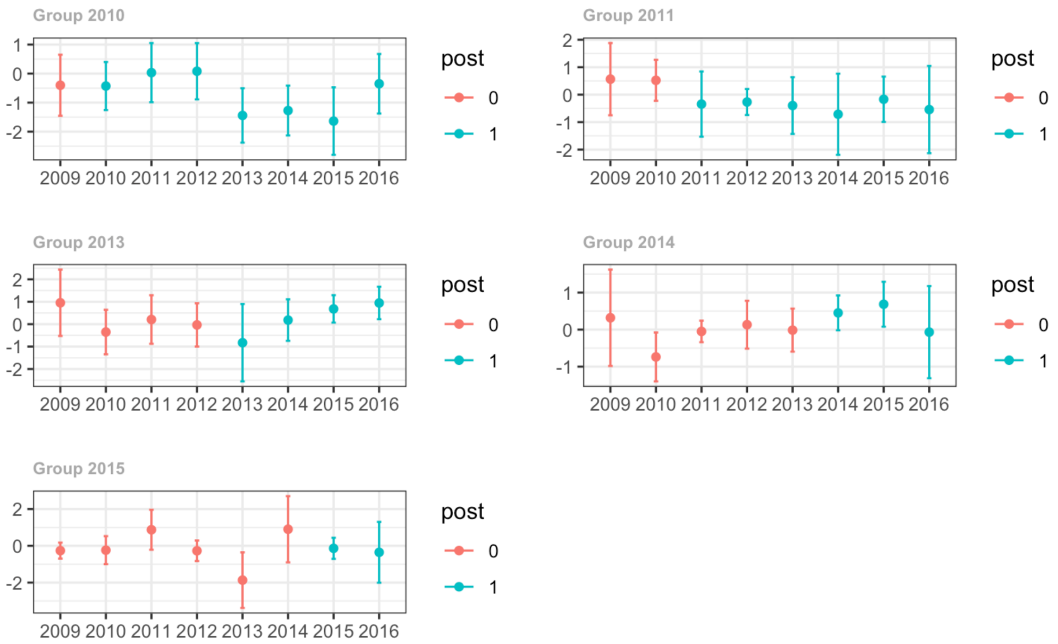


Figure A.18: Log(Gross Profit) under conditional (connections) DID

We can now examine the effect of winning a 218 grant on connected companies. Taking into account the small total number of observations (N=567), we can still see the positive relationship between gross profit and winning a grant for connected companies, which is in line with previous results.

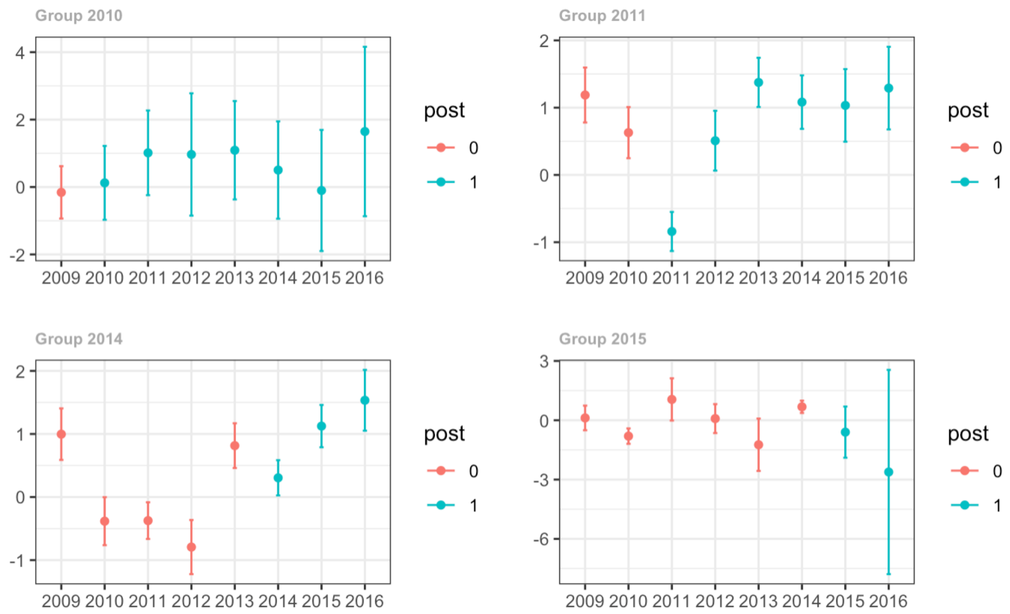


Figure A.19: Log(Gross Profit) for connected firms

Similarly examining fixed assets for the unconnected companies that don't have missing data in the sample, we do not see any effect of winning an R&D grant.

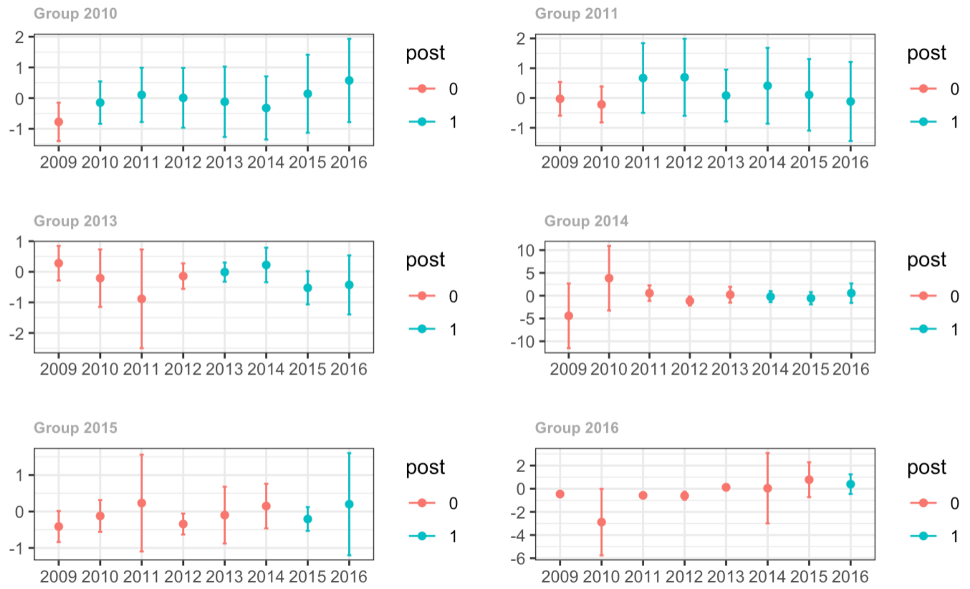


Figure A.20: Log(Fixed Assets) under conditional DID

By contrast, even on a small sample of connected firms (N=639), we can see a positive relationship between fixed assets and winning a grant in a current or preceding period, which is in line with the baseline results in Table 4.7.

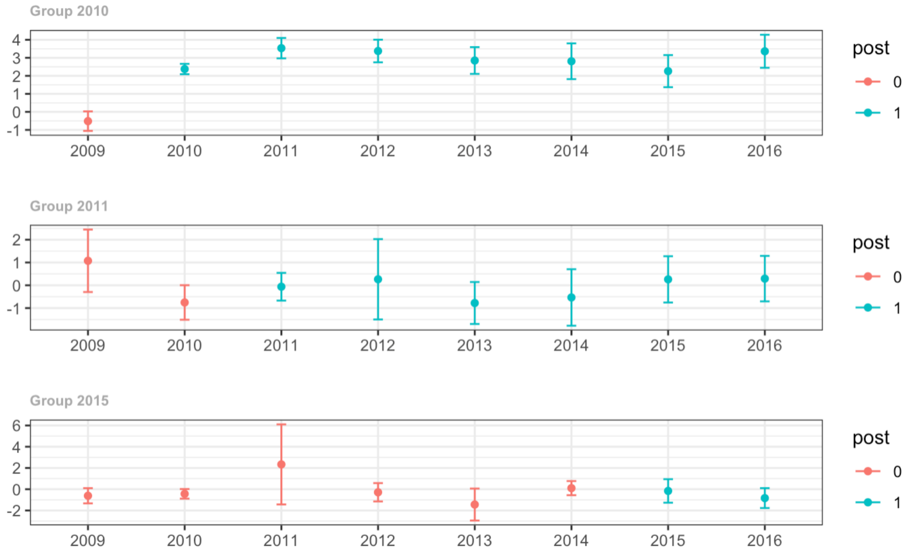


Figure A.21: Log(Fixed Assets) for connected firms

Figures A.22 and A.23 present the results for ROE and ROA for the full sample and for the subsample of connected companies. The figures do not indicate any link between winning an R&D grant and change in corporate performance for either case. As in the baseline specification, winning an R&D grant has no effect on either ROA or ROE for both connected and unconnected companies.

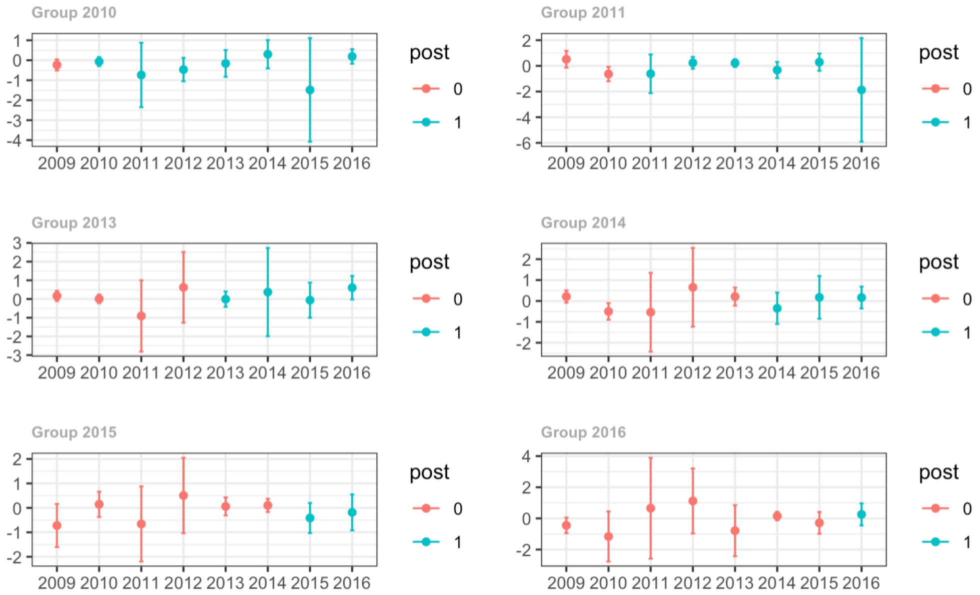


Figure A.22: ROE under conditional DID(N=5265)

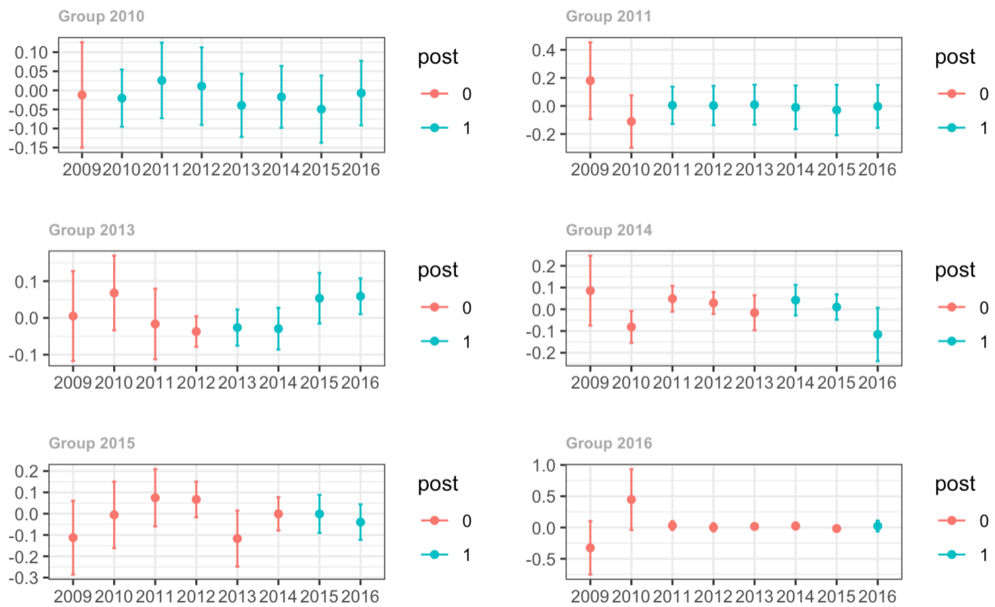


Figure A.23: ROA under conditional DID(N=5427)

Figure A.24: ROE for connected firms (N=1161)

A.14 Trajectory Balancing

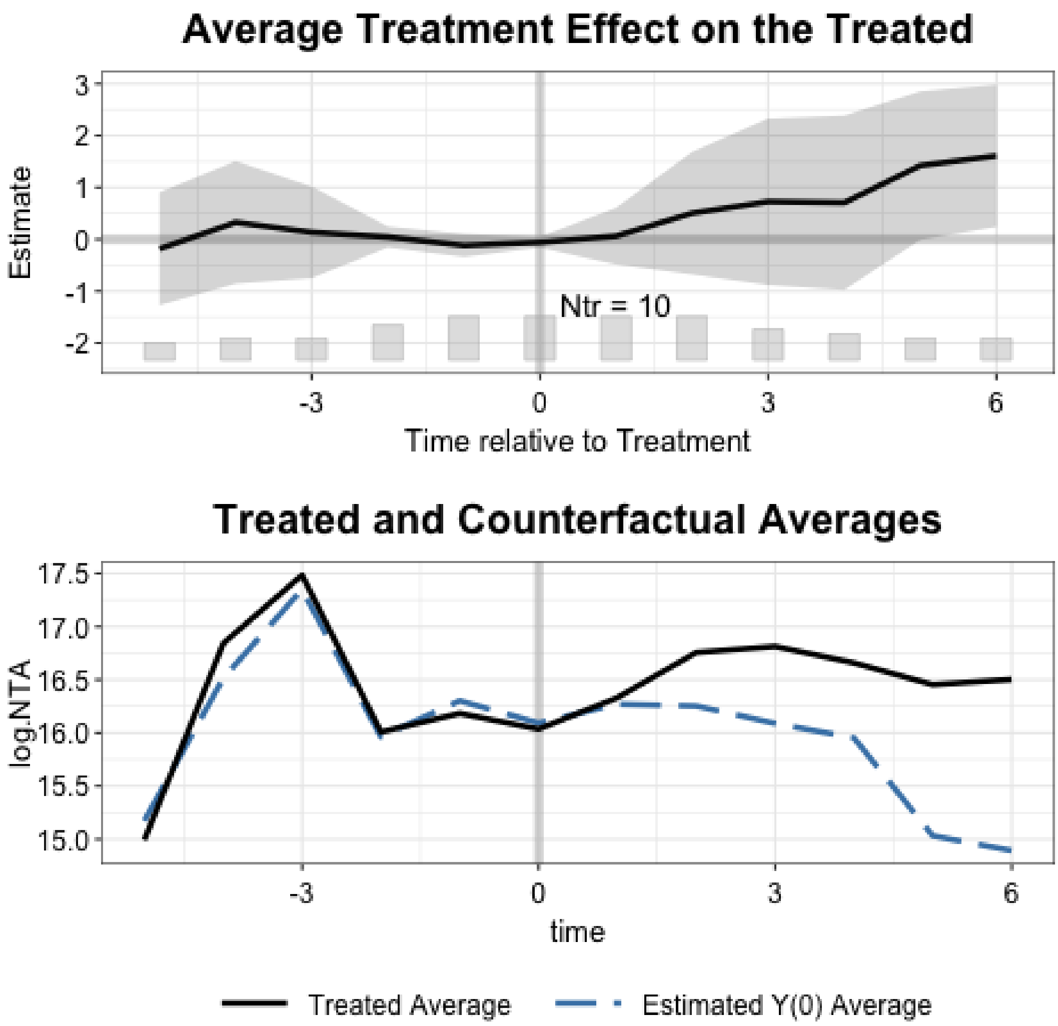


Figure A.25: Log(Fixed Assets) for connected firms

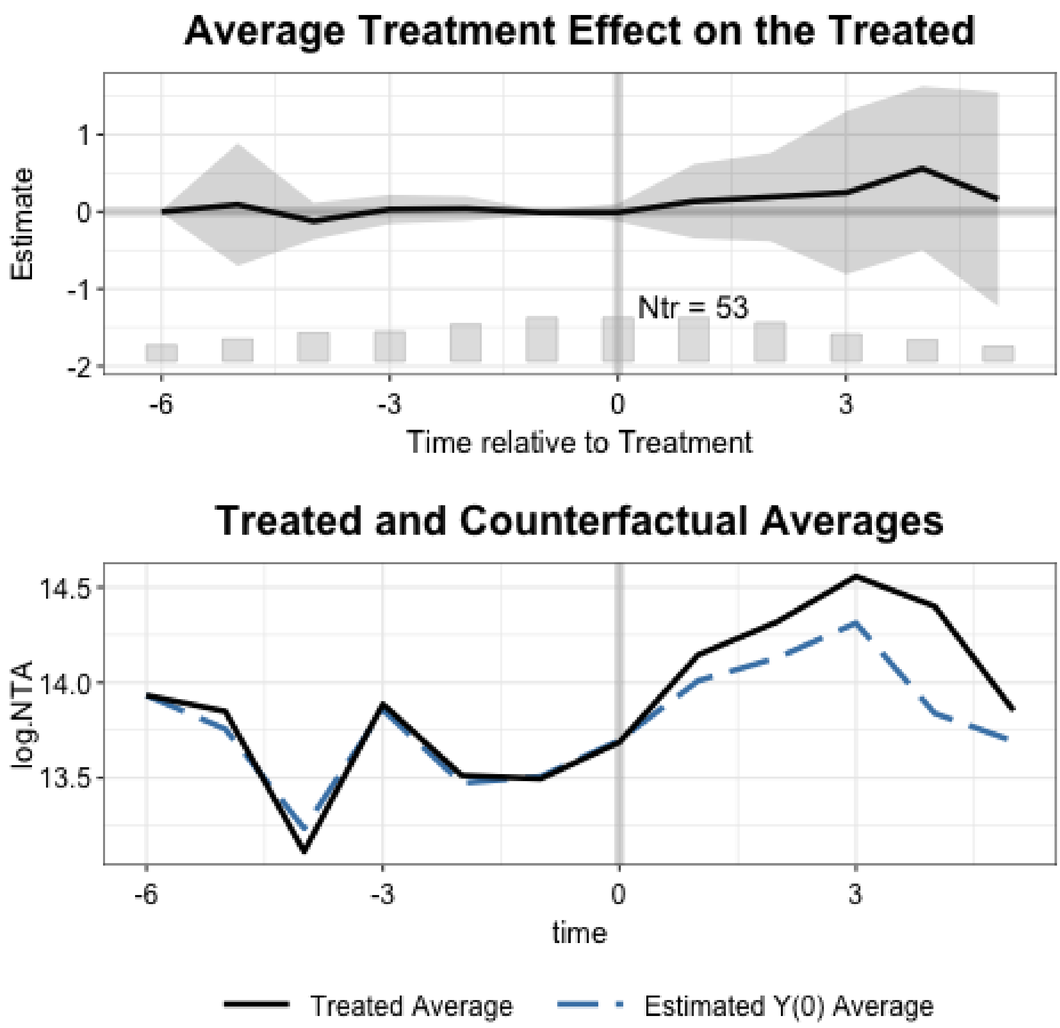


Figure A.26: Log(Fixed Assets) for unconnected firms

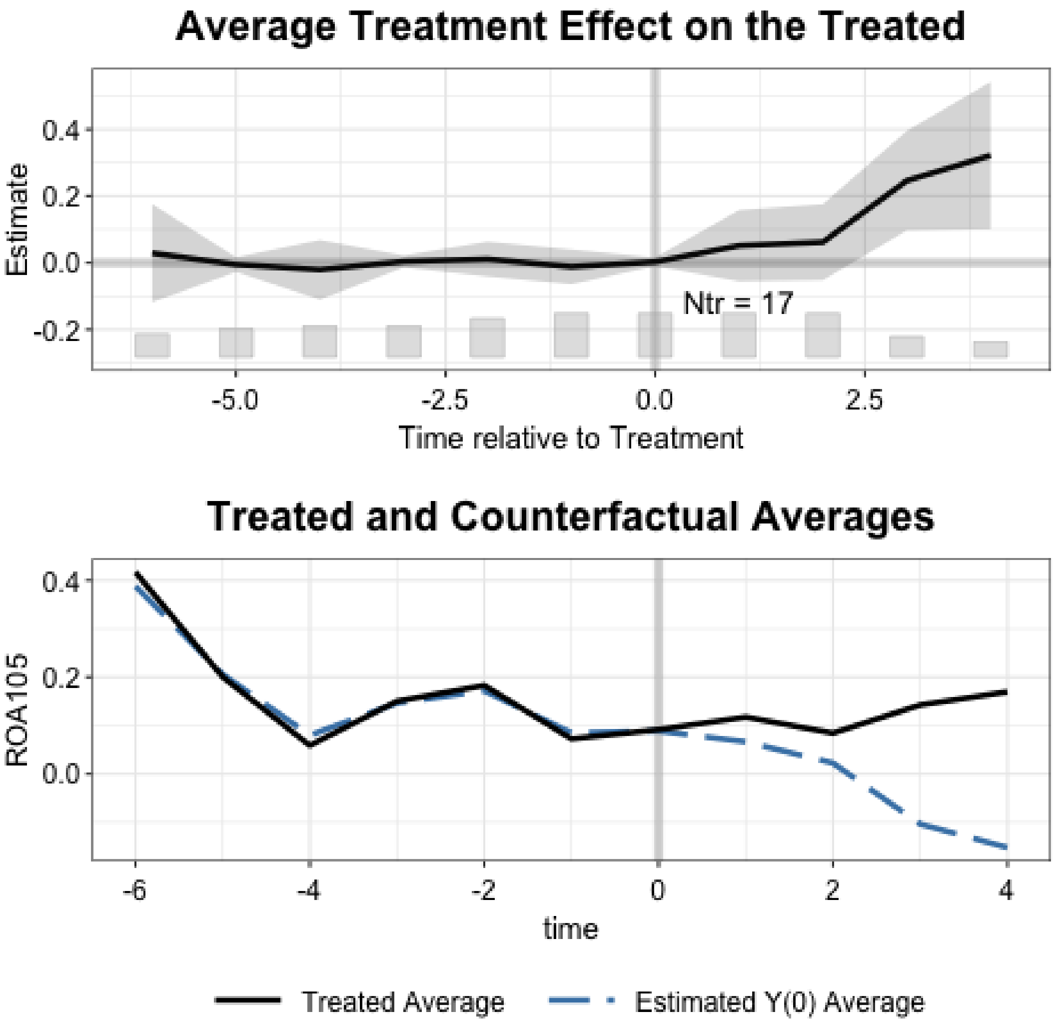


Figure A.27: ROA for connected firms

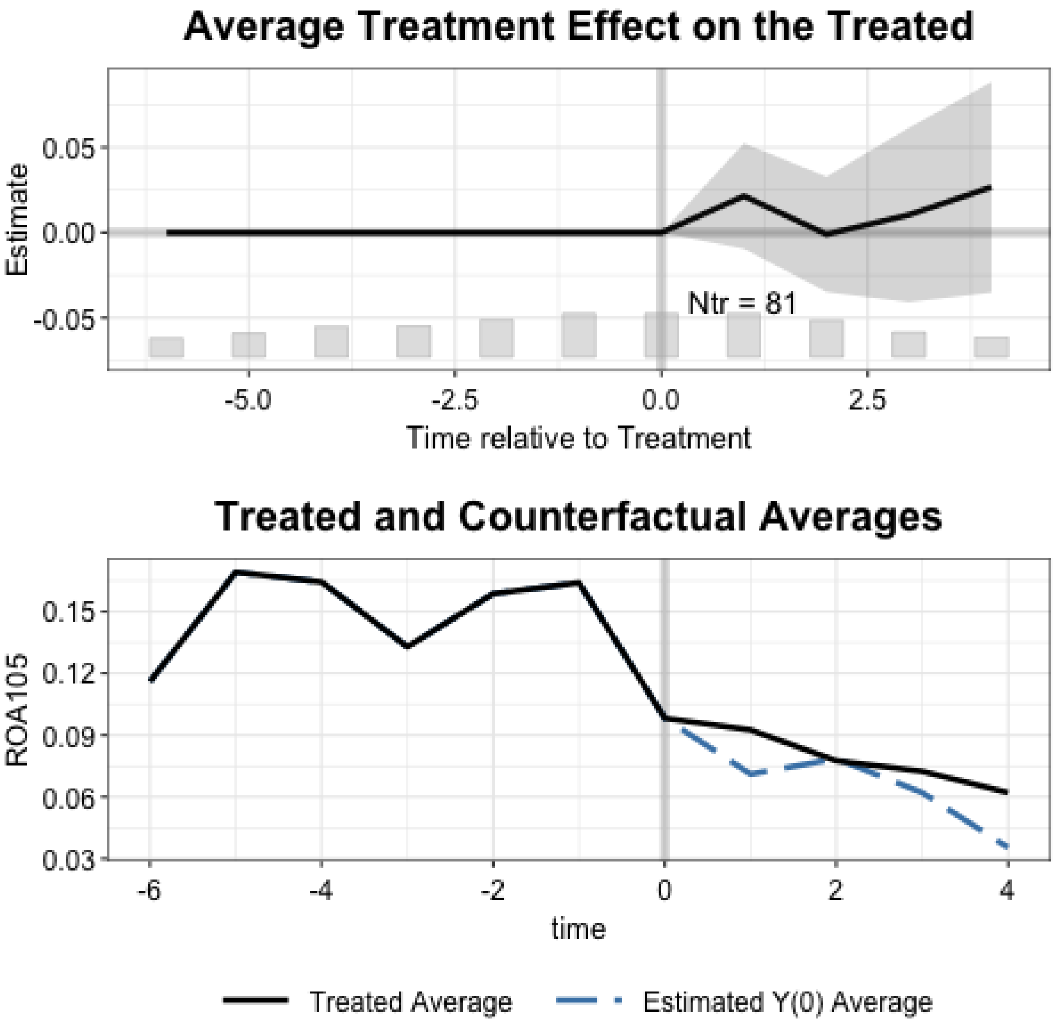


Figure A.28: ROA for unconnected firms

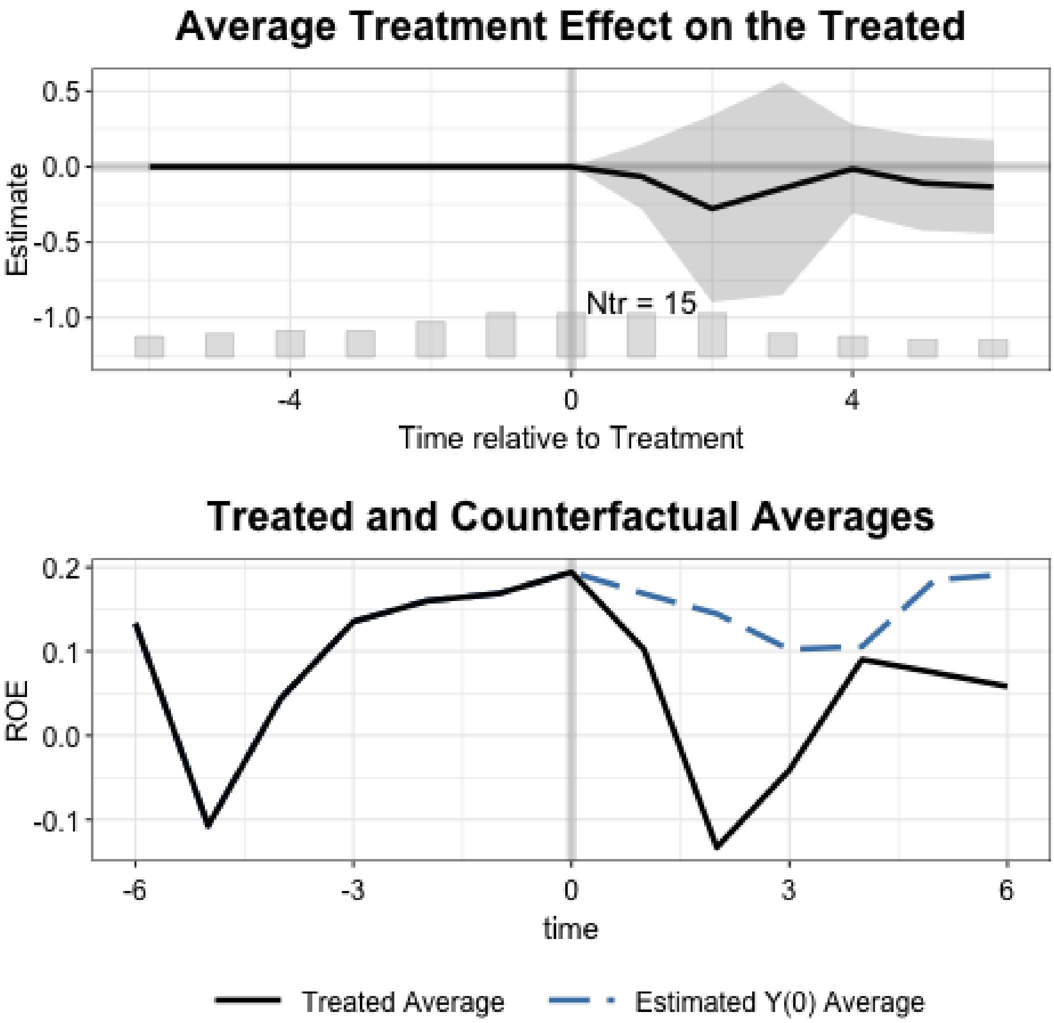


Figure A.29: ROE for connected firms

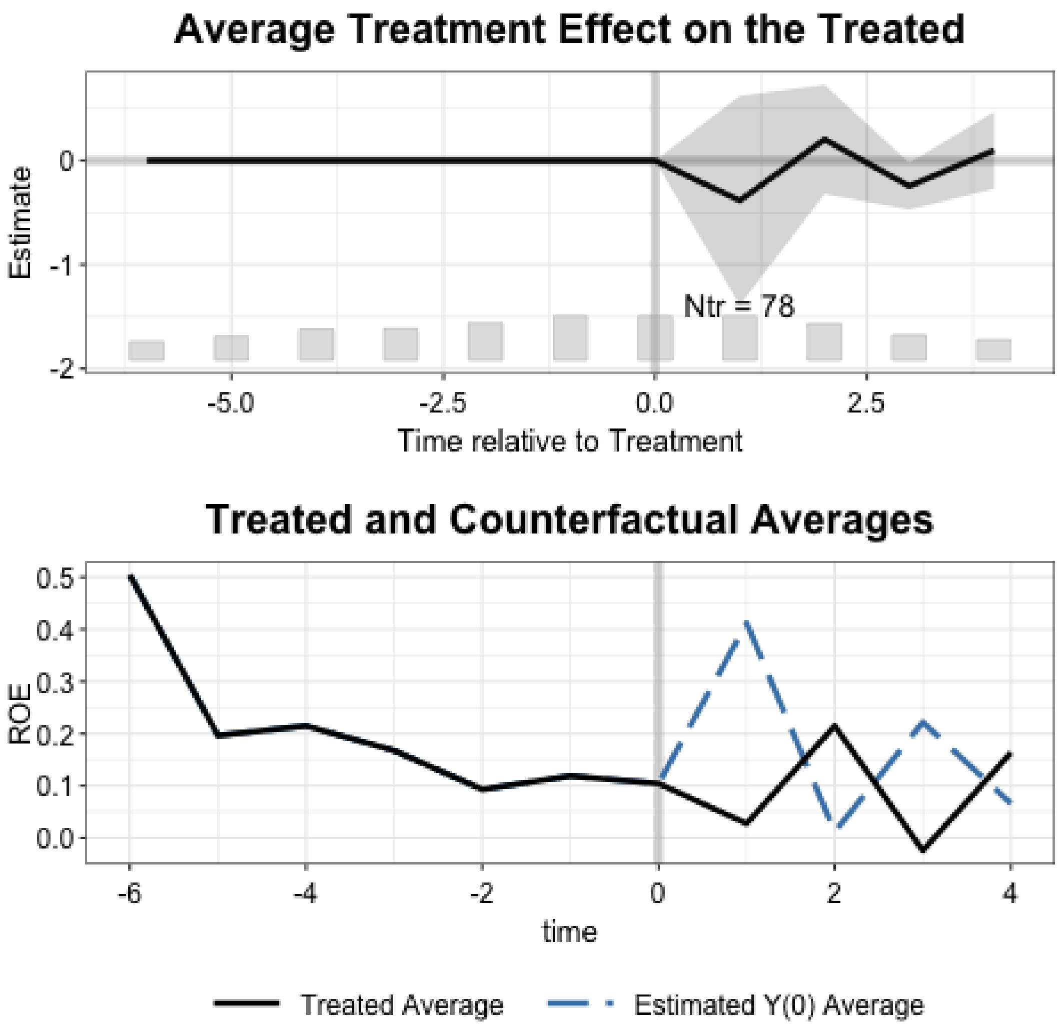


Figure A.30: ROE for unconnected firms

A.15 Government contracts during R&D phase of connected companies

Time	ATT	S.E.	z-score	CI.lower	CI.upper	p.value	n.Treated
-6	0	0	-0.45	0	0	0.65	10
-5	0	0	-0.43	0	0	0.67	17
-4	0	0	-0.51	0	0	0.61	22
-3	0	0	-0.96	0	0	0.34	22
-2	0	0	-0.78	0	0	0.44	26
-1	0	0	-1.68	0	0	0.1	31
0	0	0	-1.08	0	0	0.28	31
1	2.24	1.54	1.54	-0.15	4.62	0.12	31
2	4.66	2.23	2.09	0.99	8.32	0.04	21
3	0.11	2.37	0.05	-3.79	4.02	0.96	14
4	2.46	2.96	0.83	-2.41	7.33	0.41	9
5	-1.62	2.74	-0.59	-6.13	2.89	0.55	9
6	-2.79	4.41	-0.63	-10.04	4.46	0.53	5

Table A.8: Effect of winning a 218 grant on the volume of awarded government contracts for connected companies by year

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