Saving Soviet Science: The Impact of Grants When Government R&D Funding Disappears

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Abstract

How do grants impact scientific productivity? I estimate the impact of a large-scale grant program, funded by financier George Soros, that provided individual and team-based grants to thousands of scientists following the dissolution of the Soviet Union and the end of public funding for Soviet science. I match scientists to their publications and locations using the Thomson Reuters ISI Web of Science database and create a unique scientist-level panel dataset. Using quasi-experimental methods facilitated by the grant eligibility criteria, I show that the individual grants more than doubled researcher publications and induced scientists to remain in the science sector. The team grant also increased publications, suggesting an important role for complementarities in team production of research. My findings show that grants significantly increase scientific productivity in a market in which there are few alternate research funding opportunities. The results suggest that policy levers can play an important role in the adjustment process of labor markets after sharp economic changes; in this case, a relatively small amount of funding can maintain participation in the science sector and can impact "brain drain".

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1 Introduction

Governments fund science in order to support the production of basic scientific knowledge, a key input for innovation, and ultimately, economic growth (Brooks, 1994; Romer, 1990). How can policymakers most effectively support scientists in the advancement of scientific knowledge? The answer to this question is still not well-understood, especially considering the extent of government resources devoted to this pursuit. Existing research has almost exclusively focused on developed country settings, where levels of government R&D funding are high and financing opportunities abound. Therefore, estimates of the impact of any specific R&D funding program are typically underwhelming due to the wide availability of alternate funding opportunities (e.g. Jacob and Lefgren, 2007) or a potentially inelastic supply of scientists (Goolsbee, 1998).[1]

In this paper, I estimate the impact of one type of R&D funding - research grants for basic scientists - on scientific output and scientists' decisions in a setting with very limited public sector funding for science: the former Soviet Union. The Soviet Union once had a very large scientific labor force and R&D budget on par with the U.S. The end of the USSR in 1991, and the subsequent crisis that followed, essentially ended public funding for the Soviet science sector and decimated scientists' salaries. Drawing upon the earliest large-scale "emergency" grant program for Soviet scientists, funded by financier George Soros under the auspices of the International Science Foundation (ISF), I estimate the impact of grants when there is a large scientific labor force but limited funding opportunities for scientists. These two concurrent "experiments", the dramatic drop in government R&D funding and the ISF grant program, provide an opportunity to estimate the marginal impact of funding for science when there are few funding opportunities and the supply of scientists is presumably very elastic.

The ISF grant program had two components - an individual and a team-based grant. The first component was an individual cash grant of $500, which represented approximately one year's salary at the time, and was awarded to over 26,000 basic scientists actively publishing in top Soviet/Russian and international journals. The second component was aimed at supporting the research team of the top scientists. An additional

[1] However, evidence shows that the supply of science students is not inelastic. Freeman (1975b) draws upon the collapse of the science market in the US in the postwar period and shows large elasticities in the supply of physics students in response to physics salary changes.

$1,000 was given to the "best" scientists among all those who received the individual cash grant, which they were to divide among members of their research team.

There are still few studies providing evidence on the causal impact of grants on scientific output due to the associated empirical challenges. Because grant receipt is likely to be correlated with ability or other unobserved factors, simple estimates of the impact of grant receipt would tend to be biased upwards due to selection issues (see Jaffe (2002) for a discussion). Grants are rarely randomly assigned, and instead are usually awarded after extensive review processes, the deliberations of which are often confidential. Apart from Jacob and Lefgren (2007), who exploit discontinuities in NIH priority scores and grant receipt, few studies have been able to study grant programs that provide conditions in which to avoid selection problems.

In this case, I can employ quasi-experimental methods to obtain causal estimates of the impact of the grants. The ISF grants were called "emergency" grants, because Soros desired that the funds be dispersed to scientists as quickly as possible considering the dire situation. Therefore, a simple eligibility criteria had to be used. After deliberations among the Russian and American ISF Board members, a minimum number of publications was chosen for eligibility for the individual grant: at least 3 publications between 1988 and the time of the grant program announcement in 1993. Moreover, the recipients of the team grant would be the scientists who had the highest impact factor scores[2] among all those who applied based on each scientist's 3 top publications, so no additional application process was used.

The suddenness of the program and the simple, non-linear structure of the eligibility rules allow me to avoid typical selection issues and utilize exogenous variation in grant receipt. I estimate the causal impact of the grants by comparing scientists who just missed the eligibility cutoffs with those who just made them using regression discontinuity (RD) and difference-in-differences (DD) approaches. The reasoning is that scientists who just missed the cutoffs are a good counterfactual group for those who who just made the cutoff - they are likely to be very similar in observable and unobservable ways, and only differ in their receipt of the grant.

Theoretical work in this area suggests that differing incentive schemes can play a

[2]See Appendix A.3 for further information on the calculation of the impact factor scores.

role in the production of scientific knowledge and thus, the structure of grants and the incentives they provide likely matter for scientists' outcomes (e.g. Manso, 2009). The two types of grants in this case provide an opportunity to estimate the impact of funding when it is awarded to an individual scientist, and in line with the recent evidence on the increasing importance of collaboration and teams in scientific research, when it is awarded to a scientist's research team (e.g. Azoulay et al., 2010; Wuchty et al., 2007).[3]

Scientific grants can have an impact on both the extensive margin (size of the science sector) and the intensive margin (output of researchers in the science sector). Both margins are likely to be salient in the post-Soviet setting. A key concern during this time was that scientists would exit the science sector because salaries had dropped too low and there were alternative career options in the private sector. Another concern was "brain drain" - that scientists would emigrate to western countries, or might be recruited by rogue nations or terrorist organizations for their knowledge related to weapons. Thus, in addition to the intensive margin, I examine the impact of grants on the extensive margin and on emigration rates.

The expected impact of the grants on these outcomes is not clearcut from a theoretical standpoint. First, it is not clear how a one-time pecuniary shock would affect participation in the science sector or productivity, especially considering that challenges in enforcement may have essentially made the individual grant "no strings-attached". Second, the expected impact on migration rates is ambiguous. The individual grant may have decreased migration costs by reducing credit constraints, thereby increasing migration probabilities; or it may have provided temporary means of subsistence to scientists that deterred migration in the short run. I provide a conceptual framework in which to think about the possible impacts the grants may have had on outcomes based on models of occupational choice and the migration decision. I also consider the role of incentives embedded in the structure of the two types of grants - the team grant, which would be expected to facilitate research but not migration, and the individual grant, which could do either.

To test these hypotheses, I create a panel dataset of grantees and non-grantees and match them to their publications and locations using the Thomson Reuter ISI Web

[3]However, I cannot compare the relative importance of 2 grants, because as described in the empirical section, the estimates are local treatment effects based on different samples of scientists who are on the margin of receiving each grant.

of Science database.[4] My analysis provides evidence that both grants had a positive impact on researcher publications. The individual cash grant prevented scientists from exiting science, particularly in the poorer, non-Moscow areas, and doubled researcher publications on the margin. With higher wages, more outside career options and alternative funding options in Moscow, this suggests that the individual grant had more "bite" outside of Moscow, which is consistent with theoretical predictions. The individual grant appears to have prevented emigration among scientists, but only in Moscow, where the costs of migration were lower. The team grant also increased the team leader's publications on the margin, suggesting that there are complementaries in the team production of research. The team grant, meanwhile, seems to have facilitated migration, likely by sustaining researcher productivity in the short run that kept the door open for subsequent emigration possibilities.

At one time, the Soviet Union was considered a scientific powerhouse along with the U.S.[5] While a shock to a science sector on the scale of the Soviet collapse is unlikely to recur, evidence from the Soviet experience can help inform policymakers making domestic science policy and foreign aid decisions about the ways that scientific labor markets can be impacted.[6] The magnitude and unexpectedness of the recent financial crisis shows the fragility of government resources, and many of the changes that took place regarding the incentives to stay in the science sector or the conditions in which science is done could occur in other settings and labor markets after sharp economic changes. This analysis shows that after an economic crisis, resources can be mobilized and policy levers like grants can be used to help prevent a decline in the size and productivity of the scientific labor force and to prevent "brain drain", which can have lasting impacts for innovation and economic growth.

The remainder of the paper is structured as follows. In Section 2, I provide background information on science before and after the end of the Soviet Union and about the ISF grant programs. In Section 3, I discuss a conceptual framework for analyzing the

[4]Web of Science ® prepared by THOMSON REUTERS ®, Inc. (Thomson®), Philadelphia, Pennsylvania, USA: © Copyright THOMSON REUTERS ® 2010. All rights reserved.

[5]Some estimates suggest that in the 1980s, the Soviet scientific labor force had anywhere between 10 to 30 percent more scientists and engineers than the U.S. (Graham and Dezhina, 2008).

[6]In fact, emergency aid for scientists is not unprecedented. As Khmelevskaya (2010) describes, western aid may have saved Russian science during famines in 1921-1923 after the Civil War. At this time, the American Relief Administration (ARA) provided food and other relief supplies that helped Russian scientists when they were perishing due to food shortages and emigrating to the West in large numbers.

impact of grants on productivity and scientist outcomes. Section 4 describes the data, followed by the empirical framework in Section 5. Section 6 presents the results of the empirical analysis and Section 7 concludes.

2 Background

2.1 Science in the former USSR

The first "experiment" I draw upon in this paper is the end of the Soviet science system and subsequent drop in public R & D funding. As noted earlier, the Soviet science system was big in terms of the size of the scientific labor force, and in terms of funding for science. According to Soviet science scholars, the most notable characteristics of the system were "its bigness and its high degree of centralization" (Graham and Dezhina, 2008). In 1988, the USSR/Eastern Europe had an estimated 26.6% of the world's scientists and engineers, while North America had 25.4% and Western Europe had 16.7%. In the 1970s, the USSR/Eastern Europe and North America both had approximately 33% of the world's R&D expenditures (Salomon et al., 1994).

Soviet Science was highly centralized, in that science and party elite in Moscow more or less determined scientific directions in 5-year plans. Funding was "top down" and allocated through block grants. There were no systems of competitive, peer-reviewed fellowships or funding (Graham and Dezhina, 2008). Fueled by the Cold War, science was heavily focused on fields with potential military applications, so military research fields had the most funding and researchers. However, scientists were distributed among the Academy of Sciences, universities, as well as in industrial and military facilities. The focus of my analysis is on basic researchers. Most basic and groundbreaking research was done in the Academy of Sciences, which held the most prestigious scientific positions. But in general, it was prestigious and favorable to be a scientist, and the most elite of the scientists had special perks not available to ordinary scientists or citizens, such as access to special stores or the opportunity to travel abroad to international conferences. Scientists also earned relatively higher wages, although the Soviet wage system was very compressed, so wage differentials were not large.

While scientists were rarely able to travel outside of the USSR, there was substantial contact with scientists in other communist countries. In terms of access to journals

and existing knowledge, scientists were able to order reprints from Western journals from Moscow. However, there was usually a lag in receiving reprints and often the reprints were censored. Graham and Dezhina (2008) describe some of the other features of Soviet Science, including a separation between teaching and research, political restrictions that included secrecy, discrimination against ethnic groups, and suppression of certain scientific fields for ideological reasons.

When the Soviet Union collapsed in 1991, there were dramatic drops in funding for science and the wages of scientists. Figure 1 shows the decline of government R&D expenditures for Russia after the end of the USSR, when R&D levels had already dropped compared to Soviet levels. Consequently, supplies were soon in short supply, laboratories deteriorated, and water and phone service were even intermittent (Ball and Gerber, 2005). Based on interviews conducted with scientists in five former Soviet Republics about this period,[7] it appears that many scientists did not receive their salaries for some periods after the end of the USSR, or received extremely low salary payments, although this varied by region. Large cities, especially Moscow, tended to have more resources. This collapse of the Soviet system undeniably impacted the production of scientific knowledge. Figure 2 shows the total number of publications in the Thomson Reuters ISI Web of Science database with an address in the former USSR. The drop in publications after the end of the USSR in 1991 clearly visible.

Despite this bleak picture, the end of the USSR also brought about many freedoms for scientists, including greater mobility and contact with the western world, as well as alternative career options in private sector. Many scientists chose to move abroad to the United States, Israel or Europe to continue their careers. Others remained at home and sought opportunities to continue their research, in spite of the economic instability. Some, meanwhile, left science completely and pursued other career options. By 1993, Russian government estimates of the rate of change in researchers in the Academy of Science as a share of 1991 levels were -6.5%, -31% in industrial science and technology, and -35.2% in higher education institutions (Graham and Dezhina, 2008). In my analysis, I focus on scientists who would have primarily been in the Academy of Sciences or other institutions conducting basic research.

[7] Interviews conducted with scientists in Estonia, Tajikistan, and Ukraine in 2009, and Azerbaijan and Georgia in 2010.

There was particular concern among western countries about the outflow of knowledge former Soviet scientists possessed about nuclear, chemical, and biological weapons. Worry that rogue nations or terrorist groups would recruit scientists to build weapons of mass destruction, or that they would sell their knowledge without even leaving their countries, was a key motivation for the creation of many western assistance programs, including programs for collaboration with Western universities, nonproliferation assistance programs, and employment programs for scientists. In a recent study about former Soviet Scientists, Ball and Gerber (2005) surveyed Russian scientists in 2002-2003 about western assistance programs. Their findings suggest that these programs did appear to reduce the potential for scientists to work for terrorist organizations or rogue nations.

2.2 Soros' International Science Foundation

Perhaps the most well-known and earliest assistance program for scientists after the end of the USSR was initiated by George Soros. On December 9, 1992 Soros announced that he would allocate $100 million over 2 years to support former Soviet scientists and created the International Science Foundation (ISF). From 1993 to 1997, the ISF implemented 9 assistance programs and Soros reportedly spent over $250 million (see Dezhina (2000) for more information about the ISF and its activities). Soros' motivation for creating the ISF was broadly to prevent the destruction of Soviet science. He had the realization early on that supporting science was critical for economic recovery in the region, and is said to have wanted to attract the attention of Western governments so that they provide further aid for Soviet science. He also was concerned about "brain drain" and considered scientists on the "front line of the struggle for an open society" (Dezhina, 2000).

The first ISF program, administered in 1993, was the Individual Emergency Grants program. The time between the announcement to disbursement of the individual grants was only 4 months, which led to the simple selection criteria. Phase 1, the hallmark program of the ISF, provided an immediate cash grant of $500 for "leading" basic scientists in former USSR, where eligible scientists had to show a publication record of 3 publications in international journals or top Soviet journals from 1988-1993 (see the list of qualifying Soviet and Russian journals in Appendix Table B1). Applicants who

met the 3 publication criteria automatically received the $500 grant if they submitted an application. The applicant also had to certify that he/she intended "to devote most of his/her time in 1993 to continue the research project listed in the application", had not worked abroad more than 3 months in 1992, and had a personal income in 1992 not greater than $1,000. Phase 2 of the program provided supplementary support of $1,000 to the research team members of the top scientists based on an impact factor score for each scientist calculated by the ISF staff. I discuss the details of the emergency grant program in more detail in the empirical framework section.

Although $500 may seem like a trivial amount today, as mentioned earlier, it represented approximately one year's salary for scientists at the time. Many scientists were receiving extremely low salaries, such as $7/month [8] or even 20 cents/month (Dezhina, 2000), or none at all. The average wage during this time was indeed very low throughout the former Soviet Union. Calculations from the 1993 Russian Longitudinal Monitoring Survey, a household survey, suggest that the average wage in Russia was 32,000 rubles/month, or approximately $26. Many grantees remember that the grant was a significant amount at the time and many said they used the money for subsistence purposes.[9] There was significant media attention given to the role of the ISF, and many accounts claimed that Soros had "saved Soviet Science."

3 Conceptual Framework

In this section I discuss a conceptual framework for considering the impact of two types of grants - an individual grant structured as a wage subsidy/cash transfer, and a team-based grant, which is more directly tied to research. I first consider scientists' outcomes on the intensive and extensive margins of science by drawing upon a model of occupational choice and elements of the researcher production function, followed by a model of the migration decision. Since the focus of my analysis is on the impact of the *grants* in particular, and not the other economic and institutional changes going on after the end of the USSR, I will consider how the grants impacted the marginal scientist's

[8]Based on interviews conducted with scientists in Estonia, Tajikistan and Ukraine in 2009.

[9]For example, a grantee in chemistry expressed his/her gratitude in a letter to Soros dated August 5, 1993, writing: "500 US $, which I have received from your Foundation, will give me a possibility to survive at least during a year in science. You should know, that all my possible achievements in science in future will be impossible without your help, because any interval without scientific work makes the greatest problems for fruitful investigations." (OSA).

outcomes, *ceteris paribus.* As will be discussed in more detail in the empirical section, this implies that I will measure the impact of the grants by comparing scientists who are similar in their characteristics and institutional and economic environment and on the margin of receiving each grant.[10]

3.1 Occupational Choice and Productivity

3.1.1 Extensive Margin

Factors affecting the supply of scientists include compensation in science fields compared to other fields, working conditions, demand factors, and past or future supply (Ehrenberg, 1991; Freeman, 1975a,b, 1971). There is also evidence of a "taste" for science that attracts certain individuals to the science sector (Stern, 2004). In models of occupational choice, a worker chooses an occupation based on individual preferences or abilities, and job characteristics and wages that are market-determined (Freeman, 1971). Using this approach for the decision regarding the *extensive margin* of science, for individuals who have already chosen to be a scientist in the previous period, after an economic shock he/she chooses the sector with the highest utility. A scientist will choose to stay in the science sector s if utility is higher than in the non-science sector n:

$$U(x_s, \gamma_s + Y, v_s) > U(x_n, \gamma_n + Y, v_n) \tag{1}$$

where x is the vector of job characteristics, γ is expected lifetime earnings (given market wages and ability), Y is non-wage income, and v are features associated with doing science that reflects an individual's taste for science.

The individual cash grant can be thought of as a one-time wage subsidy in this framework that effectively increases the wage rate in the science sector, w_s, since grantees had to certify that they intended to spend most of their time in 1993 doing research. As described in the previous section, w_s was low throughout the former Soviet Union in 1993, as were non-science sector wages, w_n. Thus, the temporary pecuniary shock provided by the individual grant, which was equivalent to one year's salary, would increase w_s and thus γ_s. If the increase is large enough so that $\gamma_s > \gamma_n$, the grant would induce scientists to choose the science sector, *ceteris paribus.* Since the non-science sector wage was higher

[10]Thus, in this analysis I will not address the more general selection of individuals between sectors and across countries after the end of the USSR.

in some cities, especially in Moscow, the wage increase may not be large enough to induce participation in science.

Note that since there there was no monitoring or follow-up on the research activities of grantees, it is possible that the grant increased Y rather than γ_s. Then, if the grant induces individuals to stay in science, this would reflect an income effect in occupational choice. Another possibility is that there were non-pecuniary benefits of the grant. In this case, even if the temporary pecuniary shock is not enough for $\gamma_s > \gamma_n$, the grant may provide a signal to scientists that there will be future funding opportunities, which increases γ_s relative to γ_n. While all these channels may lead to a short term decision to stay in science, the grant may also induce a longer term effect by sustaining scientists until economic conditions improved and/or by maintaining their ties to the research community during the crisis period.

Next, I consider the impact of the the team grant, which increases the science sector wage rate for each of the *team members* specified by the grant applicant. Using logic similar to the individual grant analysis, this would induce the team members to stay in the science sector by increasing utility in the science sector relative to the non-science sector. Since the focus of my analysis is the impact of the team grant on the outcomes of the *team leader*, I do not expect the grant to significantly impact the team leader's decision to choose the science sector, since the grant does not directly increase their wage or non-wage income. However, having a team to assist with research in the short run could increase future expected earnings by increasing productivity, which could induce participation in science. Assuming that having a team at work reflects better working conditions, the team grant could also impact working conditions (x), which would increase the utility associated with the science sector.

3.1.2 Intensive Margin

I next consider how each type of grant impacts research output (publications) once a scientist has chosen to remain in the science sector. In a simple researcher production function,[11] an individual lead scientist's research output R can be thought of as a function

[11] Since the only differences between scientists on the margin of receiving the grant is *only* the grant, all other inputs would be held constant. Thus, I do not delve into a more nuanced or dynamic version of the production function that accounts for factors such as lab organization (Carayol and Matt, 2004), life cycle effects (Levin and Stephan, 1991), or institutional features of science that lead to knowledge generation, such as an individual research agenda, the free exchange of ideas, the reward structures and public disclosure through journal publication (Merton, 1973).

of direct research inputs (e.g. equipment or chemicals) D, accumulated knowledge K, the scientist's time spent doing research h, effort e, and the research team's time spent doing research G, which is the combined time of each team member g_i, so $G=\sum_{i=1}^{n} g_i$:

$$R = f(D, K, h, e, G) \tag{2}$$

The increase in the wage rate w_s associated with the individual grant could be expected to further increase time, h, or effort, e, the scientist devotes to research, assuming $h(w_s, Y)$ and $e(w_s)$. Assuming that time and effort are positively related to research output, the individual grant would tend to increase R. However, if all scientists who choose the science sector devote some level of h and e to science beyond which there are greatly diminished marginal returns, the impact of the grant would be negligible on the intensive margin. On the other hand, the team grant would be more likely to impact the intensive margin of science than the individual grant. The team grant increases the team's time spent doing science, G, which would more directly facilitate research for the team leader.[12]

Again, if the role of the grants go beyond the pecuniary benefits, productivity could be affected through other channels. Both the individual and team grant could be associated with prestige that increases the scientist's reputation, which as Arora et al. (1998) show, is associated with greater productivity, and could lead to future funding opportunities. The grants could also give the scientist more confidence that could lead to an increase in e. Both of these effects could be considered an "anointment effect".

In the empirical analysis, I will measure the response in participation in science ($R = 0, 1$) and in research output (for $R > 0$) for a scientist to the the increase in w_s associated with the individual grant. I will estimate the elasticity $\frac{\partial R}{\partial w_s}$, which can arise from changes I do not observe in e.g. h, e or "anointment" effects.[13] For the team grant, I similarly estimate the response in participation in science and output to the increase in

[12]In an overview of the inputs in the researcher production function, Stephan (1996) describes these time elements that would likely be impacted by individual and team-based grants. First, she points to the time a researcher spends doing research, suggesting that scientists do not have "instant insights" but that rather "science takes time." Second, in the discussion of research resources, she describes the importance of graduate students and postdoctoral researchers, i.e. a scientist's research team, suggesting that they are a "necessary component of research."

[13]If the grant increased Y instead of w_s, since I only observe the change in R, it is also possible that the elasticity I estimate will represent: $\frac{\partial R}{\partial Y} = \frac{\partial f}{\partial h} \cdot \frac{\partial h}{\partial Y}$ While I will not be able to distinguish between these possibilities, the main goal of my analysis is to measure the change in research activity R caused by the grant. In this case, if this elasticity is positive, it would reflect an income effect in research activity.

the team's wages associated with the team grant.

3.2 The Migration Decision

In a typical model of the migration decision, a potential migrant chooses the country in which expected income is maximized (see Borjas, 1999). Income in the two countries is net of migration costs (direct or other costs, such as psychic costs of leaving behind family), but do not generally include other factors (e.g. influence of personal network), apart from their role in increasing/decreasing migration costs. For scientists, we can imagine a model in which the objective is to maximize utility based on expected income, expected research output (e.g. Levin and Stephan, 1991), as well as job and country attributes. We also expect scientists with greater access to information or with a global social/professional network to be more likely to migrate, as these factors would tend to be associated with lower migration costs.

Given a utility function similar to (1), a scientist who has *already* chosen the science sector will now evaluate the economic benefits and non-pecuniary benefits associated with being a scientist at home or abroad[14]. A scientist will choose to stay in their home country *(h)* instead of going to a foreign country *(f)* if:

$$U(x_h, m_h, \gamma_h + Y, p_h) > U(x_f, m_f, \gamma_f + Y - C, p_f) \tag{3}$$

where x is the vector of job characteristics, m is the vector of country attributes, γ is expected earnings, Y is non-wage income, C is migration costs, and p is expected research productivity. In the empirics I will measure the response in emigration ($h = 0, 1$) for a scientist to the increase in w_s associated with the individual grant and the team grant.

The individual cash grant would have increased science sector wages both at home and abroad. Thus, the grant would not impact the migration decision through this channel. However, the individual grant may have prevented "brain drain" by resolving a temporary subsistence problem that would otherwise force a move. We know that w_s was very low, perhaps below the subsistence level in many areas. Moreover, we can assume that Y was low for the typical individual in the former USSR in 1993. The

[14] In this analysis, I am not concerned with the migration decisions of individuals who have already left the science sector, since they are most likely no longer contributing to basic knowledge production in either country. To see whether they are involved in innovative activity not captured by publication measures, I have to matched scientists to patent data in the U.S., but find few matches at this stage.

hyperinflation that accompanied the end of the USSR made individuals' savings from Soviet times almost worthless, and individuals were very credit constrained. In this setting, it may be the case that the only option for non-grantees to subsist and continue to do science was to emigrate. This would lead to a reduction in migration associated with the grant.

Alternatively, the individual grant could have resolved credit constraints and covered fixed migration costs C, which would lead to an increase in migration among grantees. For example, the \$500 could be used to purchase a plane ticket or to obtain a visa. While one aim of the ISF grants was to decrease "brain drain", from a theoretical standpoint, it appears that the grants may have created perverse incentives for emigration.

For the team-based grant, the expected impacts on emigration are also ambiguous. In one scenario, the team grant increases expected productivity at home, p_h[15]. This can lead to a reduction in emigration among grantees in the short run. In another scenario, the team grant may allow the leader to devote time to other activities that decrease C and lead to emigration, by freeing up time that would be otherwise spent on lab-related activities. For example, the leader could spend time fostering international connections or attending international conferences. This would give the leader greater access to information or a global social/professional network, which would facilitate emigration. She could also spend more time earning money outside of the institute, would would ease credit constraints and facilitate to migration. Similar to the reasoning with the individual grant, in another scenario the grant monies could have been facilitated migration among the research team members, which might also induce the team leader to consider emigrating if this implies an increase in productivity abroad, p_f.

Finally, both grants could impact migration through the earlier mentioned "anointment effect". The grants could help the team leaders acquire additional grants and funding by improving their reputation or visibility abroad, which increases productivity and serves as a signal of quality to international researchers. Since the grants came from an international donor, receiving the grant may also make a scientist more open to international collaboration and interaction with foreign researchers, which also facilitates

[15] Due to productivity advantages abroad, without the grant we can assume that $p_f > p_h$ (Kahn and MacGarvie, 2008).

migration by decreasing migration costs.

In sum, the conceptual framework discussed in this section suggests a range of forces on scientists' outcomes, many of which have ambiguous properties theoretically. The individual grant appears likely to facilitate participation in the science sector, while the team grant is expected to facilitate research, thereby impacting the intensive margin of science. The expected impact of both grants on migration is not clear cut, but the individual grant might be expected to encourage emigration, while the team grant discourages emigration. In light of these ambiguities, I now turn to providing empirical estimates of the response in these outcomes to the income and/or reputation shock provided by the grants.

4 Empirical Framework

In this section I describe the quasi-experimental approaches I employ to estimate the causal effect of the two grants on scientists' outcomes: regression discontinuity (RD) and difference-in-differences (DD) approaches for the individual grant that provided immediate aid of $500 to scientists, and matching techniques within a DD framework for the team grant that provided support of $1,000 to the best scientists (all who submitted applications for the individual grant) to distribute among their research team members.[16]

As discussed earlier, because grant receipt is likely to be correlated with ability or other unobserved factors, simple estimates of the impact of the grant would be biased due to selection problems. Because of the eligibility rules, I can avoid these selection issues by exploiting cutoffs for each grant around which grantees and non-grantees look very similar, and thus creating a suitable comparison group for the treatment group. Selection was determined by productivity of the applicant scientists, based on their publication activity and impact factors from the ISI's Journal Citation Report (see Appendix A.3 for details on the impact factor scores).

The cutoff for receiving a $500 grant was chosen as "3/5": 3 articles published in preceding 5 years (1988-1993) in international journals covered by the ISI Web of Science or a list of qualifying Russian journals (listed in Appendix Table B1). Approximately

[16]The ISF grant application states that the winner would be asked by the ISF to provide a list of up to 4 additional research personnel with the amount requested for each person, up to $300. To avoid corruption issues, the applicant would not name administrative superiors or immediate relatives.

26,000 grants of $500 awarded. In addition, supplementary support of $1,000 was given to approximately 2,000 research teams led by researchers with the highest impact factors in each scientific field (based on 3 articles with the highest impact factor scores). The impact factor scores were calculated by the ISF staff using the journal impact factors listed in the 1992 ISI Journal Citation Report. In order to receive the individual grant, scientists had to submit an application in which they listed their 3 publications. If they had the qualifying number of publications and certified the criteria discussed in Section 2.2 with their signature, they automatically received the individual grant.

4.1 Individual Grant

To estimate the causal impact of the $500 individual grant, I compare the outcomes of scientists who just missed and scientists who just met the "3/5" eligibility cutoff of 3 publications between 1988-1993.[17] I do this to avoid selection issues that arise because of correlation between grant receipt and observed or unobserved factors, and the cutoff provides a source of exogenous variation in grant receipt. Scientists who just missed or made the "3/5" cutoff are likely to be very similar in observable and unobservable ways, but they only differ in treatment status (their receipt of the grant). I could define the scientist just at the "3/5" cutoff in a number of ways. One comparison is between those who had 2 publications vs. 3 publications between 1988-1993. However, one publication represents an arguably large difference in productivity during the eligibility period. Thus, the group of scientists with only 2 publications between 1988-1993 are likely to be different from scientists with 3 publications in terms of observed productivity or unobserved factors. Therefore, in order to compare scientists who are as similar as possible but only differ in grant receipt I use the *timing* of the 1st qualifying publication.

As an example, consider two physicists, about the same age, with similar areas of specialty, living in Moscow in 1993. Physicist A published 1 article in 1988 and 2 articles in 1992 in top qualifying journals.[18] Physicist B published 1 article in 1987 and 2 articles in 1992 in similar journals. Physicist A was eligible for the individual cash grant because she had 3 publications between 1988-1993, while Physicist B was not eligible. Physicist

[17]Figure B1 in Appendix B shows the distribution of publications in the 1988-1993 eligibility period in the full scientist sample described in the next section. The median is 4.

[18]These individuals may have published in journals that didn't qualify based on the ISF criteria. These would have been less prominent Soviet/Russian language journals.

A and B are very similar in many ways, but the year in which they each published their 1st qualifying publication (1987 vs. 1988) determined whether they were eligible to receive the grant.[19]

4.1.1 "Fuzzy" Regression Discontinuity Approach

The first approach I use is a "fuzzy" RD design, which relies on a discontinuity in the probability of receiving the individual grant when the year of the 1st qualifying publication is 1988. The intuition for this approach is to use the year of the 1st qualifying publication as the "running" variable (also called the "assignment" or "forcing" variable).[20] The "running" variable determines treatment status if there is a discontinuous jump in the probability of treatment at the cutoff (here 1988), but all other factors should evolve smoothly at the cutoff (Lee and Lemieux, 2010). Figure 3 provides an example of how the running variable is constructed and how it relates to grant eligibility.

The RD is analysis is "fuzzy" in this case because there was imperfect take-up of the program, i.e. not all eligible scientists applied for the grant.[21] Moreover, some scientists in my sample below the 1988 cutoff received the grant.[22] Therefore, the jump in the probability of grant receipt is less than one at the 1988 cutoff. As described in Lee and Lemieux (2010), in this case I can use the year of the 1st qualifying article as an instrument for receiving the grant in order to obtain an estimate of the "Treatment-on-the-Treated" (TOT). I use an instrumental variables (IV) framework for the "fuzzy" RD design and a local linear regression (LLR) specification, where I predict grant receipt using the discontinuity at 1988 for the year of the 1st qualifying publication. Then I use the predicted probability of grant receipt to estimate the treatment effect on scientist

[19] I could also define the cutoff as the year of the *3rd qualifying publication* with the cutoff around 1993. However, since the grant program was announced in early 1993 and applications were accepted for several months after the announcement, using this cutoff introduces the possibility that individuals were able to manipulate the running variable. This could occur if individuals submitted articles to qualifying journals for publication after learning about the eligibility requirements in order to meet the "3/5" cutoff, but otherwise would not have published the article until after 1993.

[20] Figure B2 in Appendix B shows the distribution of scientists across the running variable.

[21] Appendix Table B2 shows the results of an OLS regression predicting grant receipt among individuals who qualified for the grant with 3-10 publications during the 1988-1993 qualifying period. The coefficients on the covariates show that there was some selection in who applied for the grant, but not as much as might be expected. Grantees were less productive, but the coefficients are very small. Fewer chemists applied for the grant. Russians and Ukrainians were mush more likely to apply.

[22] This arises due to imperfect name matching or other sources of error in the construction of the running variable using data available from the Web of Science database rather than using the publications listed on the original applications, which were destroyed after ISF activities ended.

outcomes. The LLR specifications for scientist i are:

$$Grant_i = \lambda + \delta AboveCut_i + \gamma AboveCut_i * (\Upsilon - 1988)_i + \tau(\Upsilon - 1988)_i + X_i\psi + \eta_i \quad (4)$$

$$y_i = \alpha + \beta Grant_i + \phi AboveCut_i * (\Upsilon - 1988)_i + \pi(\Upsilon - 1988)_i + X_i\theta + \varepsilon_i \quad (5)$$

where $Grant_i$ is receipt of the individual cash grant, $AboveCut$ indicates whether the year of the 1st qualifying article is after 1988, Υ is the year of the 1st qualifying article so that $\Upsilon - 1988$ is the distance from the cutoff in years, y_i is either number of publications, the outcome of staying in science (y=1 if publications during the period are greater than 0, y=0 otherwise), migrating conditional on staying in science (y=1 if a scientist has at least 1 publication with a foreign affiliation, y=0 otherwise), and X_i are individual covariates, such as age. The coefficient β will reflect any impacts associated with receipt of the grant.

Typically, in RD designs it is assumed that the running variable is continuous. However, as Lee and Card (2008) discuss, there are many situations when the running variable is discrete, often in months or years, which raises a number of issues regarding the estimates obtained with an RD design. The key issue is that when the running variable is not continuous, it is not possible to compare individuals in small bins around the cutoff. In this case, the running variable in years, so it is discrete.[23] Lee and Card (2008) propose introducing random specification errors into the model by including a grouped error component for different values of the running variable. I implement this by clustering the standard errors by each value of the year of the 1st qualifying publication.

4.1.2 Difference-in-Differences Approach

In the second approach, I exploit the panel nature of the data by using scientist fixed effects models. Here, I only compare scientists like Physicist A and Physicist B right around the 1988 cutoff: I compare scientists who were just eligible for the grant by having 3 publications between 1988-1993 and one publication in 1988, with scientists who just missed being eligible by having 2 publications between 1988-1993 and one publication in 1987.

[23] It is possible to construct a more continuous measure of the running variable by using the month or quarter of publication. However, not all journals are published monthly, and this analysis would be based on a much smaller subset of my sample.

Using a panel of these scientists' publications and locations, which I describe in the following section, I then use a difference-in-differences (DD) framework to estimate the impact of the grants on productivity. In particular, to estimate the impact of the grant on publications y for scientist i in year t, I estimate the following regression:

$$y_{it} = \alpha + \beta_1 AboveCut * Post93_{it} + \beta_2 Post93_{it} + X_{it}\delta + \rho_i + \lambda_t + \varepsilon_{it} \tag{6}$$

where *Post93* is an indicator for years after 1993, *AboveCut*Post93* is an indicator for years after the grants were distributed for the eligible scientists, X_{it} are time-varying covariates (i.e. age), ρ_i are scientist fixed effects, and λ_t are calendar year fixed effects. The coefficient of interest, β_1 will reflect productivity changes attributed to the grant. Note that since not all scientists who met the 3 publication eligibility criteria submitted an application for the grant, β_1 is an estimate of the "Intent-to-Treat" (ITT), which can be considered a lower bound of the effect of the grant program.

Since the dependent variable in this regression is publication counts, a skewed non-negative variable, I also estimate conditional quasi-maximum likelihood (QML) estimates of the fixed effects Poisson model (Hausman et al., 1984). As described in Azoulay et al. (2010), I calculate QML "robust" standard errors, for which the concerns regarding standard errors in conventional DD estimation due to serial correlation in outcomes pointed out by Bertrand et al. (2004) are not applicable.

I also estimate OLS regressions of the following form to estimate the impact of the grant on the probability of discrete scientist outcomes, where for scientist i:

$$y_i = \alpha + \beta AboveCut_i + X_i\delta + \varepsilon_i \tag{7}$$

and y is either the outcome of staying in science (y=1 if publications during the period are greater than 0, y=0 otherwise), migrating (y=1 if a scientist has at least 1 publication with a foreign affiliation, y=0 otherwise), and X is a vector of individual characteristics.

4.2 Team Grant

For the team grant analysis, I exploit the impact factor score cutoff to find a suitable comparison group for the treatment group. In this case, I use matching methods based on observables, including the impact factor score calculated for each scientist, to create a control group among the non-team grant recipients. By recipient of the team

grant, I mean the leader of the research team (the one who qualified for the $500 grant by having 3 publications between 1988-1993), not the team members themselves.[24]

Note that it would also be appropriate to also use an RD design to estimate the impact of the team grant using the score calculated from the impact factor of each scientist as the running variable. However, the number of scientists in each field receiving the team grant was small, so there is not a large mass around each of the cutoffs. Moreover, while I could re-center the cutoffs to obtain a larger mass, the original scores used for the cutoff were destroyed, so determining the exact cutoff introduces considerable error. Since all team grant recipients submitted an application for the $500 grant, I argue that there should not be selection on unobservables into the treatment group, making the use of matching methods more appropriate than in other situations.

I use a nonparametric matching method, "Coarsened Exact Matching" (CEM) (Blackwell et al., 2009), which has been used in the recent economics of science and innovation literature to create matched control grops for scientists, articles, and patents (e.g. Azoulay et al., 2010; Singh and Agrawal, 2010). As Blackwell et al. (2009) describe, the basic approach of CEM is to temporarily coarsen each covariate used in the matching process,[25] create unique strata based the coarsened values of the covariates, assign each observation to a stratum, and then drop any observations in strata in which there isn't a control observation for each treatment observation. Note that this implies that any treated observation for which there is no control observation in the strata are dropped. At the end of the process, we are left with an equal number of treatment and control observations that are balanced on the covariates.

In this case, CEM is preferable to exact matching techniques because of the role of the impact factor cutoff. Since I want to find control scientists who look similar to the team grant recipients in all respects except that they *just missed the impact factor cutoff*, this implies that the team grant recipients should have slightly higher impact factor scores than the control scientists. By matching on the coarsened impact factor score, previous publications, career age, location, and field, I am able to identify a control scientist for each team grant recipient who is very similar in observables apart from a slightly lower impact factor score.

[24]The team member names were not listed in the ISF documents at the Open Society Archives.
[25]With cutpoints that are user-defined or defined using CEM's automatic binning algorithm

After creating a sample of treatment and control scientists, I then use the DD framework as described in Section 4.1.2 and estimating questions (6) and (7), where $AboveCut$ is now $TeamGrant$, to estimate the impact of the team grant on the outcomes of interest.

5 Data

5.1 Scientist Data

For the individual grant analysis, I created a scientist-year level dataset using data from the Thomas Reuters ISI Web of Science. I first identified a sample of scientists who were "doing science" in one of the former Soviet republics around the time of the grant program. To do this, I took the list of Russian language journals provided by the ISF as "eligible" journals with high impact factor scores (>0.05) and extracted all author names for articles published between 1986-1994 (see Appendix Table B1 for the list of qualifying Russian/Soviet journals). Then, I identified the subset of authors who had one article in 1992 or 1993 with an address in the former Soviet Union. While there is no way to know for certain whether some of these scientists had already emigrated by 1993, they would likely be the more productive scientists, which would tend to downward bias my estimates. Appendix A provides further information on the sample construction. Table 1 provides summary statistics for the full sample of scientists. About 50% of the sample received the individual cash grant. The largest shares of scientists are in Chemistry, the Life Sciences, and Physics. Almost half of the scientists were located in Moscow.

Next, I identified the scientists in the sample who received the ISF grants. Data on grant recipients who were in the former USSR in 1993 and submitted an application for the $500 grant comes from grantee lists obtained from the archives of the ISF held at the Open Society Archives in Budapest, Hungary. I was able to find 82% of the ISF grant recipients in the sample extracted from Russian language journal (23,083 out of 28,139). The discrepancy arises from spelling issues or because some grantees didn't publish in Russian language journals, but rather only in international journals. Information for over 26,000 grantees of the $500 individual cash grants include each scientist's full name (first, patronymic[26], last), country, city, scientific field, and gender (based on patronymic

[26] A middle name based on ones father's name commonly used among Slavic language speakers. For males, the name

names). Since the ISF ended operations in 1999, many official records were destroyed, including some information about grantees. While complete characteristics for all scientists in the sample are not available, additional information is available for subsets of scientists. The most important characteristic missing for some scientists is age, which is available for scientists in 5 of the 15 former republics. Because age is missing for so many researchers, I use career age (date of first publication in the database) as a proxy.

Finally, I limit the sample to the scientists who had published 2 or 3 articles between 1988-1993 for the individual cash grant analysis to obtain a sample of scientists who just missed the 3 publication cutoff. For the team grant analysis, I matched the team grant recipients to control scientists from the full grantee dataset.

5.2 Publication and Affiliation Data

The scientists are matched to publication and affiliation data primarily using the Thomson Reuters ISI Web of Science (hereafter ISI) database. I also match physicists, mathematicians and astronomers to publications in the SAO/NASA Astrophysics Data System (ADS) Abstract Service as a robustness check. The ISI database includes over 100 top journals of the former USSR and Russian language journals. The ISI includes journal backfiles to 1900, however journals entered the database at different times. By the 1970s, most of the Russian journals in the database in later years had entered the database. The ISI database played a prominent role in the eligibility for ISF's grant programs. The ISF announced that it would use publications which appeared in the 1992 ISI database for the $500 grant eligibility cutoff, and impact factors from the 1992 Journal Citation Report for the $1,000 cutoff. However, some key journal backfiles are not in the database, nor are some less-known or highly specialized journals.[27] Finally, I digitized the impact factors for journals using the 1992 Journal Citation Report. As described in the ISF documents, I recreated the impact factor score for each scientist by summing the impact factors for the 3 articles published from 1988-1993 with the highest journal impact factor.

The final panel dataset includes publication data for each scientist from the year

ends in either -evich, or –ovich; for females, the name ends in -ovna, or -evna. In formal settings, Slavic language speakers are always addressed by their first and patronymic names. Because of this custom, scientists typically publish using their first and middle initial, although this has become less common in recent years due to different journal styles.

[27]To check the completeness of the publication data and to gather additional outcome variables, I have done internet searches for a subset of scientists and searches using other publication databases like Scopus and Google Scholar.

they first enter the ISI database through 2008. I limit the sample to 1978-2003 for most of the analysis to ensure that a large share of the scientists are in the sample for the majority of years.

6 Results

6.1 Individual Cash Grant

Tables 2 and 3 show the summary statistics for the sample of scientists just below (control) and just above (grant eligible) the 3 publication cutoff in terms of the year of the 1st qualifying publication. It is clear that the group below the cutoff looks very similar to the group eligible to receive the grant. The only significant difference is that there are almost 7 percent more grantees who come from Russia. In terms of their previous publication record from 1978-1986, the average for both groups is relatively low, around 4 publications per scientist. Most of the scientists come from Russia, which is in line with the distribution among the larger grantee sample. A large share of the scientists are physicists, which is also similar to the distribution in the larger sample. Both groups had their first publication in the ISI database around 1976, 17 years before the ISF grant program. Thus, these scientists are older, already established researchers.

First, I provide graphical analysis of the RD results. Figure 4 shows the discontinuity around the 1988 cutoff - it is a plot of the share of scientists receiving the individual cash grant by the year of the 1st qualifying article. Although the share of eligible scientists receiving the grant is only 25% at 1988, there is a sharp increase in grant receipt at this threshold.[28] Figure 4 shows that crossing the 1988 cutoff increases grant receipt by 15 percentage points. Figures 5a and b show career age and pre-grant publications (1978-1983) around the cutoff. These show that there are no jumps in the covariates around the cutoff. The differences at the 1988 cutoff are not significant when estimated with LLRs. Table 3 also shows that the means of the covariates for scientists just below and just above the cutoff are not significantly different.

Figure 6 shows the main effect for articles published in the period shortly after the grant was disbursed, from 1994-1997. This shows the reduced form effect, with a

[28]Appendix Figure B3 shows the share of scientists receiving the grant by 1/2 year rather than yearly bins, a more continuous measure. However, only 40% of the sample has information on the month of publication attached to the 1st qualifying publication, so all further analysis is done using yearly bins. Appendix Figure B4 shows the "other side" of the cutoff around 1993.

jump of approximately 0.4 publications at the cutoff. Scaling this up by 6.6 (1/0.15) gives a TOT of 2.6 publications. Figure 7 shows the effect of the grant over time. It plots the fuzzy RD estimate of the impact of grants on publications averaged over 2 years. Before the 1993, there was no significant difference in publications, but after 1993, the grantees had approximately 0.5 publications more on average than the non-grantees over 2 years, with the effect peaking in 1999-2000. By 2005-2006, the effect is again not significantly different from zero, but it appears that there is some impact that continues into 2007-2008, suggesting that the grant had long run impacts.

Before presenting the fuzzy RD estimates, I first present a placebo test to show that the discontinuity at the 1988 cutoff is not driven by choice of the running variable and the way in in which it is constructed. For this test, I replicated the process used to create the running variable (as exhibited in Figure 3), except that the sample included individuals who just missed having 4 publications during the 1988-1993 qualifying period rather than 3. We would not expect a discontinuity in grant receipt nor in subsequent publications around this 1988 cutoff, since all individuals around the cutoff were eligible for the grant. Figure 8a shows that there is no jump in grant receipt at 1988 (unlike in Figure 4). Figure 8b shows that the mean publications after the grant program from 1994-1997 do not increase above the 1988 cutoff (unlike in Figure 5).[29]

The fuzzy RD estimates for the outcomes indicated in each row are shown in Table 4. The baseline means for those scientists just below the cutoff (1st qualifying publication in 1987) are presented as a reference. The RD estimates show that the individual grant is associated with large and significant impacts on the number of publications (combines extensive and intensive margin). Publications from 1994-1997 increase by 1.9 publications from a baseline of 1.7, and from 1998-2002 by 2.9 from a baseline of 1.9. The grant more than doubles the number of publications around the cutoff in the short run. The total effect from 1994-2002 is an increase of 4.8 publications on average from a baseline of 3.5. A rough calcuation shows that the total increase in publications from 1994-2002 for individuals right on the margin was approximately 700, which means Soros and the ISF spent about $100 per publication.[30]

[29]There is no effect of the grant in the IV regression estimate corresponding to this graph.

[30]This calculation is based on the 141 grant recipients who had their first qualifying publication in 1988 and 2 additional publications from 1989-1003 (26% of the 543 individuals who just reached eligibility). For these 141 individuals, there was an increase of 683 publications that can be attributed to grant receipt (141x4.84), with a cost of $70,500 (141x500), or

There are also significant impacts on staying in science (extensive margin) in the longer run. The rate of staying in science from 1998-2002 rises by 40 percentage points from a baseline of 50 percent. Table 4 shows that the grant also had an impact on publications conditional on staying in science, or on the intensive margin. Moreover, the grant also had an impact on citations, which accounts for the varying quality of publications. Both conditional publications and citations to publications by grantees (averaged across all publications by the grantee) increased in the short run (1994-1997) relative to non-grantees. This suggests that conditional on staying in science, grantees may have exerted more effort or spent more time doing science.

Based on the discussion of the expected impact of the grant in Section 3, we would expect heterogeneity by the location of scientists. In places where the non-science sector wage is higher, the grant would be expected to have a smaller effect. Moreover, in a setting with more alternative funding opportunities for researchers, we would also expect the grant to have a smaller effect. To measure heterogeneity by location, I estimate the impact of the grant separately for scientists located in Moscow in 1993 and scientists located outside of Moscow.

I focus on Moscow for several reasons. The cost of living was higher in Moscow, so the $500 was likely to be worth less to recipients in Moscow. As the economic situation in Moscow was relatively better than in other parts of the former USSR, there were probably more viable non-science career options. Moreover, being the historic center of decision-making and with more visibility among e.g. international organizations, scientists in Moscow were more likely to have alternate funding opportunities than in other parts of the former USSR. Finally, regarding emigration, we would also expect heterogeneity in the impact of the grant due to differing migration costs in Moscow. With the main international airport and most embassies located in Moscow, the costs of travel and visa would be lower for Moscow residents.

Table 5 presents the RD estimates for the Moscow and non-Moscow samples separately. While the effect on publications is similar in the short run, in the longer run, the effect on the number of publications is much larger for non-Moscow scientists and the effects are no longer significant when the sample is restricted to Moscow residents. On

$103 per publication.

the extensive margin, we see that there is no impact of the grant on staying in science is Moscow, but the effect is large outside of Moscow.

The impact on migration was not significant overall, but when I restrict the estimation to only those individuals in Moscow, the grant has a negative effect on emigration. The rate of migration among those who stayed in science[31] decreased by 32 percentage points. In other words, in Moscow at least, the grant seems to have prevented "brain drain". Moscow residents were more likely to have opportunities to travel and have access to information from the West, which is most likely why the grant played a role there versus in other areas where there were fewer opportunities to migrate.

Next, I turn to the panel analysis using scientist fixed effects and restricting the sample to the scientists who were 1 year around the cutoff. Graphs of the mean publications for these scientists are shown in Figure 9.[32] The solid line represents the grant-eligible scientists with 3 publications between 1988-1993 and one publication in 1988. The dashed line represents the scientists who just missed the publication cutoff, with 2 publications between 1988-1993 and one in 1987. The graph shows that after 1993, when the grants were distributed, there is a notable increase in mean publications for the Grant Eligible scientists.

As a test to rule out that the increase after 1993 is not a result of the way the sample was constructed, Figure 10 provides a placebo test using a sample constructed based on a mock "eligibility" window 10 years prior, from 1978-1983.[33] We would not expect any differences in productivity after 1983 among scientists who published one article in 1977 and one in 1978, as there was no treatment at this time that would differentially affect scientists around a 1978 cutoff. Figure 9 shows that mean publications do not appear to increase after the placebo window, unlike after the actual eligibility window.

The main regression results corresponding to Figure 9 are presented in Table 6. Table 6 shows results for the DD estimates with OLS as well as the fixed effect Poisson models with scientist fixed effects. Column 3 in Table 6 shows that the interaction

[31] Since migration is determined from a change in affiliation, which comes from publication data, I can only estimate the probability of migration conditional on staying in science.

[32] Figure B5 in the Appendix shows the means for years prior to 1992. See Appendix A for explanation about how the jumps in the means in the eligibility periods are artifacts of the sample construction.

[33] Figure B6 in the Appendix shows the means for years prior to 1982. See Appendix A for explanation about how the jumps in the means in the eligibility periods are artifacts of the sample construction.

between having 3 publications (above the cutoff) and the post-grant period is positive and significant: being eligible for the grant increases the rate of publication by 20 percent per year.[34]

In Table 7, I show the DD estimates including an interaction term allowing the grant to have a different impact in Moscow. Columns (1) and (3) show that the increase in the publication rate attributed to grant eligibility is much larger outside of Moscow, which in is line with the RD results. The Poisson results in Column (3) show that publications among grant-eligible scientists were 37% higher than non-eligible scientists.

I also present estimates of the impact of the grant on the discrete outcomes (staying in science and migration) from the DD sample in Table 8. With a smaller sample and because I estimate the ITT here rather the TOT, few results are significant in this analysis. However, confirming the key results from the RD analysis, I find that outside of Moscow, the grant induced individuals to stay in science.

Viewed together, both the RD and DD estimates show that the individual cash grant had an impact on publications, particularly outside of Moscow. The RD estimates which provide measures of the TOT are larger, while the panel estimates can be thought of as a lower bound, as they estimate an ITT. The impact on migration is only significant in the RD analysis, which is based on a larger sample of scientists.

6.2 Team Grant

The summary statistics for the matched sample of team grant winners and non-team grant winners are shown in Tables 9 and 10. Each grant winner was matched to a non-grant winner using CEM based on the impact factor score, pre-1988 publications, 1988-1993 publications, career age, scientific field, and republic.[35] The covariates in Table 8 are very similar across the two groups. We would expect the impact factor score to be higher among the team grantees, since it was used as the selection criteria.

Figure 11 shows the pre- and post-grant publication mean trends for the team grant winners and non-grant winners. The trends are very similar up to the grant program in 1993 and then the treatment effect is visible around 1995. The DD scientist fixed effect

[34] The Poisson estimates are interpreted as a (e^{β}-1)x100 percent change in the dependent variable, so being grant eligible is associated with a ($e^{0.184}$)x100 =20% increase in publications.

[35] Age is coarsened into 3 strata; pre-1988 and 1988-1993 publications are coarsened into 5 strata each (0 to 50th, 50th to 75th, 75th to 90th, 90th to 95th, and above the 95th percentile); the impact factor score is also coarsened into 5 strata (0 to 60th, 60th to 75th, 75th to 90th, 90th to 95th, and above the 95th percentile).

estimates corresponding to this graph are shown in Table 12. Columns (1) and (3) show that receiving the team grant led significantly more publications (8.3% more based on Poisson estimates).

There were no significant effects of the team grant on staying in science, which is not surprising considering that the treatment and control scientists are all top scientists who would have incentives and a preference for staying in the science sector. Table 12 shows that the team grant had an impact on the likelihood of migration. Column (1) shows a 5.7 percentage point increase in the rate of emigration for team grant recipients. However, the impact does not vary depending on whether the scientists was in Moscow or outside of Moscow, like the individual cash grant, as shown in Column (2). In Column (3) I include an interaction term with the field of Chemistry, and the effect is larger for the non-Chemistry fields and smaller for Chemistry. This suggests that the impact varied by field.

More investigation into the impact of the grant is needed to determine how it leads to greater emigration rates. In order to see how the team grant may have affected the team members themselves, I examined the outcomes of "potential" team members, since I do not know the names of the actual team members who received the grant payments. I identified these potential team members by taking the coauthors of team grant recipients and limiting the sample to those scientists who published just one article before 1993 in either 1992 or 1993. This ensured that the team members were not individual cash grant recipients and that they were likely young scientists, rather than well-established scientists who would have their own research groups.

Due to these restrictions, the sample size was small (N=456). The regression results in Table 13 show that there is significant difference among the "potential" team members of the team grant recipients and controls in their probability of staying in science in the short run, but not in the long run. There is a 11.9 percentage point increase in staying in science from 1994-1997 among team members whose leader received the grant (Column 1), but no significant difference from 1998-2002. This result is consistent with the story that the grant induced team members to stay in science in the short run, which increased the team leader's productivity due to complementarities in team production of research. Later, when we observe an increase in emigration among the team leaders

who received the grant, we no longer see an effect on the team members. There were no differences in migration, unlike the finding for the team leader, but the sample size is very small, since the sample is further restricted to those who stay in science.

7 Conclusions

In this paper, I estimate the impact of grants on scientific output and scientists' decisions in the former Soviet Union, a country that once had a very large scientific labor force and R&D budget. The end of the Soviet Union in 1991, and the subsequent crisis that followed, essentially ended public funding for the Soviet science sector and scientists' salaries. Unlike studies of the impact of research funding in developed country contexts, this setting allowed me to estimate the impact of grants when there are few alternate funding opportunities for scientists and the supply of scientists is elastic.

I show that individual and team-based grants impact scientist outcomes on the intensive and extensive margins, and affect "brain drain". I find that the individual cash grant more than doubled publications on the margin and prevented scientists from exiting science. In spending \$500 per grantee, the increase in publications that can be attributed to grant receipt roughly translates to Soros and the ISF having spent approximately \$100 per publication. The individual cash grant also appears to have prevented emigration in Moscow among scientists who remained in the science sector. Meanwhile, the team grant led to an increase in the team leader's publications on the margin and led to an increase in emigration conditional on staying in science. It appears that the team grant may have induced team members to stay in science, which points to the channel through which the team leader's productivity increased. However, more investigation is needed to understand how the grant led to increased emigration, but it is likely that sustaining researcher productivity in the short run kept the door open for subsequent emigration possibilities.

My findings add to the limited evidence on the impact of grants on researcher productivity and "brain drain", and suggest that in resource-constrained settings where there are very few alternative funding opportunities, grants can have an large impact and the supply of scientists is very elastic. However, when there are alternative funding opportunities or higher wages, like in Moscow in my analysis or has been shown in the

US, it is difficult to document the causal impact of funding even when the funds are known to be critical for research.

While the collapse of the Soviet Union was a unique historical event, there are insights from this paper for policymakers in a variety of settings. The evidence shows that grants matter for scientific productivity and there is a part of the scientist supply curve that is very elastic. It also shows that foreign aid can have a real impact on the production of scientific knowledge in developing countries and can impact "brain drain", but the impact may vary depending on the type of individuals being targeted. Moreover, the analysis shows that the structure of the grants are important, and that there are complementarities in the team production of research. I believe the evidence I provide can help inform policymakers about the ways that scientists' decisions can be influenced and ways to support the science sector, especially after sharp economic changes, in order to sustain scientific productivity and impact long-term economic growth.

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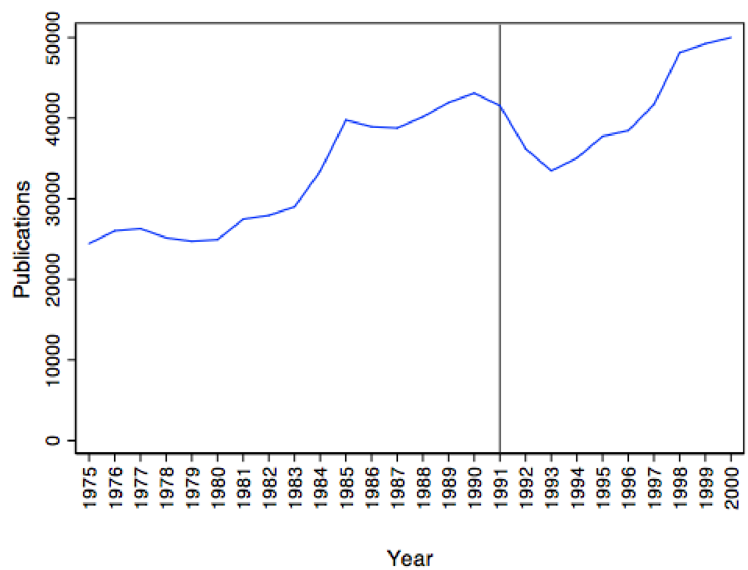
Figure 1: Russian R&D Funding, 1990-2001

Notes: This figure shows the trend in total R&D funding in Russia. Data comes from the 2004 Science & Engineering Indicators.

Figure 2: Total Publications in (Former) USSR Countries, 1975-2000



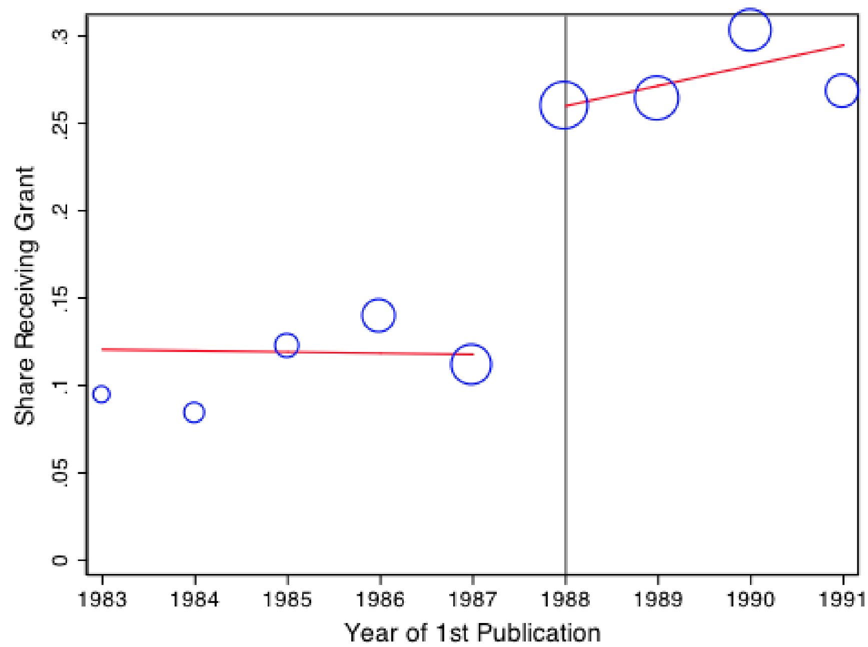
Notes: This figure shows the trend in the total number of publications with an address in the (former) USSR in the ISI/Thomson Reuters Web of Science database. The vertical line indicates the end of the USSR in 1991.

Figure 3: Example of Grant Eligibility & Year of 1st Qualifying Publication

Scientist	Publications†				Total Qualifying Publications	Grant Eligible
	1986	1987	1988	1989		
A			0	1	3	Yes
B			1		3	Yes
C		1			2	No
D	1	0			2	No

†The value of the “running” variable used in the regression discontinuity analysis.

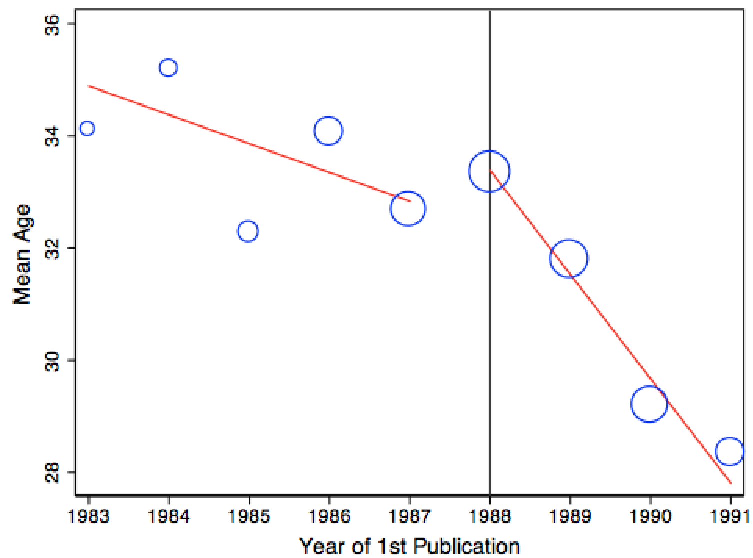
Figure 4: Share Receiving Individual Grant by Year of 1st Qualifying Publication



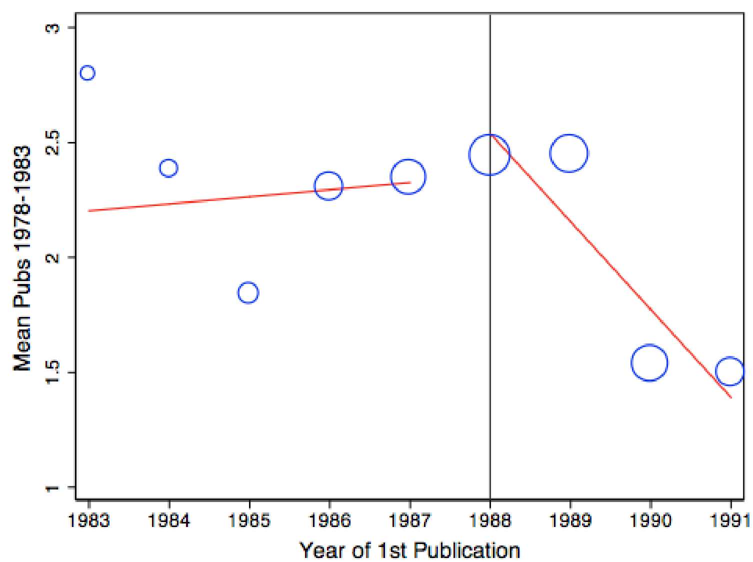
Notes: Each dot represents the share of scientists receiving the $500 individual grant. The size of the dots represent the distribution of scientists across the running variable, the year of the first of the 3 qualifying publications. The line through the dots represents a linear prediction weighted by the number of observations in each year that varies on either side of the cutoff for years 1983-1991. The vertical line represents cutoff before which scientists did not qualify for the grant. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

Figure 5: Selected Covariates by Year of 1st Qualifying Article

(a) Age

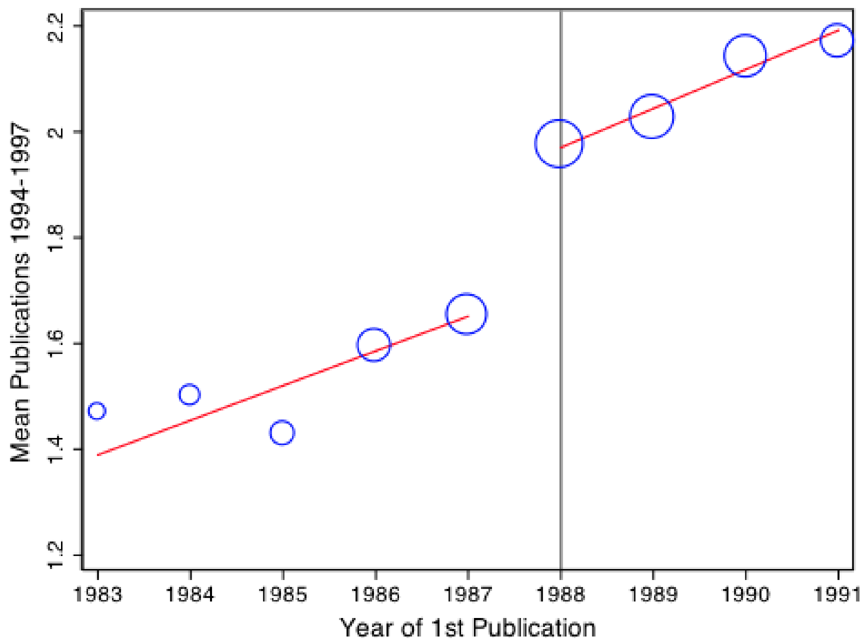


(b) Pre-Grant Publications (1978-1983)



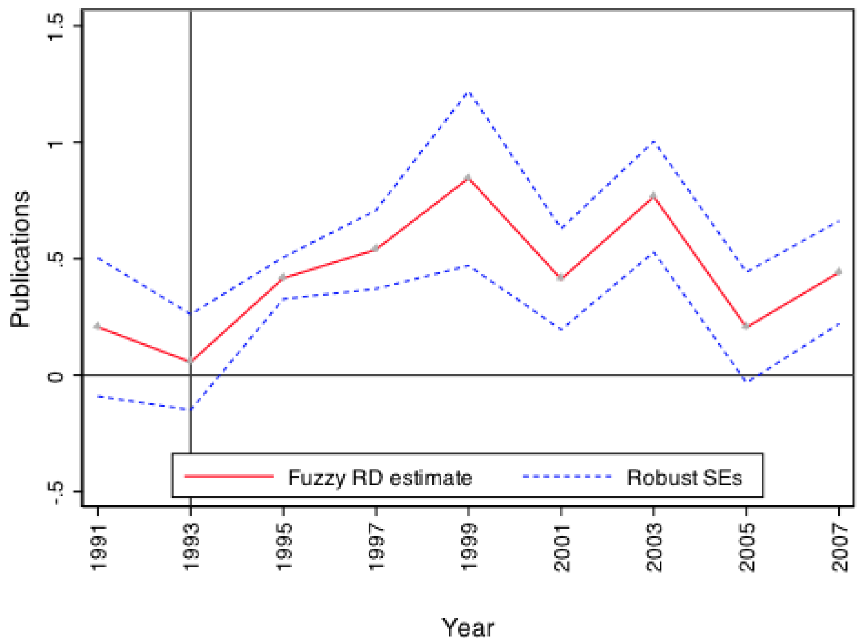
Notes: Each dot represents for (a) the mean career age and (b) the mean number of cumulative publications 1978-1983 of scientists in each year. The size of the dots represent the distribution of scientists across the running variable, the year of the first of the 3 qualifying publications. The line through the dots represents a linear prediction weighted by the number of observations in each year that varies on either side of the cutoff for years 1983-1991. The vertical line represents cutoff before which scientists did not qualify for the grant. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

Figure 6: No. of Publications 1994-1997 by Year of 1st Qualifying Article



Notes: Each dot represents the mean number of cumulative publications 1994-1997 for scientists in each year. The size of the dots represent the distribution of scientists across the running variable, the year of the first of the 3 qualifying publications. The line through the dots represents a linear prediction weighted by the number of observations in each year that varies on either side of the cutoff for years 1983-1991. The vertical line represents cutoff before which scientists did not qualify for the grant. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

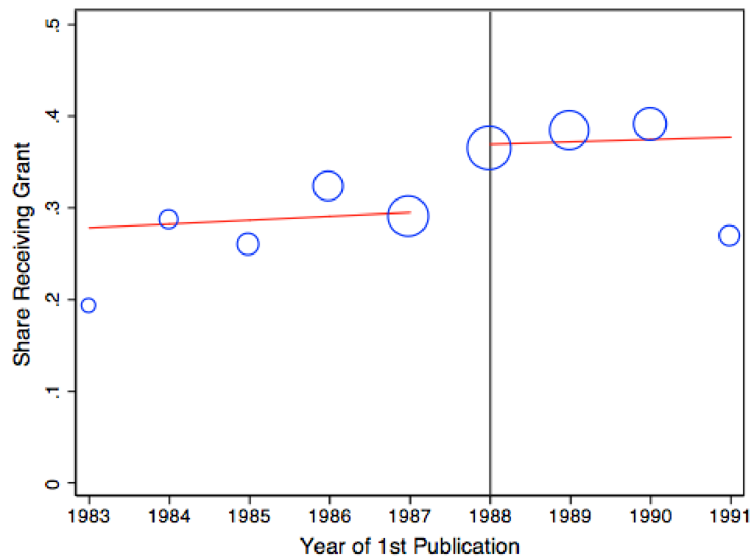
Figure 7: Fuzzy RD Estimates for Publications Over Time (2 Yr Averages)



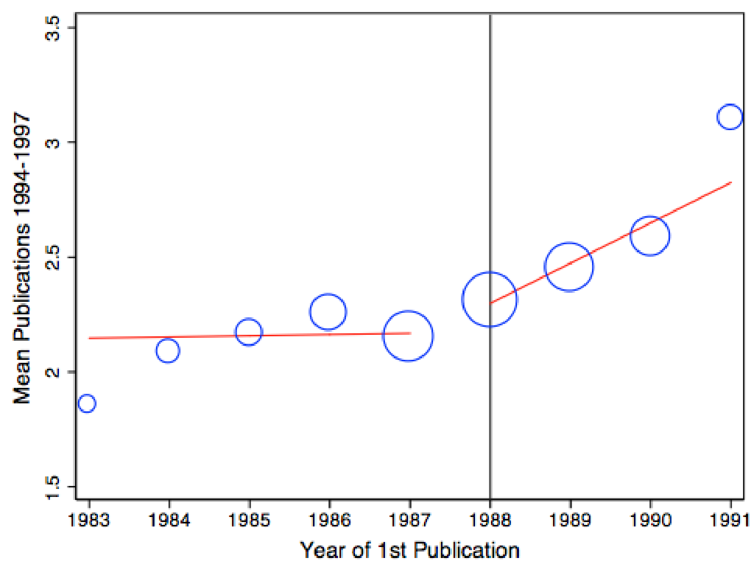
Notes: Each point is a fuzzy RD estimate of the effect of the individual grant on publications averaged over 2 years as specified in Section 4 in the text for running variable (year of the first qualifying publication) values 1983-1991. Regressions include career age controls. Robust standard errors are clustered by the year of the 1st qualifying article. See Section 5 in the text and Appendix A for a detailed description of the data.

Figure 8: Fuzzy RD Placebo Test - Eligibility Based on 4 Publications

(a) Share Receiving Grant



(b) Publications 1994-1997



Notes: Each dot represents for (a) the share of scientists receiving the $500 individual grant and (b) the mean number of cumulative publications 1994-1997 for scientists in each year. The size of the dots represent the distribution of scientists across the running variable, the year of the first of the 4 "qualifying" publications. The line through the dots represents a linear prediction weighted by the number of observations in each year that varies on either side of the cutoff for years 1983-1991. The vertical line represents cutoff before which scientists did not "qualify" for the grant. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

Figure 9: Actual 1988-1993 Eligibility Window for $500 Grant

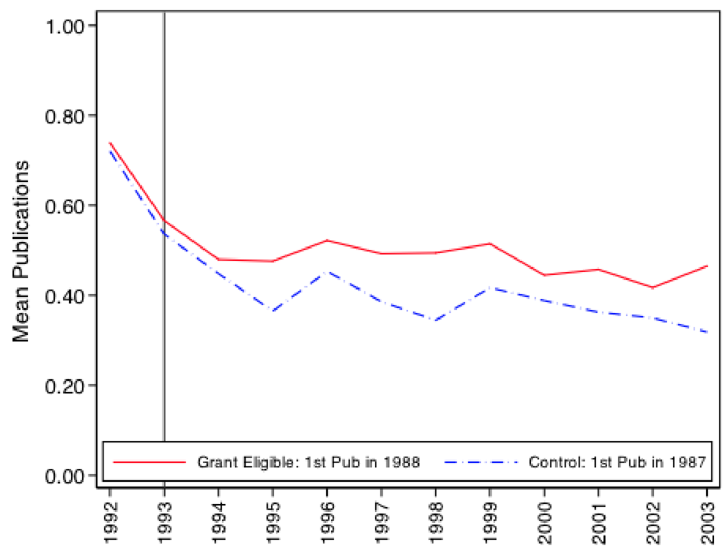
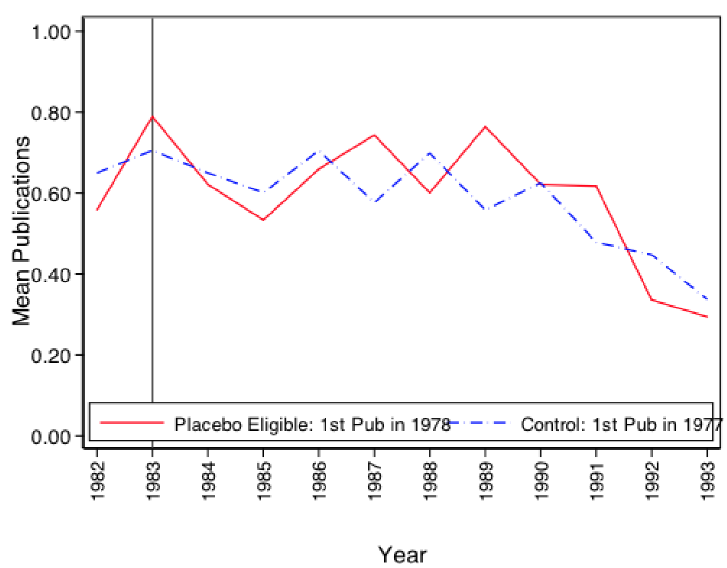
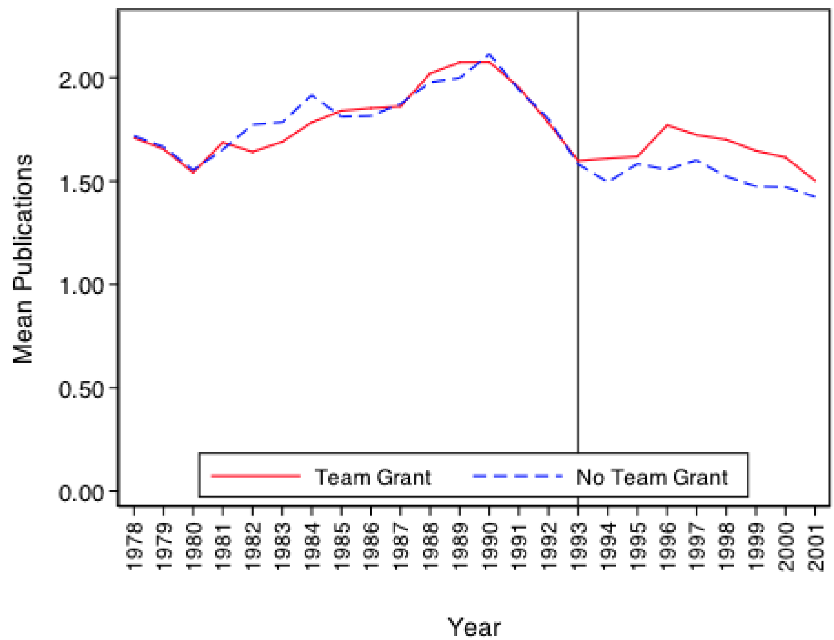


Figure 10: Placebo Test for $500 Grant: "Eligibility" based on 1978-1983 Window



Notes: See Section 5 in the text and Appendix A for a detailed description of the data.

Figure 11: Team Grant: Treatment and Control Trends



Notes: See Sections 4 and 5 in the text and Appendix A for a detailed description of the matching process and the data.

Table 1: Summary Statistics for Full Soviet Scientist Sample

	Mean	Std. Dev.	Min.	Max.
Grantee	0.523	0.500	0	1
No. Pubs 1978-1993	16.589	22.687	1	340
No. Cites 1978-1993	67.634	163.986	0	3950
Yr of First Pub	1976.653	10.937	1945	1993
Non-USSR Coau. Pre-91	0.126	0.332	0	1
Ave Coauthors 1978-1993	4.568	2.180	1	19
Field				
Astronomy	0.017	0.128	0	1
Chemistry	0.296	0.456	0	1
Earth Sciences	0.080	0.271	0	1
Life Sciences	0.205	0.404	0	1
Mathematics	0.055	0.229	0	1
Mechanics	0.005	0.068	0	1
Physics	0.342	0.474	0	1
Republic				
Armenia	0.008	0.090	0	1
Azerbaijan	0.007	0.084	0	1
Belarus	0.032	0.175	0	1
Estonia	0.002	0.046	0	1
Georgia	0.000	0.017	0	1
Kazakhstan	0.012	0.108	0	1
Kirghizstan	0.001	0.032	0	1
Latvia	0.005	0.068	0	1
Lithuania	0.005	0.069	0	1
Moldova	0.006	0.076	0	1
Russia	0.746	0.435	0	1
Tadzhikistan	0.002	0.042	0	1
Turkmenistan	0.001	0.035	0	1
Ukraine	0.121	0.326	0	1
Uzbekistan	0.038	0.191	0	1
Moscow	0.466	0.499	0	1
Observations	18121			

Notes: Summary statistics are based on scientist-level data constructed using publication data from the Thomson Reuters ISI Web of Science database. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 2: Summary Statistics for Scientists Near $500 Grant Cutoff

	Control	Grant Eligible	Difference
Grantee	0.11	0.26	-0.148***
No. Pubs 1978-1986	3.81	4.07	-0.268
No. Cites 1978-1986	10.03	12.12	-2.090
Yr of first Pub	1976.31	1975.65	0.662
Non-USSR Coau. Pre-91	0.06	0.05	0.011
Ave. No. Coau. 1978-1986	4.21	4.21	0.004
Field			
Astronomy	0.02	0.01	0.007
Chemistry	0.29	0.28	0.012
Earth Sciences	0.11	0.10	0.008
Life Sciences	0.24	0.23	0.007
Mathematics	0.05	0.06	-0.012
Mechanics	0.00	0.00	0.001
Physics	0.29	0.31	-0.023
Location			
Russia	0.64	0.71	-0.068*
Ukraine	0.13	0.12	0.019
Moscow	0.41	0.45	-0.033
Observations	386	543	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: Stars indicate the results of t-tests for the equality of means. Control indicates scientists ineligible for the grant with their 1st qualifying publication in 1987 and 2 publications 1988-1993. Grant Eligible indicates scientists eligible for the grant with their 1st qualifying publication in 1988 and 2 additional publications 1989-1993. Summary statistics are based on scientist-level data constructed using publication data from the Thomson Reuters ISI Web of Science database and grantee data from the Open Society Archives in Budapest. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 3: Outcome Variables for Scientists Near $500 Grant Cutoff

	Mean	Std. Dev.	Min.	Max.	N
Below Cutoff: 1st Qualifying Pub in 1987					
No. Pubs 1994-1997	1.653	2.135	0	14	386
No. Pubs 1998-2002	1.863	4.084	0	63	386
Stayed in Science 1994-1997	0.598	0.491	0	1	386
Stayed in Science 1998-2002	0.495	0.501	0	1	386
Migrated Anytime Post 1993	0.100	0.300	0	1	211
Above Cutoff: 1st Qualifying Pub in 1988					
No. Pubs 1994-1997	1.974	2.788	0	22	543
No. Pubs 1998-2002	2.333	4.533	0	44	543
Stayed in Science 1994-1997	0.624	0.485	0	1	543
Stayed in Science 1998-2002	0.554	0.497	0	1	543
Migrated Anytime Post 1993	0.093	0.291	0	1	301
Observations	929				

Notes: Summary statistics are based on scientist-level data constructed using publication data from the Thomson Reuters ISI Web of Science database. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 4: Fuzzy RD Estimates of Impact of $500 Grant

	Mean, Year=1987	Full Sample (1)
Above Cutoff		0.133**
		(0.030)
F-statistic		22.752
Publications, 1994-1997	1.653	1.913**
		(0.348)
Publications, 1998-2002	1.863	2.928+
		(1.356)
Citations, 1994-1997	5.008	40.805**
		(8.986)
Citations, 1998-2002	11.091	28.642
		(20.647)
Remain in Science, 1994-1997	0.598	0.077
		(0.109)
Remain in Science, 1998-2002	0.495	0.408*
		(0.171)
Cond'l Publications, 1994-1997	2.762	1.990**
		(0.441)
Cond'l Publications, 1998-2002	3.764	1.853
		(1.311)
Ave. Citations, 1994-1997	3.000	7.453*
		(2.274)
Ave. Citations, 1998-2002	3.000	4.096
		(2.247)
Migrate Post-1993	0.100	-0.119
		(0.068)
Nb. of Obs.	386	2,602

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: The first column is the mean outcome for scientists who just missed the cutoff, i.e. year of the first qualifying publication is 1987. In the second column, the first row is the first stage results predicting grant receipt. The remaining rows are the RD estimates, where each row is a separate regression coefficient on grant receipt as specified in Section 4 in the text for running variable (year of the first qualifying publication) values 1983-1991. Regressions include career age controls. Robust standard errors are in parentheses, clustered by the year of the first qualifying publication. To obtain reduced form estimates, divide the RD estimate by (1/0.13 = 7.7). See Section 5 in the text and Appendix A for a detailed description of the data.

Table 5: Fuzzy RD Estimates of Impact of $500 Grant, Moscow & Non-Moscow

	Non-Moscow	Moscow
	(1)	(2)
Above Cutoff	0.156^{**}	0.105^{*}
	(0.038)	(0.049)
F-stat	14.917	9.284
Cum. Publications, 1994-1997	1.969^{**}	1.696^{+}
	(0.219)	(0.851)
Cum. Publications, 1998-2002	3.591^{+}	1.414
	(1.728)	(1.489)
Cum. Citations, 1994-1997	44.251^{**}	32.887
	(7.372)	(22.993)
Cum. Citations, 1998-2002	35.525	10.812
	(30.588)	(37.648)
Remain in Science, 1994-1997	0.382^{*}	-0.541
	(0.127)	(0.337)
Remain in Science, 1998-2002	0.615^{+}	-0.049
	(0.291)	(0.279)
Cum. Cond'l Publications, 1994-1997	1.084	3.230^{**}
	(0.618)	(0.507)
Cum. Cond'l Publications, 1998-2002	1.387	1.801
	(2.526)	(2.244)
Ave. Citations, 1994-1997	8.839^{*}	5.869
	(3.719)	(6.648)
Ave. Citations, 1998-2002	10.628^{+}	-7.580
	(5.690)	(5.761)
Migrate Post-1993	0.041	-0.324^{**}
	(0.139)	(0.088)
Nb. of Obs.	1,457	1,145

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: The first row is the first stage results predicting grant receipt. The first column are RD estimates for the non-Moscow sample, where each row is a separate regression coefficient on grant receipt as specified in Section 4 in the text for running variable (year of the first qualifying publication) values 1983-1991. Column (2) is for the Moscow sample only. Regressions include career age controls. Robust standard errors are in parentheses, clustered by the year of the first qualifying publication. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 6: Fixed Effect Model Estimates of Impact of $500 Grant

	OLS		Poisson FE	
	Publications	Cites	Publications	Cites
	(1)	(2)	(3)	(4)
Grant Eligible x Post 1993	0.068	1.151^{+}	0.184^{+}	0.323
	(0.050)	(0.687)	(0.110)	(0.305)
Post 1993	-0.327^{**}	-0.760	-0.939^{**}	-0.059
	(0.065)	(0.649)	(0.160)	(0.487)
Constant	0.637^{**}	2.063^{**}		
	(0.041)	(0.334)		
R2	0.026	0.006		
Wald Chi2			757	1,630
Nb. of Obs.	18,848	18,848	18,080	16,789
Nb. Clust.	929	929	929	929

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: Columns (1) and (2) are ordinary least squares (OLS) models and Columns (3) and (4) are quasi-maximum likelihood Poisson models. Observations are at the scientist-year-level and include years 1978-2003, apart from 1987-1989 due to sample restrictions discussed on Section 4 of the text. Dependent variables are total yearly publications and citations (by the year the root article was published in). Regressions include individual and year fixed effects and age controls. Robust standard errors in parentheses (QML for Poisson FE). Poisson FE estimates are interpreted as (e^{β}-1)x100 percent change, so ($e^{0.184}$-1)x100=20%. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 7: Fixed Effect Model Estimates of Impact of $500 Grant, Moscow

	OLS		Poisson FE	
	Publications	Cites	Publications	Cites
	(1)	(2)	(3)	(4)
Grant Eligible x Post 1993	0.131^{+}	1.592	0.316^{+}	0.396
	(0.075)	(1.054)	(0.170)	(0.485)
Grant Eligible x Post 1993	-0.144	-0.979	-0.324	-0.179
x Moscow	(0.098)	(1.382)	(0.216)	(0.604)
Constant	0.637^{**}	2.066^{**}		
	(0.041)	(0.334)		
R2	0.027	0.006		
Wald Chi2			764	1,656
Nb. of Obs.	18,848	18,848	18,848	16,789
Nb. Clust.	929	929	929	929

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: Columns (1) and (2) are ordinary least squares (OLS) models and Columns (3) and (4) are quasi-maximum likelihood Poisson models. Observations are at the scientist-year-level and include years 1978-2003, apart from 1987-1989 due to sample restrictions discussed on Section 4 of the text. Dependent variables are total yearly publications and citations (by the year the root article was published in). Regressions include individual and year fixed effects and age controls. Robust standard errors in parentheses (QML for Poisson FE). Poisson FE estimates are interpreted as (e^{β}-1)x100 percent change, so ($e^{0.316}$-1)x100=37%. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 8: OLS Estimates of Impact of $500 Grant on Staying in Science & Migration

	Science Post 1993 (1)	Science Post 1993 (2)	Migrate Post 1993 (3)	Migrate Post 1993 (4)
Grant Eligible	0.035	0.073^{+}	-0.004	0.013
	(0.029)	(0.040)	(0.027)	(0.035)
Grant Eligible x Moscow		-0.092		-0.034
		(0.058)		(0.054)
Moscow		0.102^{*}		0.043
		(0.045)		(0.042)
Constant	0.522^{**}	0.492^{**}	0.198^{**}	0.181^{**}
	(0.056)	(0.059)	(0.052)	(0.053)
R2	0.017	0.022	0.008	0.011
Nb. of Obs.	929	929	512	512

Standard errors in parentheses

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: Estimates are from ordinary least squares (OLS) models. Observations are at the scientist-level. Dependent variables are staying in science (publishing at least one article in the ISI database after 1993) or migrating (conditional on publishing after 1993). Regressions include age controls. Robust standard errors in parentheses. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 9: Summary Statistics for Matched Control & Team Grant Samples

	Control	Treatment (Team Grantee)	Difference
Impact Factor Score†	3.65	4.12	-0.470*
Female†	0.17	0.17	0.000
Cum. No. Pubs Pre-1993†	35.28	34.93	0.352
Cum. No. Cites Pre-1993	207.39	233.20	-25.806
Yr of First Publication†	1973.94	1973.90	0.038
Ave. No. Coauthors Pre-1993	5.29	5.23	0.060
Non-USSR Coauthor Pre-1991	0.21	0.23	-0.020
Field†			
Astronomy	0.01	0.01	0.000
Chemistry	0.24	0.24	0.000
Earth Sciences	0.06	0.06	0.000
Life Sciences	0.29	0.29	0.000
Mathematics	0.04	0.04	0.000
Mechanics	0.02	0.02	0.000
Physics	0.35	0.35	0.000
Location			
Russia†	0.88	0.88	0.000
Moscow	0.48	0.44	0.043
Observations	1027	1027	

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: †indicates covariates used for the matching process as described in the text. Stars indicate the results of t-tests for the equality of means. Summary statistics are based on scientist-level data constructed using publication data from the Thomson Reuters ISI Web of Science database and grantee data from the Open Society Archives in Budapest. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 10: Outcome Variables for Matched Control & Team Grantee Samples

	Mean	Std. Dev.	Min.	Max.	N
Control Scientists					
No. Pubs 1994-1997	6.234	7.263	0	56	1,027
No. Pubs 1998-2002	7.312	10.081	0	102	1,027
Stayed in science 1994-1997	0.857	0.350	0	1	1,027
Stayed in science 1998-2002	0.788	0.409	0	1	1,027
Migrated Anytime Post 1993	0.155	0.362	0	1	729
Team Grant Recipients					
No. Pubs 1994-1997	6.722	8.927	0	70	1,027
No. Pubs 1998-2002	7.969	12.280	0	121	1,027
Stayed in science 1994-1997	0.848	0.359	0	1	1,027
Stayed in science 1998-2002	0.789	0.408	0	1	1,027
Migrated Anytime Post 1993	0.212	0.409	0	1	753
Observations	2054				

Notes: Summary statistics are based on scientist-level data constructed using publication data from the Thomson Reuters ISI Web of Science database and grantee data from the Open Society Archives in Budapest. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 11: Fixed Effect Model Estimates of the Impact of Team Grant

	OLS		Poisson FE	
	Publications	Cites	Publications	Cites
	(1)	(2)	(3)	(4)
Team Grant x Post 1993	0.131^{+}	0.975	0.083^{+}	0.034
	(0.076)	(1.396)	(0.044)	(0.114)
Post 1993	-0.130	-5.878	-0.033	-0.462
	(0.101)	(4.838)	(0.049)	(0.347)
Constant	1.307^{**}	12.550^{**}		
	(0.048)	(3.763)		
R2	0.027	0.003		
Wald Chi2			535	158
Nb. of Obs.	48,490	48,490	48,490	47,852
Nb. Clust.	2,054	2,054	2,054	2,054

$^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: Columns (1) and (2) are ordinary least squares (OLS) models and Columns (3) and (4) are quasi-maximum likelihood Poisson models. Observations are at the scientist-year-level and include years 1978-2003. Dependent variables are total yearly publications and citations (by the year the root article was published in). Regressions include individual and year fixed effects and age controls. Robust standard errors in parentheses (QML for Poisson FE). Poisson FE estimates are interpreted as (e^{β}-1)x100 percent change, so ($e^{0.083}$-1)x100=8.6%. See Section 5 in the text and Appendix A for a detailed description of the data.

Table 12: Impact of Team Grant on Migration

	Migrate Post 1993 (1)	Migrate Post 1993 (2)	Migrate Post 1993 (3)
Team Grant	0.057**	0.044	0.067**
	(0.020)	(0.029)	(0.024)
Team Grant x Moscow		0.026	
		(0.040)	
Moscow		-0.002	
		(0.027)	
Team Grant x Chemistry			-0.034
			(0.042)
Chemistry			-0.052+
			(0.028)
Constant	-7.249**	-7.446**	-6.581**
	(1.983)	(2.020)	(1.994)
R2	0.015	0.016	0.022
Nb. of Obs.	1,482	1,482	1,482

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: Estimates are from ordinary least squares (OLS) models. Observations are at the scientist-level for only those scientists who published and have an address after 1993. Regressions include age controls. Robust standard errors in parentheses. See Sections 5 and 6in the text and Appendix A for a detailed description of the data.

Table 13: Impact of Team Grant on "Team Member" Outcomes

	Science 1994-1997 (1)	Science 1998-2002 (2)
Team Grant	0.119*	0.024
	(0.047)	(0.045)
R2	0.263	0.047
Nb. of Obs.	456	456

Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: Estimates are from ordinary least squares (OLS) models. Observations are at the scientist-level. Regressions include scientific field controls. Robust standard errors in parentheses. See Section 5 in the text and Appendix A for a detailed description of the data.

Appendix A Data Description

In this appendix I include further details about the construction of the dataset.

A.1 Publication Data

To create the sample of scientists who published in the top Soviet and Russian journals, I first identified these journals in the Thomson Reuters ISI Web of Science (ISI). I relied primarily on the list of journals identified by the ISF as "qualifying" journals for potential grantees in Appendix Table B1. In addition to searching journal titles for these titles (which are in Russian), I identified the English language translations as well. I also checked the journals identified as Russian language journals using the language field in the ISI in case I missed articles published using different English translations.

The ISI publications are not associated with one scientific field, but with rather many scientific subject categories. In order to assign a scientific field to each individual scientist, I did the following. First, I assigned a likely broader scientific field to each of the 221 unique subject categories in the sample of publications based on the search of scientist names. The fields I assigned were one of the 7 major scientific field identified by the ISF (Astronomy, Chemistry, Earth Sciences, Life Sciences, Mathematics, Mechanics, and Physics). Note that when the grantees applied for the grants, they were asked to choose from one of these scientific fields and a number of subfields. Many of the subject categories clearly belonged to a scientific field, e.g. "Cell Biology" was coded as Biology and "Chemistry, Organic" was coded as "Chemistry". For other fields, I used resources that listed field codes along with the scientific field associated with it. For example, Thomson Reuters Journal Citation Report and Essential Science Indicators list subject categories with the broader scientific field, e.g. "Acoustics" is listed under "Physics".

I also compared field codes with the results of analysis presented in (Leydesdorff and Rafols, 2009), who use exploratory factor analysis of the matrix of field codes in the ISI database to determine the disciplines associated with each subject category. If a subject category could belong to more than one scientific field, I did not code it. Then, to assign a scientific field to each publication, I chose the most common scientific field among the subject categories. Then, for each scientist, I chose the most common scientific field among all the publications he/she published.

A.2 Transliteration & Name Matching Issues

A challenge in matching the scientists to publication data is how names from the Cyrillic alphabet are transliterated into the Latin alphabet. Using a name dictionary Polyglossum 3.71 created by ETS Publishing House (Moscow) that is based on several official standards for transliterations (e.g. ISO 9-1995, OVIR of Russia regulations), I identified possible spellings for each last name and searched for each variant in the publication databases. For example, an example of a surname in my sample in the Latin alphabet is Kuznetsov. This Cyrillic name (Кузнецов) has multiple transliterations, which I identified with the name dictionary:

Кузнецов:
Kuznetsov
Kuznecov
Kouznetsov (*OVIR USSR)

where "OVIR USSR" is the transliteration standard used by the "Office of Visas and Registration" of the USSR. Note that this is not an issue for many names, such as Ivanov, or names from the Baltic countries, as in these countries the languages use the Latin alphabet.

Additionally, typical name ambiguity issues arise, including common names (such as Ivanov, like Smith in the U.S.). I exclude these names from the analysis. In the original grantee list, approximately 4% of the grantees had non-unique names. I also trim the data by excluding name with more than 500 publications during the period, since the likelihood of common names is higher for these occurrences. The results do not change significantly when these observations are included.

A.3 Impact Factor Score

An impact factor is "a measure of the frequency with which the average article in a journal has been cited in a particular year or period." (Thomson Reuters) It is often used as a measure of the quality of a journal. Thomson Reuters calculates impact factors for journals in its databases and publishes them annually in the *Journal Citation Reports*

(JCR).

As described in the application for the ISF grants, the ISF staff calculated an impact factor score for each scientist based on the 3 papers with the highest impact factor listed in the applicant's application. The impact factors were taken from the 1992 JCR, which was based on citations in 1991.

The impact factors in the JCR are a ratio of citations and citable items published from the previous 2 years, or the following:

A= total cites in 1991

B= 1991 cites to articles published in 1989-90 (this is a subset of A)

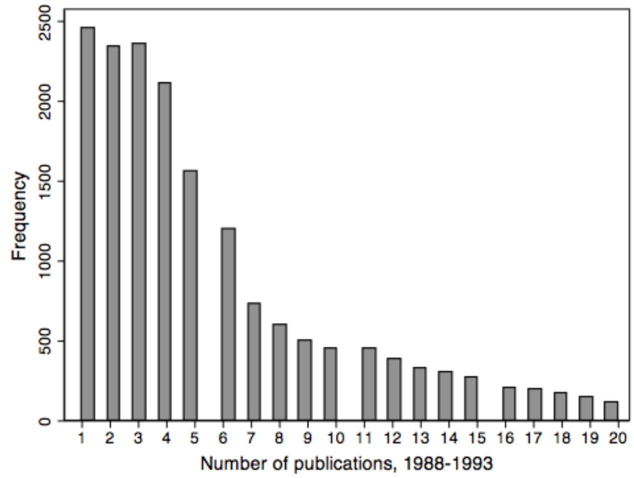
C= number of articles published in 1989-90

D= B/C = 1991 impact factor

Since the original impact factor scores created by the ISF staff were destroyed when the ISF closed, I recreated the scores. First, I digitized the impact factors for journals using the 1992 JCR. Then, I created an impact factor score for each scientist by summing the impact factors for the 3 articles published from 1988-1993 with the highest journal impact factor.

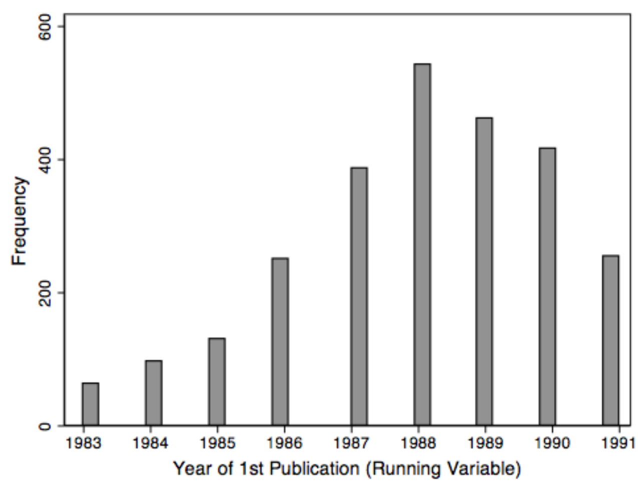
Appendix B Additional Tables & Figures

Figure B1: Distribution of Number of Qualifying Publications (1988-1993 Period)



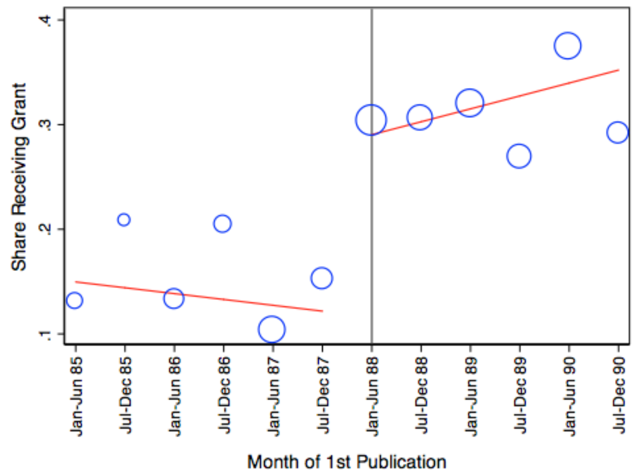
Notes: The bars show the number of scientists in the sample with the relevant number of qualifying publications from 1988-1993 in the Thomson Reuters ISI Web of Science database (through 10 qualifying publications). See Section 5 in the text and Appendix A for more detail and description of the data.

Figure B2: Distribution of Scientists Across Running Variable



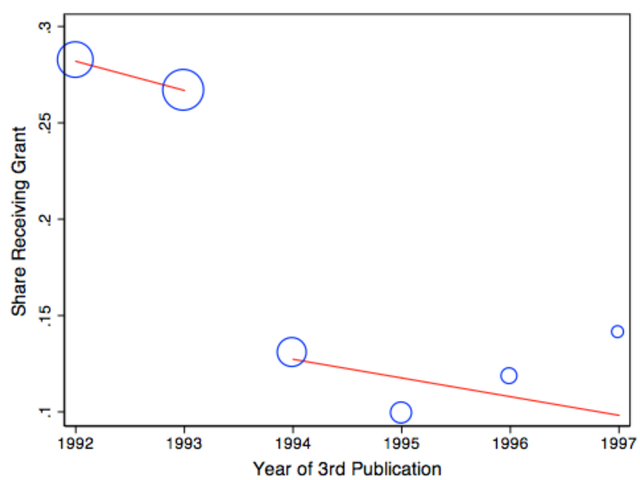
Notes: The bars show the number of scientists in the sample with their first qualifying publication in the year indicated. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

Figure B3: Share Receiving Individual Grant in 1/2 Year Bins



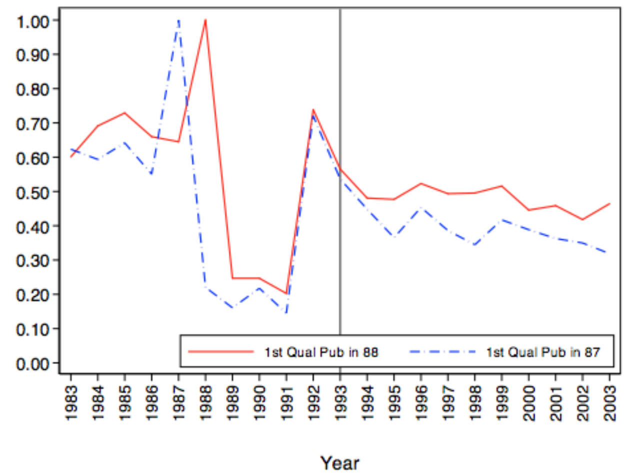
Notes: The running variable is the timing of the first of the 3 qualifying publications in 1/2 year increments. The line through the dots represents a linear prediction weighted by the number of observations in each year that varies on either side of the cutoff for years 1983-1991. The vertical line represents cutoff before which scientists did not qualify for the grant. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

Figure B4: Other side of RD cutoff



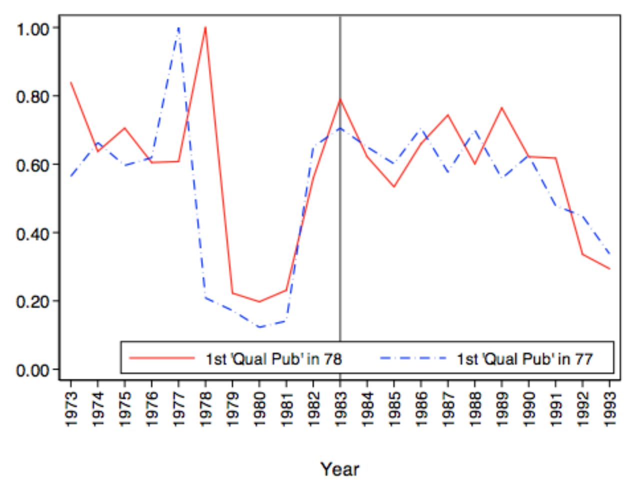
Notes: The running variable is the year of the last of the 3 qualifying publications. The line through the dots represents a linear prediction weighted by the number of observations in each year that varies on either side of the cutoff for years 1992-1997. The vertical line represents cutoff after which scientists did not qualify for the grant. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

Figure B5: Actual 1988-1993 Eligibility Window, Pre-1992 Means



Notes: This figure is an extension of Figure 9 and shows the pre-1992 mean publications. It shows the jumps at 1987 (control group) and 1988 (grant eligible group) at 1 publication, which was the basis for selection into the sample. The 1992 and 1993 means are also higher since inclusion in the sample was conditional on publishing in 1992 or 1993 and having a former USSR address. See Sections 4 and 5 in the text and Appendix A for more detail and description of the data.

Figure B6: Placebo Test With 1978-1983 Window, Pre-1982 Means



Notes: This figure is an extension of Figure 10 and shows the pre-1982 mean publications. See Figure B5, Sections 4 and 5 in the text, and Appendix A for more detail and description of the data.

Table B1: List of Qualifying Journals from the former USSR

1. AKUSTICHESKII ZHURNAL
2. ANTIBIOTKI I KHIMIOTERAPIYA
3. ARKHIV PATOLOGII
4. ASTRONOMICHESKII ZHURNAL
5. BIOLOGICHESKIE MEMBRANY
6. BIOLOGIYA MORYA
7. BIOORGANICHESKAYA KHIMIYA
8. BIOFIZIKA
9. BIOKHIMIYA
10. BYULLETEN EKSPERIMENTALNOI BIOLOGII I MEDITSINI
11. VESTNIK AKADEMII MEDITSINSKIKH NAUK SSSR
12. VESTNIK AKADEMII NAUK SSSR
13. VESTNIK MOSKOVSKOGO UNIVERSITEfA SERIYA F1Z1KA I ASTRONOMIYA
14. VESTNIK MOSKOVSKOGO UNIVERSITETA SERIYA KHIMIYA
15. VESTNIK MOSKOVSKOGO UNIVERSITEfA SERIYA MATEMATIKII MEKHAN1KI
16. VOPROSY VIRUSOLOGII
17. VOPROSY MEDITSINSKOI KHIMII
18. VOPROSY ONKOLOGII
19. VYSOKOMOLEKULYARNYE SOEDINENIYA SERIYA A
20. VYSOKOMOLEKULYARNYE SOEDINENIYA SERIYA B
21. GENETIKA
22. GEOMAGNETIZM I AERONOMIYA
23. GEOTEKTONIKA
24. GEOKHIMIYA
25. DIFFERENTSIALNYE URAVNENIYA
26. DOKLADY AKADEMII NAUK BSSR
27. DOKLADY AKADEMII NAUK SSSR
28. ZHURNAL ANALITICHESKOI KHIMII SSSR
29. ZHURNAL VYSSHEI NERVNOI DEYATELNOSTI IMENI I P PAVLOVA
30. ZHURNAL MIKROBIOLOGII EPIDEMILOGII I IMMUNOLOGII
31. ZHURNAL NEORGAATJCHESKOI KHIMII
32. ZHURNAL OBSHCHEI BIOLOGII
33. ZHURNAL OBSHCHEI KHIMII
34. ZHURNAL ORGANICHESKOI KHIMII
35. ZHURNAL STRUKTURNOI KHIMII
36. ZHURNAL TEKHNICHESKOI FIZIKI
37. ZHURNAL FIZICHESKOI KHIMII
38. ZHURNAL EVOLYUTSIONNOI BIOKHIMII I FIZIOLOGII
39. ZHURNAL EKSPERIMENTALNOI I TEORETICHESKOI FIZIKI
40. ZOOLOGICHESKY ZHURNAL
41. IZVESTIYA AKADEMII NAUK SSSR SERIYA BIOLOGICHESKAYA
42. IZVESTIYA AKADEMII NAUK SSSR SERIYA GEOLOGICHESKAYA
43. IZVESTIYA AKADEMII NAUK SSSR SERIYA FIZIKI ATMOSFERI I OKEANA
44. IZVESTIYA AKADEMII NAUK SSSR SERIYA FIZIKI ZEMLI
45. IZVESTIYA AKADEMII NAUK SSSR SERIYA FIZICHESKAYA
46. IZVESTIYA AKADEMII NAUK SSSR SERIYA KHIMICHESKAYA
47. IZVESTIYA VYSSHIKH UCHEBNIKH SERIYA RADIOFIZIKA
48. IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENII SERIYA FIZIKA
49. IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENII SERIYA KHIMIYA I KHIMCHESKAYA TEKHNOLOGIYA
50. IZVESTIYA SIBIRSKOGO OTIJELENIYA AKADEMII NAUK SSSR SERIYA KHIMICHESKIKH NAUK
51. IZMERITELNAYA TEKHNIKA
52. KARDIOLOGIYA
53. KVANTOVAYA ELEKRONIKA
54. KIBERNETIKA

(Continued on next page)

55. KJNETIKA I KATALIZ
56. KOLLOIDNTI ZHURNAL
57. KOORDINATSIONNAYA KHIMIYA
58. KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA
59. KRISTALLOGRAFIYA
60. MATEMATICHESKYE ZAMETKI
61. MATEMATICHESKII SBORNJK
62. MIKOLOGIYA I FTIOPATALOGIYA
63. MIKROBIOLOGIYA
64. MOLEKULYARNAYA BIOLOGIYA
65. NEIROFIZIOLOGIYA
66. NEORGANIZHESKYE MATERrALI
67. NEFTEKHIMIYA
68. OKEANOLGIYA
69. OPTIKA I SPEKTROSKOPIYA
70. PARAZITOLOGIYA
71. PISMA V "ASTRONOMICHESKII ZHURNAL"
71. PlSMA V "ZHURNAL TEKHN1CHESKOI FIZIK"
73. PISMA V "ZHURNAL EKSPERlMENTALNOI I TEORETICHESKOI FIZIKI"
74. POCHVOVEDENIE
75. PRIBORY I TEKHNlKA EKSPERlMENTA
76. PIRKLADNAYA MATEMATIKA I MEKHANlKA
77. RADIOTEKHN1KA I ELEKTRONIKA
78. RADIOKHIMIYA
79. REAKTSIONNAYA SPOSOBNOST ORGANICHESKIKH SOEDINENII
80. SIBIRSKII MATEMATICHESKII ZHURNAL
81. TEORETICHESKAYA I EKSPERIMENTALNAYA KHIMIYA
82. TEORETICHESKAYA I MATEMATICHESKAYA FIZIKA
83. TEORIYA VEROYATNOSTEI I EE PRIMENENIE
84. TEPLOFIZlKA VYSOKIKH TEMPERATUR
85. TERAPEVTICHESKII ARKHlV
86. UKRAINSKII BIOKHIMICHESKII ZHURNAL
87. UKRAINSKII FIZICHESKII ZHURNAL
88. UKRAINSKII KHIMICHESKII ZHURNAL
89. USPEKHI FIZICHESKIKH NAUK
90. USPEKHI KHIMII
91. USPEKHI MATEMATICHESKIKH NAUK
92. FARMAKOLOGIYA I TOKSIKOLOGIYA
93. FIZlKA GORENlYA I VZRYVA
94. FIZlKIA I TEKHNlKA POLUPROVODNIKOV
95. FIZlKA METALLOV I METALLOVEDENIE
96. FIZlKA NIZKIKH TEMPERATUR
97. FIZlKA TVERDOGO TELA
98. FIZIOLOGICHESKII ZHURNAL
99. FIZIOLOGIYA RASTENII
100. FUNKTSIONALNYI ANALIZ I EGO PRILOZHENIE
101. KHIMIKO-FARMATSEVTICHESKII ZHURNAL
102. KHIMICHESKAYA FIZIKA

Notes: List reproduced from the International Science Foundation's Individual Emergency Grant application in the Open Society Archives.

Table B2: Selection Among Individial Grant Applicants

Dependent Variable:	Grant Receipt
No. Pubs 1975-1991	-0.001*
	(0.001)
No. Cites 1975-1991	0.0003**
	(0.000)
Yr of first Pub	0.001
	(0.001)
Non-USSR Coau. Pre-91	0.020
	(0.015)
Ave. No. Coau. 1975-1991	-0.010**
	(0.002)
Field (Astronomy Omitted)	
Chemistry	-0.143**
	(0.032)
Earth Sciences	0.009
	(0.035)
Life Sciences	-0.046
	(0.033)
Mathematics	-0.021
	(0.037)
Mechanics	-0.140+
	(0.073)
Physics	-0.038
	(0.032)
Location	
Russia	0.179**
	(0.014)
Ukraine	0.104**
	(0.017)
Moscow	-0.001
	(0.010)
Qual. Pubs 1988-1993	0.122**
	(0.002)
Constant	-1.344
	(1.117)
R2	0.309
Nb. of Obs.	8,837

Standard errors in parentheses

+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Notes: OLS estimates with robust standard errors in parentheses. Observations are at the scientist-level. Sample is restricted to all individuals who qualified for the individual grant with 3-10 publications during the 1988-1993 qualifying period. See Section 5 in the text and Appendix A for a detailed description of the data.