Bureaucrats, Skills, and Cooperation: Transgovernmental Networks in Nuclear Energy, Science, and Technology (NEST)

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How do skills affect cooperation? While little scholarly attention has been paid to this question, the impact of skills on competition has been studied at length (Booth and Snower 1996; Thelen 2004; Mayer and Solga 2008; Thelen 2014). Scholars have analyzed how competition shapes the distribution of training and have found evidence that when resources are scarce, workers that are younger, more skilled, and employed benefit overwhelmingly from employer and state investment in skill upgrading (Thelen 2014; Mayer and Solga 2008; Booth and Snower 1996). We also know that the level of skills of the workforce may trigger poaching behavior between competing employers and make them less inclined to invest in employees' general training (Becker 2009). The effect of different skill levels on economic competition has been examined across countries and political economists are in strong agreement that "skills have become a highly valued commodity in the new 'knowledge society' and a strategic asset in the economic competition among nations" (Mayer and Solga 2008: 2). Yet, states cooperate just as often as they compete. Cooperation across the developing world, in particular, is at an all-time high as a result of democratization, globalization, and the information age (Alcañiz 2012; WorldBank 2012). These three processes and all they entail have simplified and multiplied the ways in which actors across borders, even across regions, work together. In a world where some of the practical barriers to collaboration have been removed thanks to innovative communication channels, an actor's skillset may be one of the more significant discriminators in cooperation. This is especially true in Latin America and the rest of the developing world, where cooperating countries regularly operate with insufficient budgets. If all participants suffer from a shortage of economic resources, skills (or the lack there of) can be a greater barrier to cooperation than funds.

In this paper I examine how inadequate skills and funds for training create incentives for bureaucrats to cooperate. What do career bureaucrats in technical agencies do when their expertise becomes obsolete but their employer, the state, does not invest in upgrading it? I argue that bureaucrats in the developing world, accustomed to insufficient and irregular funding in training, develop strategies to compensate for the lack of resources at home. One of these strategies is to cooperate with foreign peers in order to access new skills and pool existing resources. The argument presented here is based on a common problem: state research funds are highly susceptible to budget cuts, and consequently, fluctuate a great deal (Dickson 2003 ; Velho 2005). Irregular government funding generates uncertainty in all bureaucrats, but it can be particularly disruptive to well-established expert agencies given that their programs are contingent on the state's continued ability to hire and train skilled personnel. This is exacerbated by the wave of spending cuts implemented in the 1990s and 2000s in Latin America and many other developing countries resulting from neoliberal reforms and financial crises (Huber and Solt 2004). In fact, over the past two decades, expert bureaucrats and the state agencies they populate have been caught between two opposing forces. On the one hand, recurrent economic crisis (and ensuing budget cuts) lead to fewer available resources. On the other hand, the information revolution has placed a large premium on highly skilled labor (both inside and outside of the bureaucracy) and consequently skilled bureaucrats are expected to resolve complex problems (such as water pollution, the negative effects of climate change on agricultural production, or energy crises to name a few) despite inadequate funding.

Thus, regardless how scarce resources might be, state experts are still required to do their job. This creates an incentive to maintain critical skills sharp and current. Bureaucrats in agencies in charge of nuclear policy need a degree of specialization to carry out the tasks assigned to them. Often, their particular skillset is what got them hired in the first place. The more specialized the area in which they work, the greater the impact of skills on job and career advancements. Thus, here I analyze transgovernmental cooperation across the developing world in nuclear energy, science, and technology (NEST) as a function of career bureaucrats' skill-investment strategy (Keohane and Nye 1974).[1] I argue that bureaucrats respond to decreased state funding by networking with foreign peers. Transgovernmental collaboration provides state experts and their agencies with the opportunity to pool scarce resources, to attract funds from international donors, and above all, to update their technical skills.

If the incentive to invest in their skillset drives the international behavior of the bureaucrat, then two empirical observations should follow. First, a decrease in government spending should correlate with increased participation of bureaucrats in transgovernmental cooperation. Government cuts signal lean times ahead and cue state experts to seek alternatives to state funding. Activating ties with foreign peers and working together on cross-national projects allow bureaucrats to pool existing resources and better the chances of accessing donor funds. Second, if skill upgrading is the primary causal mechanism behind transgovernmentalism in NEST, the empirical analyses should reveal a homophily effect. Homophily refers to the tendency of actors who share similar characteristics to work together, as simply expressed by the adage *Birds of a feather, flock together* (McPherson, Smith-Lovin et al. 2001; Maoz 2012). If bureaucrats' priority is to advance their skills, they will want to seek out partners who have superior training. The rationale for this is straightforward.[2] Consequently, most bureaucrats

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[1] Keohane and Nye first defined transgovernmentalism in their seminal study, as a set of relations formed by the cross-border "interactions among sub-units of different governments that are not controlled or closely guided by the policies of the cabinets or chief executives of those governments" Keohane and Nye, 1974: 43.

[2] As stated by Booth and Snower: "When people acquire skills, they make each other more productive. Since most work is team work, my productivity generally depends on your productivity. The more training you have – on-the-job or off-the-job – the more I can learn from you about doing the job effectively, and the more productively the two of us can interact in production, innovation, distribution, and sales" (Booth and Snower 1996: 1).

would prefer to collaborate with foreign peers in advanced programs. However, partner selection goes both ways and experts with superior skills will naturally prefer to work with colleagues from more advanced agencies (or if they are at the top of their field, with their true peers). As not everyone will be able to get their first preference, I expect a second preference –to collaborate with bureaucrats of equal skill– to result in the dominant strategy. Hence, if skill-investment is the driving strategy, we should find empirical evidence of skill homophily within the transgovernmental networks of nuclear bureaucrats.

To test my skill-based theory, I use region-specific cross-national co-sponsorship data of projects in nuclear energy, science, and technology (NEST) for 84 countries.[3] Projects include cross-national training of nuclear personnel; the establishment of new (and maintenance of existing) laboratories; standardizing nuclear techniques within region; and organizing and managing nuclear knowledge through translations, reports, manuals, and bibliographies.[4] These projects have applications beyond the nuclear field which include biotechnology, agriculture, industry, public health, nuclear safety, and energy.[5] I compiled one large database consisting of projects implemented by participating countries in Latin America, Africa, and Asia under three regional programs between 1980 and 2008. The programs are the Regional Cooperative Arrangement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL), the African Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA), and the Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific (RCA). Participants in ARCAL, AFRA, and RCA are bureaucrats who come from the central state agency in charge of nuclear energy, science, and

[3] See Table A.1 in Annex for a list of participating countries.
[4] See IAEA TC at http://www-tc.iaea.org/tcweb/default.asp.
[5] See IAEA TC at http://www-tc.iaea.org/tcweb/default.asp.

technology, such as Nuclear Energy Agencies; Science & Technology Agencies; National Universities; and Ministries of Energy, Mining, the Environment, Industry, Electricity, and Foreign Affairs.[6] Specifically, the periods of time analyzed are for ARCAL, 1984-2008; AFRA, 1991-2008; and RCA, 1979-2008. The data includes information by country, year, and project, allowing for model specifications that control for the different incentives to participate. The International Atomic Energy Agency (IAEA) sponsors these programs with some technical and financial assistance, but as I show in the following sections, these collaborative networks are much more bottom up, and are forged by its participating bureaucrats.

The article proceeds as follows. I first offer a case study of the effects of decreased government spending on state investment in the nuclear sector. Here I examine Argentina and Brazil, two high-skilled nuclear energy producers in Latin America. In the following section, I expand my analysis to all countries of the developing world, exploring how government spending and existing levels of skills in the bureaucracy and outside affect cooperation. In the subsequent section, I offer a first take at the network data through visualization techniques. The following section presents the data, the models, and a discussion of the results. The final section offers some concluding remarks.

Argentina and Brazil: Networking Bureaucrats and Skill Acquisition Outside the State

This section examines the effect of government spending on skill investment in two state agencies, the Argentine National Commission for Atomic Energy (CNEA) and the Brazilian National Commission for Nuclear Energy (CNEN). These two cases illustrate how the

[6] For example, Argentina and Brazil, two advanced nuclear states, participate in ARCAL projects through the National Commission of Atomic Energy (CNEA) and the National Commission of Nuclear Energy respectively. Uruguay, on the other hand, participates through its National Direction of Nuclear Energy and Technology of the Ministry of Industry, Energy, and Mining.

withdrawal of state support and fluctuation of government funding drive expert bureaucrats to formulate adaptation strategies. From the beginning of the nuclear era in the 1950s, the Argentine and Brazilian governments made sustained and significant investments in nuclear capacity and expertise (Solingen 1993). But after a catastrophic economic crisis and the ensuing democratization of the two countries in the early 1980s, state support became unreliable. Drawing from in-depth interviews carried out with key Argentine and Brazilian nuclear bureaucrats over a decade and extensive archival work in Latin America, this section shows how experts take up skill investment by seeking know-how and training from abroad when states withdraw. Finally, this section also illustrates the partner-selection mechanism behind the observed homophily effect in skill-driven transgovernmental cooperation.

In Latin America, the 1980s were to be known as “the lost decade of development” given the severe economic emergency –triggered by the 1982 foreign debt crisis— that swept the Region (Frieden 1991). Already by 1983, Argentina and Brazil were broke and facing default on their foreign debt. The days of the military governments, in power since 1976 and 1964 respectively, were numbered. The ensuing democratization of the two countries, together with the economic catastrophe, made it impossible for the new civilian governments to maintain past levels of state investment in nuclear skills. The programs lost state support and nuclear bureaucrats in the two countries were left to their own devices during the worst of the crisis (Alcañiz 2005). The following decade brought even deeper cuts, as the two countries implemented more radical market reforms sponsored by the IMF (Weyland 2002). In Argentina, where market reforms were particularly draconian, the nuclear sector saw several years of lean budgets. The former head of CNEA described the effect of cuts and austerity on the program:

> “There is no investment, we have even lost people. Do you know how costly it is to put together groups with capacity to realize technology, and not even cutting-

> edge nuclear technology, but at least hi-tech? Generations! Ten years at least, and they just disintegrate with a call to voluntary retirement. It's pathetic. The state in which the department of reactors of CNEA has been left in is pathetic."[7]

Hiring freezes closely follow spending cuts. When they persist over time, state agencies cannot update their critical skills and as a result, bureaucratic expertise often becomes obsolete and institutional knowledge is lost. Hiring freezes in the information age are especially egregious as research organizations need to hold steady rates of investment in skills in order to remain abreast of technological change.[8] Expert bureaucrats do not only anticipate spending cuts by their own governments, they may also become aware of cuts happening in peer institutions across the border. One Brazilian CNEN expert described his interest in the events in Argentina through the analogy of a popular ad campaign in his country in the 1980s. The "*Efeito Orloff: Eu sou você amanhã*" was an Orloff vodka TV commercial where a stranger urges a man at a bar to only drink the best brand of vodka in order to avoid a hangover the next morning. When the drinking man asks the stranger who he is, the latter replies: "I am you, tomorrow." The CNEN expert likens the commercial to how Brazilians pay attention to spending cuts in Argentina and their effect on CNEA.[9]

What do Argentine and Brazilian nuclear experts do when they anticipate spending cuts that will hinder projects and programs? They find alternative ways through which they can continue investing in skills:

> "What we do here to maintain the program in times of no money is to invest in personnel training. A master's degree, a doctorate. You spend a lot less. Technical research is much more expensive than thesis research, so we invest in human resources. Technical cooperation through IAEA, many of the projects in which

[7] Emma Perez Ferreira. President of CNEA 1987-1989. Interview with the author, March 2001, Buenos Aires, Argentina.
[8] Increasingly this has become a major concern in science agencies in the United States. See "NOAA institutes a hiring freeze, worrying emergency managers" at http://www.multibriefs.com/briefs/iaem/NOAA.pdf
[9] Laercio Vinhas. Director of International Cooperation of CNEN. Interview with the author, Rio de Janeiro, Brazil 2006.

> CNEN participates, significantly contributes to the self-reliance and autonomy of the program. It's extremely important. Horizontal cooperation preserves active knowledge"[10]

Despite a history of regional rivalry,[11] Argentine and Brazilian nuclear bureaucrats began to cooperate on projects and train together at the worst of the economic crisis in the mid-1980s. Bilateral cooperation entailed working together on complex projects, cross-national training of nuclear power plant personnel, and coordinating nuclear foreign policy. Bureaucrats in CNEA and CNEN formalized the comprehensive partnership by drafting a series of protocols. The "protocols, created by the working group and the Permanent Committee, were mainly initiatives of the two technical organisms (CNEA and CNEN)."[12] The first nuclear protocol adopted under the framework of the 1986 Integration Act between Argentina and Brazil established common rules to deal with the sharing of radiation safety information.[13] The effectiveness of the Protocol for the Immediate Information and Reciprocal Assistance in Case of Nuclear Accidents and Radiological Emergencies (Carasales 1997; Ornstein 1998)[14] was put to test the next year. A private hospital in Goiania, Brazil, moved to a new location without safely dismantling its old radiotherapy equipment. In 1987, it was discovered that the abandoned equipment had been stolen by locals to sell as scrap metal.[15] Within hours of the ghastly discovery, CNEN had alerted CNEA and the latter was sending two specialists in radioactive protection and radioactive waste

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[10] Laercio Vinhas. Director of International Cooperation of CNEN. Interview with the author, Rio de Janeiro, Brazil 2006.

[11] On Argentine-Brazilian rivalry, see J. Child 1985 and 1988; J. Redick, J. Carasales & P. Wrobel 1995; J. Carasales 1997; J. Redick 1998.

[12] Captain R. Ornstein. Director of International Relations of CNEA. Interview with the author, May 2001, Buenos Aires, Argentina. Working groups and the Permanent Committee were created to advance cooperation and coordination in the nuclear sector.

[13] The *Acta de Integración*, signed in July 1986 by Presidents Alfonsín and Sarney, was the direct precedent of the Mercosur and included rules for policy coordination in different areas.

[14] Nuclear experts in both countries point out with pride that this type of security agreement predated the ones established by the IAEA after the disaster of Chernobyl (Carasales 1997 and Ornstein 1998).

[15] See http://www-pub.iaea.org/mtcd/publications/pdf/pub815_web.pdf

to the scene.[16] The president of CNEA at that time recalled the incident. When she was informed by her Brazilian counterpart, she sent the Argentine technicians without waiting for an executive order by the President (required for nuclear experts traveling abroad).[17] "I told the president of CNEN, 'I am sending over our specialists,' that same afternoon. I called [President] Alfonsín and he approved it. Our people participated in the cleanup of an entire neighborhood, which had to be closed off."[18]

Upgrading bureaucrats' technical skills was at the heart of the Argentine-Brazilian partnership, especially in nuclear energy plant operation and management. A number of cross-national training sessions were in this area:

> "Argentines train in a simulator here. When nuclear reactors are shut down, they require a lot of people to do maintenance. Our nuclear power plants do not have sufficient technical personnel, so they hire high skill temporary workers. When Atucha and Embalse shut down for maintenance, a contingent of Brazilians go to work. And when Angra shuts down, Argentine technicians come over. They have an open tab, nobody pays, they just exchange in kind. For example, Brazilian technicians from a reprocessing plant were trained in Argentina. They do research together, people go back and forth. Whenever there is any emergency drill in the power plants in Argentina, there is a Brazilian observer."[19]

Nuclear experts in Argentina and Brazil continue to pool resources, share research costs, and hone critical skills in cooperation. These bureaucrats seek each other out on a bilateral base, within the framework of the sectoral agreements forged in the 1980s, cooperating on nuclear development and coordinating nonproliferation policy.[20] But they also partner up within larger networks such as the Regional Cooperative Arrangement for the Promotion of Nuclear Science

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[16] Emma Perez Ferreira. President of CNEA 1987-1989. Interview with the author, March 2001, Buenos Aires, Argentina.
[17] Emma Perez Ferreira. President of CNEA 1987-1989. Interview with the author, March 2001, Buenos Aires, Argentina.
[18] Emma Perez Ferreira. President of CNEA 1987-1989. Interview with the author in March 2001. Buenos Aires, Argentina.
[19] Laercio Vinhas. Director of International Cooperation of CNEN. Interview with the author, Rio de Janeiro, Brazil 2006.
[20] Regarding the two countries common nuclear policy, see the Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials (ABACC) at http://www.abacc.org.br/

and Technology in Latin America and the Caribbean (ARCAL). As the next Section will show, of the 77 ARCAL projects in which Argentina and Brazil participated, they did so together in 74. As discussed in the Introduction, I expect a homophily effect in cooperative ties forged to advance skills. Argentina and Brazil, at similar levels of program development, benefit from pairing up much more than if they were to collaborate with a less developed country. Still, larger networks multiply, by the number of participating actors, the amount of resources that go in the common pool. The next Section focuses on these larger networks, which expert bureaucrats use to substitute skills and expertise that they are not getting from their home states.

Transnational Networks in Nuclear Energy, Science, and Technology (NEST)

In the previous section, I described the network of cooperation between Argentine and Brazilian nuclear agencies and their bureaucrats. Bilateral cooperation resulted from bureaucrats' need to find alternative resources once the state withdrew and funding towards the nuclear sector faltered. Argentina and Brazil exemplify transgovernmental cooperation among advanced nuclear programs staffed with highly skilled bureaucrats. In this section, I consider a larger universe of cases, and examine transgovernmental networks in Nuclear Energy, Science, and Technology (NEST) throughout the Developing World. For decades, nuclear experts in Latin America, Africa, and Asia collaborate with regional peers in technical projects with applications in multiple fields (such as human health, water, food and agriculture, and the environment) through ARCAL, AFRA, and RCA.[21] Drawing from extensive archival research and in-depth

[21] Again, the three major research-based networks in NEST developed across the three largest regions of the developing world: the Regional Cooperative Arrangement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL), the African Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology (AFRA), and the Regional Co-operative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific (RCA). See http://www.iaea.org/technicalcooperation/programme/index.html

interviews in Latin America and the world headquarter of the International Atomic Energy Agency (IAEA) in Vienna, Austria (which sponsors the three programs), I describe these three collaboration networks of nuclear bureaucrats. The section explains how state experts cooperate with foreign peers to design, adopt, and implement complex projects under extremely constricted budgets and how by participating in these projects, they gain access to technical skills, scientific knowledge, and know-how on best practices.

Briefly, Latin Americans founded ARCAL in 1984 (a few years after the Asian RCA was created) at a time of great change; just two years after the 1982 foreign debt crisis and at the beginning of the wave of democratization that deeply changed the political dynamics of the region. The initiative was originally proposed by the countries of the Andean Group (AG) and soon thereafter endorsed by the Southern Cone states.[22] A few years later, the remaining Latin American countries, including the Central American states, Mexico and the Caribbean states of Cuba, the Dominican Republic and Jamaica, joined the agreement. The central mission of ARCAL was to promote horizontal cooperation, pool regional resources, and transfer know-how and technology from the more advanced to the least advanced countries.[23]

Since their emergence, these networks have increased the number of participants and cross-national projects dramatically. Currently, regular participants in Latin America stand at 20; in Africa, 32; and in Asia, 17.[24] The RCA leads the pack in the number of completed and active projects, with over 130 projects that are under way or finalized; ARCAL, 119; and AFRA, a

[22] The Andean Group is made up by Bolivia, Columbia, Ecuador, Peru and Venezuela. Argentina, Brazil, Chile, Paraguay and Uruguay are known as the Southern Cone states. See http://arc.cnea.gov.ar/quees/como.asp.

[23] To give a sense of the early priorities of the network, its first project in 1984 aimed at developing "the scientific and industrial applications of radioisotopes and radiation in the Latin American Region" in order "to prepare projects in the areas of radiation protection, nuclear instrumentation, radioimmunoassay (RIA) techniques in animal reproduction, food irradiation, nuclear analytical techniques, mutation breeding, utilization of research reactors, and RIA of thyroid hormones and isotope techniques in hydrology."

[24] See Table Annex 1 for a complete list of all participating countries.

region which is quickly catching up, over 80.[25] Below, Table 1 offers a breakdown of projects by area of application and region. By disaggregating by project type, we can see bureaucrats' priorities for training and skill upgrading. Latin American bureaucrats resemble their Asian colleagues in that they prioritize training in Human Health and Nuclear Safety. Projects in nuclear medicine and health make up 28% of the total number of projects ARCAL experts choose. The second priority for Latin Americans is Nuclear Safety, with 15% of all projects focused in this area.

[25] See http://www.iaea.org/technicalcooperation/Partnerships/Reg-Coop-Agreements.html

Table 1. Projects by Policy Area and Region

Type of Project	AFRICA	ASIA	LA	Total
Agriculture/Foo(	19	21	16	56
	17.27	12.65	11.19	13.37
Energy	2	17	3	22
	1.82	10.24	2.1	5.25
Environment	26	22	23	71
	23.64	13.25	16.08	16.95
Human Capital	17	16	18	51
	15.45	9.64	12.59	12.17
Human Health	23	32	40	95
	20.91	19.28	27.97	22.67
Industry	4	8	7	19
	3.64	4.82	4.9	4.53
Nuclear Safety	15	35	22	72
	13.64	21.08	15.38	17.18
Nuclear Science	4	15	14 |	33
	3.64	9.04	9.79	7.88
Total	110	166	143	419
	100	100	100	100

How are projects within these networks of collaborating bureaucrats decided and implemented? While projects are initially adopted by the bureaucrats in charge of the country's nuclear policy, the implementation phase typically involves an extended group of bureaucrats. An ARCAL liaison from Chile describes the make-up of country participants as actors who "in reality, are the small nuclear communities which developed around the national atomic agencies."[26] Both groups, the core and the periphery of a country's nuclear sector, vary greatly by level of skill within and across countries. For example, many projects include highly skilled state experts (e.g., nuclear physicists) who decide content and objectives and less skilled individuals (e.g., radiation lab technicians) who assist in implementation, both from the same county.[27]

As there is no central authority in a network, projects need to be negotiated by participants. The Argentine coordinator for ARCAL explains how bureaucrats in domestic institutions with nuclear expertise promote their own research agendas in the region:

> "Each country has certain national priorities within its own (nuclear) institutions and the project ideas come from there…we present these ideas, just like the other countries and if there is a consensus, that is, if there is a minimum of four countries that have presented similar projects in the area, they get together and move forward."[28]

This process is repeated every two years, when member states gather again and exchange ideas on possible research projects. This brainstorming and bargaining process is described by another participant of the Latin American network:

> "they [participants] would put their proposals together, analyze them… and narrow it down to 20 or 25 ideas. From these they would design their own projects."[29]

[26] María Cecilia Urbina Paredes. Chilean Program Manager of ARCAL. Interview with the author, Vienna, Austria, June 2007.
[27] See http://www.iaea.org/technicalcooperation/Regions/Latin-America/ARCAL/ARCAL.html
[28] César Tate, ARCAL liaison for Argentina. Interview with the author, Buenos Aires, Argentina, July 15, 2006.
[29] Maria Zednik, ARCAL Regional Coordinator. Interview with the author, Vienna, Austria, June 2007.

Once the projects are decided upon, country coordinators are chosen:

> "At the level of each project, the Africans will select among themselves, amongst their peers, the best scientist, engineers whoever who will be the scientific project consultant."[30]

IAEA contributions to these collaboration networks are rather modest. To get a sense of the magnitude of IAEA funding, Table 2 shows the breakdown of ARCAL's budget over 20 years (1983-2004) by type of disbursement (in kind or monetary) and source (participants, IAEA, and outside donors).

Table 2: Budget for ARCAL 1983-2004

Source of Disbursements	Type of Disbursement	US$ Million	Percent of Total Budget
ARCAL Members	In Kind	13	44 %
IAEA	Monetary	13	44%
OECD Donations	Monetary	4	12%

Theoretical Discussion and Hypotheses

Drawing on the case studies of Argentina and Brazil and extensive field research as well as the literature on skills, I expect a negative correlation between government spending and transgovernmental cooperation in NEST, whereby decreased government spending prompts

[30] Mokdad Maksoudi, Tunesian Program Manager for AFRA. Interview with the author, Vienna, Austria, June 2007.

nuclear bureaucrats to increase their participation in cross-national projects. Thus, the formulation of the central hypothesis of this article follows.

Hypothesis 1: If fear of skill-devaluation drives behavior, we should see bureaucrats pursuing skill-investment strategies like transgovernmental cooperation when government spending declines.

Regarding the effect of skills on cooperation, I advance two hypotheses. First, I follow Becker (2009) who discriminates between types and conditions the incentives workers face to take skill investment in their own hands on whether training is general or specialist. Generalist skills are more transferable, whereas specialist– specific to the firm in which the worker is employed- less so. Employers have clear incentives to pay the cost of training their workforce to specialize it. But they have little reason to bear the cost of transferable skills, as an investment in this kind of expertise may be easily lost to a competitor (O'Connell and Jungblut 2008). Consequently, workers are more likely to invest in general skills themselves. Becker's expectation makes particular sense in bureaucracies across the developing world, where research agencies typically are understaffed and civil servants are reshuffled after every political adjustment. Under those conditions, a "jack of all trades" strategy can be a winning one to ensure a career in a politicized and ever-changing bureaucracy. For these reasons, when bureaucrats cooperate internationally, I expect them to prefer projects that offer more general (or marketable) skills. In the analyses below, I control by the type of training offered in the projects and expect to see a stronger participation effect in projects that are more intensive in general skills.

Hypothesis 2-A: Following Becker, bureaucrats should be more likely to participate in cross-national projects that offer general training than in those that are more skill-specific.

Furthermore, research has shown that there are biases in access to training, whereby "those with higher skills or educational attainment are more likely to participate in training (O'Connell and Jungblut 2008: 111). Given this, I assume bureaucrats with greater technical expertise –determined by their countries' degree of bureaucratic specialization and the size of its pool of scientists — will be more active in collaboration networks. The expectation is that the more professional and specialized the employing institution is, the stronger the incentive of the employee to keep her skills current, as technology-intensive institutions will put greater technical demands on their workforce. In fact, my theory assumes an initial level of expertise in order for an investment in skill upgrade to pay off.

Hypothesis 2-B: Higher-skilled bureaucrats will participate more in cross-national projects than bureaucrats with lower level of expertise.

Finally, two more expectations are tested. First, if skill-seeking is driving transgovernmental cooperation in NEST, I expect to see a homophily effect as described in the Introduction of this article. Peer-to-peer cooperation should result from bureaucrats attempting to work with colleagues from agencies with higher level or at least equal levels of development. Past research reveals homophily to be present in many collaborative networks, such as ARCAL, AFRA, and RCA (McPherson, Smith-Lovin et al. 2001; Maoz 2012; Kinne 2013; Videras 2013). Another alternative explanation of transgovernmentalism examined here posits that cooperation is the result of international pressures. Many studies find supporting evidence that globalization processes and International Organizations promote cooperation among national bureaucrats (Bauer 2006; Hicks, Parks et al. 2008; Biermann and Siebenhüner 2009; Slaughter 2009). To test for the international effects of multilateral grants, loans, and the role of IAEA, I control for technical grants from IOs and multilateral financing.

Visualizing Networks in NEST

The data from AFRA, ARCAL, and RCA allow us to map the relative proximity of different countries and agencies, a critical first step in explaining cooperation. Indeed, in the last fifteen years political scientists have devised a very large number of strategies to translate collaborative decisions into conceptual maps that assess proximity among actors. Many of these advances have come from social network analysis (SNA), with a variety of tools to understand connections (edges) between actors (nodes). In the next section I conduct statistical analyses to measure these decisions, but first I offer a visual inspection of the data. A first strategy to explore the data is to measure the number of times that each pair of countries participates in a project in NEST. This is usually described as an “affiliation matrix,” with the diagonal vector of a matrix describing the total number of projects in which a country has participated, and the off-diagonal elements describing the number of projects that each pair of countries have join the same project.

Table 3: ARCAL Affiliation Matrix

	ARG	BLZ	BOL	BRA	CHL	COL	CRI	CUB	DOM	ECU	ESP	GTM	HND	HTI	JAM	MEX	NIC	PAN	PER	PRY	SLV	URY	VEN
ARG	77																						
BLZ	2	2																					
BOL	39	2	42																				
BRA	74	2	41	77																			
CHL	69	2	38	68	70																		
COL	41	2	32	42	40	43																	
CRI	51	2	34	50	45	32	56																
CUB	63	2	35	62	58	35	46	68															
DOM	21	2	15	19	20	14	19	23	24														
ECU	46	2	33	44	44	35	37	37	13	46													
ESP	2	0	0	1	1	0	1	2	0	1	2												
GTM	42	2	31	43	40	29	41	38	16	32	0	48											
HND	2	2	2	2	2	2	2	2	2	2	0	2	2										
HTI	8	2	5	8	8	5	6	8	7	6	1	6	2	8									
JAM	6	2	6	6	6	6	5	6	4	6	0	5	2	4	6								
MEX	67	2	34	66	63	36	47	59	21	40	1	38	2	8	6	69							
NIC	18	2	16	19	16	13	20	20	11	11	0	16	2	5	4	19	22						
PAN	26	2	20	26	25	19	27	29	13	20	0	25	2	5	4	26	16	30					
PER	58	2	36	59	55	36	42	52	19	39	2	34	2	7	4	54	20	23	62				
PRY	37	2	28	38	35	30	31	30	14	30	1	30	2	8	4	31	14	16	35	39			
SLV	21	2	20	23	19	11	20	23	13	15	1	17	2	6	3	21	12	12	23	17	24		
URY	57	2	29	55	50	32	40	54	22	33	2	32	2	8	4	54	17	22	47	32	20	59	
VEN	44	2	26	43	41	26	34	44	16	29	1	28	2	7	4	44	18	24	41	26	19	40	45

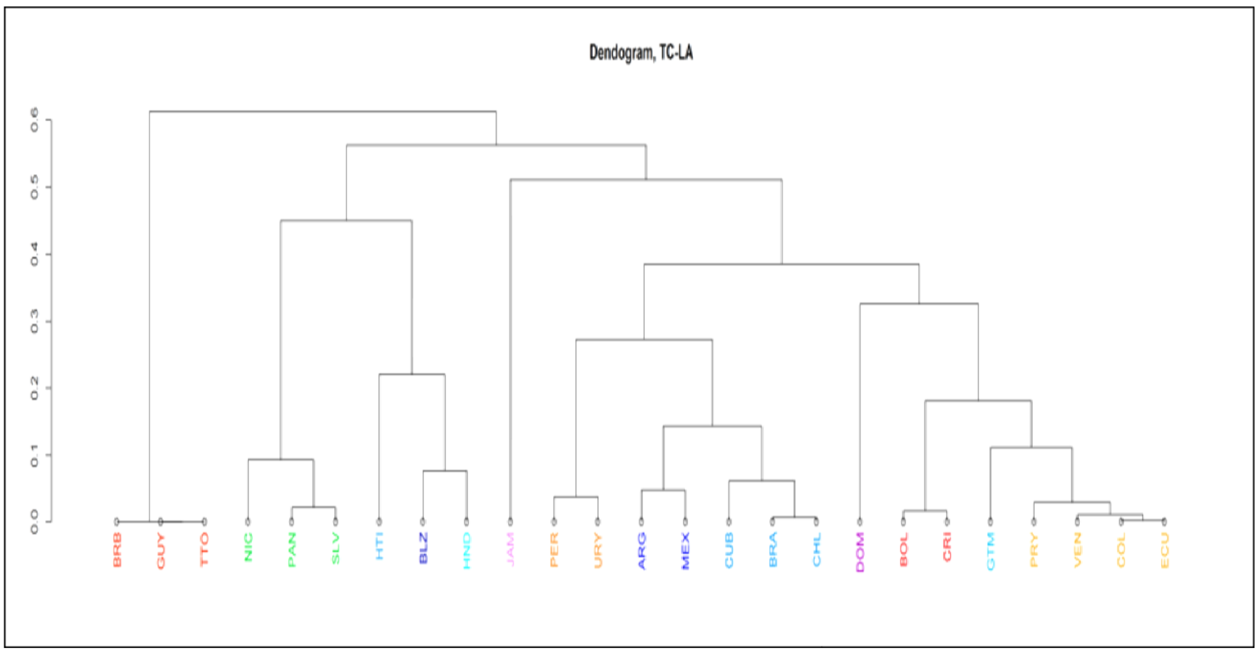
Table 3 shows the ARCAL affiliation matrix. Here, we can see that the three nuclear energy producers, Brazil, Argentina, and Mexico participated in 77, 77, and 69 projects respectively; almost all of which have been together. Unexpectedly, Chile, the third most active country with 70 projects under its belt, does not have a nuclear energy program. However, the country has invested in nuclear research since the 1950s, mostly through university programs, and has benefited from its close relation with the two South American nuclear energy producers. After the *coup d'etat* against socialist president Salvador Allende, the Pinochet dictatorship (1973-1990) gave the military a larger stake in nuclear development by strengthening the Military Center for Nuclear Studies (CENE) and signing cooperative nuclear treaties with the military governments of Argentina (1976) and Brazil (1980).[31] Cuba, a country that by its size and geographical location should be closer to smaller states such as the Dominican Republic (with participation in only 24 projects), boasts participation in 68 projects. The high participation of Cuba is partly explained by the many years of Soviet subsidy and to Fidel Castro's investment in advanced health care. Indeed, under Castro's leadership, Cuba has carved its niche as one of the high-tech medical centers of Latin America, including nuclear medicine.

The affiliation matrix also reveals that partner selection is not as discriminating as we would expect. It seems that the single most important decision in the ARCAL, AFRA, and RCA networks is whether to participate in a project or not. Regional projects in NEST tend to have a large number of members compared to other scientific networks such as those in the area of the environment. As a result, networks of collaboration are particularly dense. This makes it more difficult to reveal partner selection patterns from the raw data. To better distinguish the level of association between different partners of the collaborative network, I present dendrograms that summarize the degree of association between sets of countries. A dendrogram is a tree diagram

[31] See http://reportajes.canal13.cl/reportajes/html/ReportajesDelSiglo/Reportajes/1999/263079.html

that visualizes how actors cluster together. Actors or “points are compared for their ‘similarity’ or ‘distance’ from one another, and are grouped together with those to which they are closest or most similar” (Scott and Carrington 2011). As a data reduction technique, dendrograms take as input a matrix of differences or similarities and progressively builds a tree of association. Readers can think of these dendrograms as inverted trees, with countries as leaves that are connected to smaller branches, which in turn are connected to larger branches. The lower the connection in the dendrogram, the stronger the association between countries. The higher the connection in the dendrogram, the weaker the association.

Figure 1: Dendrogram of Association between members of the ARCAL Network

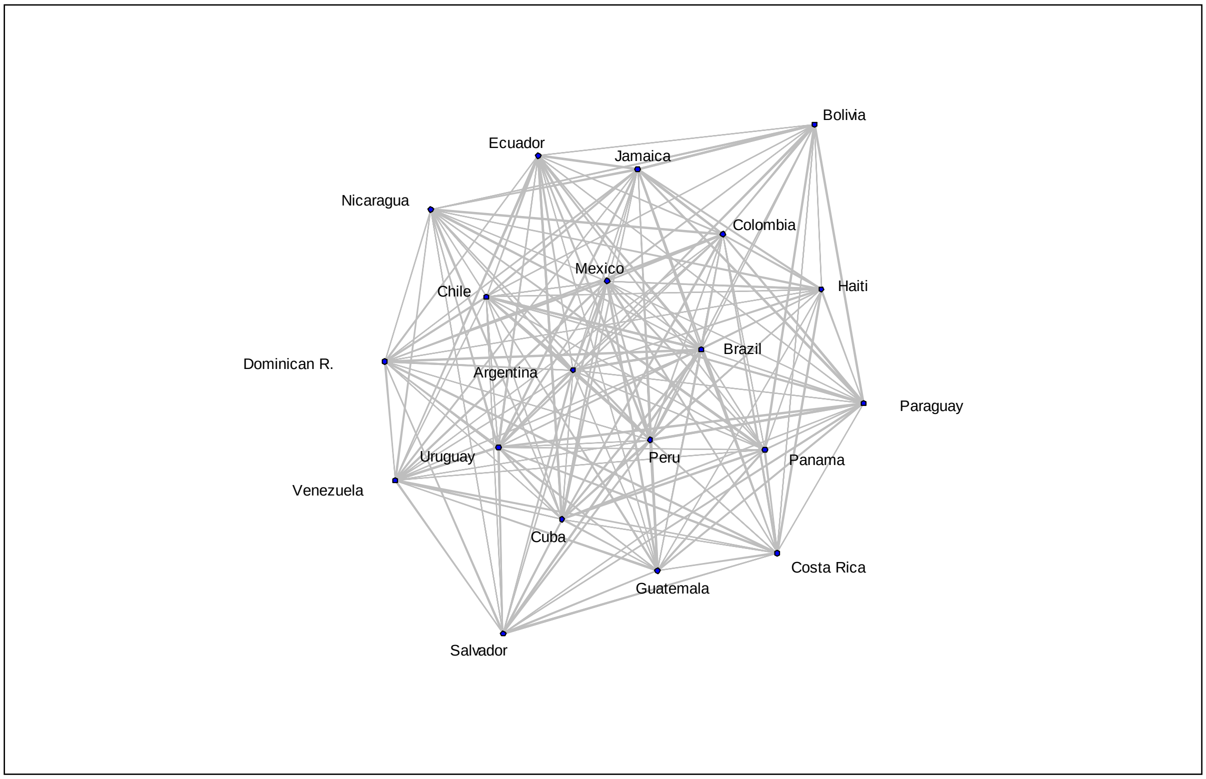


Note: Groups identified by fast-greedy community detection algorithm.

When looking at the ARCAL network in detail in Figure 1, we find the most active group of countries to be more tightly connected to each other. Peru and Uruguay, Argentina and Mexico, together with Cuba, Chile, and Brazil are all identified within a general cluster. They are separate from the countries with intermediate programs such as Ecuador, Colombia, or Costa Rica, all of which are also more likely to interact within a separate cluster of nuclear collaborators. Finally, a less connected group on the left of the dendrogram brings together smaller countries from Central America and the Caribbean which have little to no development in the nuclear sector. While the dendrograms provide insight into the degree of association between the different countries, one characteristic of the nuclear collaboration data is the high density of the networks. Indeed, Figure 2 shows how most countries in Latin America are connected. While not surprisingly, Argentina, Brazil, and Mexico take on a more central position, even smaller countries that participate in a fraction of projects tend to work with many of the other countries in the region.

The descriptive evidence is suggestive, showing that countries with more developed nuclear programs (1) are more active participants in NEST cross-national projects, (2) take more central positions in the networks, and (3) are more likely to be connected to each other. Yet, descriptive information provides little insight into the drivers of collaboration. In the next section, I introduce a variety of statistical models to explain bureaucrats' decision to collaborate and the effect of skills on transgovernmental cooperation in NEST.

Figure 2: ARCAL Collaboration Network in NEST, 1984-2004



Note: Network plot using multidimensional scaling with probabilities drawn from the affiliation matrix.

Empirical Section

This section provides empirical support for a theory of transgovernamental cooperation in NEST as a function of bureaucrats' skill-seeking strategies. I develop three sets of models that test the hypotheses discussed in the Theoretical Section. First, **participation models** measure the decision to participate in transgovernmental nuclear projects sponsored by the IAEA. Second, **dyadic models** measure the probability that two countries will collaborate on a project. Finally, **network models** analyze the determinants of each country's position (centrality) within the ARCAL, AFRA, and RCA networks. Centrality reveals how active participants are in a network by counting the number of ties each actor has with other members. As described by Wasserman and Faust (1994), “the simplest definition of actor centrality is that central actors must be the most active in the sense that they have the most ties to other actors in the network or graph” (Wasserman and Faust 1994: 178).

Data and Model Specifications

Below, I use original data of cross-national projects adopted and implemented under IAEA-sponsored regional agreements (i.e., ARCAL, AFRA, and RCA) since 1980. The data includes information by country, year, and project, allowing for model specifications that control for the different incentives to participate. The data covers 158 projects from Latin America (ARCAL), 119 projects from Africa (AFRA), and 186 projects from Asia (RCA) implemented between 1980 and 2008. Because countries within each region are eligible to participate in these programs, the full dataset includes 4,266 observations in Latin America; 4,403 in Africa; and 6,138 observations in Asia. In all, models are estimated using this large cross-sectional dataset that covers 14,807 total observations across the globe. Given the cross-sectional time series nature of the data, a variety of different models were estimated, including specifications with fixed effects and random effects that control by year and country effects.

To address the hypothesis of homophily effects, I reshaped the participation dataset to match all country dyads to test differences in the traits of potential partners. In this dataset, the number of dyads is large, combining all eligible partners by region, with a total sample size above 498,000. All dyadic models where estimated with clustered errors over the 3,000+ dyadic partners.

Dependent Variables

The three different sets of models require different treatment of the data. In its simplest form, the decision to participate takes the value of 1 if a country joins a project and 0 otherwise. In this case, models analyze the unilateral decision by a bureaucratic agency to participate in each cross-national project in NEST. In the dyadic dataset, however, I am measuring not just the decision to participate but the type of partnership in each project. In this second set of models, the dependent variable takes the value of 1 if a pair of countries is jointly participating in a project and 0 otherwise. This second dataset incorporates information about the degree of similarity among potential partners i.e. similarities in scientific and technical endowments. Finally, the network centrality score takes a value between 0 and 1, where higher scores describe higher degree centrality in the network. That is, the first set of models measure the decision to join on a project, the second one measures the decision to join with particular partners, and the third model seeks to address the level of activity of a program within the network.

The dependent variable of the first and second set of models, consequently, is binary, with the probability of participation—$Pr(Participation = 1|xb)$—being estimated using a logistic specification for cross sectional time series data. The dependent variable on the third set of models is continuous taking as input the level of centrality of each country, drawn from the affiliation matrices described in the previous section. By measuring the different share and degree of involvement in the network of actors, we are able to identify the most active or central players, which in turn inform us of the prominence of different actors.[32]

[32] Degree centrality measures the number of nodes that are adjacent to an actor n_i. The standardized measure proposed by Wasserman and Faust (1994) is $C_D(n_i) = \frac{d(n_i)}{g-1}$ where $d(n_i)$ describes the number of nodes that are adjacent to n_i and g describes the group size. See Wasserman and Faust 1994: 179.

Independent Variables

The main covariates used to explain the decision to participate include: the percent of (i) government spending over total GDP; the (ii) type of skill that is promoted by a collaborative project (general or specific); the (iii) level of skills of the national academic community as described by their published output in scientific journals; and the (iv) type of state institution, whether it is technical or political, and whether it is a nuclear organization or not.

The measure of government spending (or government consumption) as a percent of GDP was obtained from the Penn World Table Version 7.1 and, as discussed above, should have a negative effect on project participation. To create "Project Skill Content" I classified all NEST projects based on the type of training they offered to members (supply side). The variable takes the value of 1 if the project transfers general skills and 0 otherwise. Because participation in the network provides expert bureaucrats resources to upgrade their skills, I expect participation to increase for more general (over special) training. Engaging in collaboration is more critical for expert bureaucrats with higher skills. To account for the collaboration that result from higher demands for skills, I consider the number of publications in referred journals of the national scientific community, as collected by the World Development Indicators (WDI) of the World Bank.

To measure the effect of the type of bureaucratic agency involved, I created two variables. The first one, *Technical Agency* takes the value of 1 when the national institution has a primarily technical mission (not political), and 0 otherwise. The second one, *Nuclear Agency* takes the value of 1 when the national institution is specialized in nuclear science and 0 otherwise.

A number of controls were also included in the model, such as the investment and consumption percentages of GDP (World Penn Tables); the number of international technical agreements sign by the country; the total amount of multilateral credits allocated to each country in the year that the project was initiated; the total size of the economy of a country as described by the GDP; exposure to international trade (openness); the total population; and the Polity IV score with a range of -10 to 10, whereby fully autocratic regimes takes the value of -7 and fully democratic takes the value of 7 or above.

In the dyadic models, in order to measure the extent to which countries with similar levels of technological development are more likely to collaborate, I consider the absolute difference between the number of technical publications of the scientific communities of each pair of countries $[j, z]$, that is: $ABS(NPublications[j] - NPublications[z])$. As controls, I also consider the absolute difference in the number of international technical agreements signed by each pair of countries [j,z], and the difference in GDP of each pair of countries. I expect programs with similar scientific communities to be more likely to collaborate as expert bureaucrats seek to pool resources with true peers.

Participation Models: Discussion

Table 4 presents four alternative specifications to explain participation in collaborative projects in NEST. The first three models include different combinations of the parameters of interest, with a linear specification for the government spending parameters. The fourth one, model D, includes a quadratic government spending term. In the first three specifications the key variables of interest behave as expected. Government consumption is negative and statistically significant, with a one percent increase in government spending reducing the log odds ratio of project participation between -.044 to -.018, equivalent to a decline of between 5% and 2% in the odd of participating in a project for every unit of increase in spending as a percent of GDP. The effect is both statistically and substantively important. For example, between 1983 and 1989, government consumption in Brazil declined from 19.2% of GDP to 14.97, which should result in a 17% increase in the odds-ratio of collaborating in ARCAL projects. Separate models for each of the different regions provide further support for the proposed hypothesis, with government consumption having larger effects in Asia and more moderate ones in Africa.

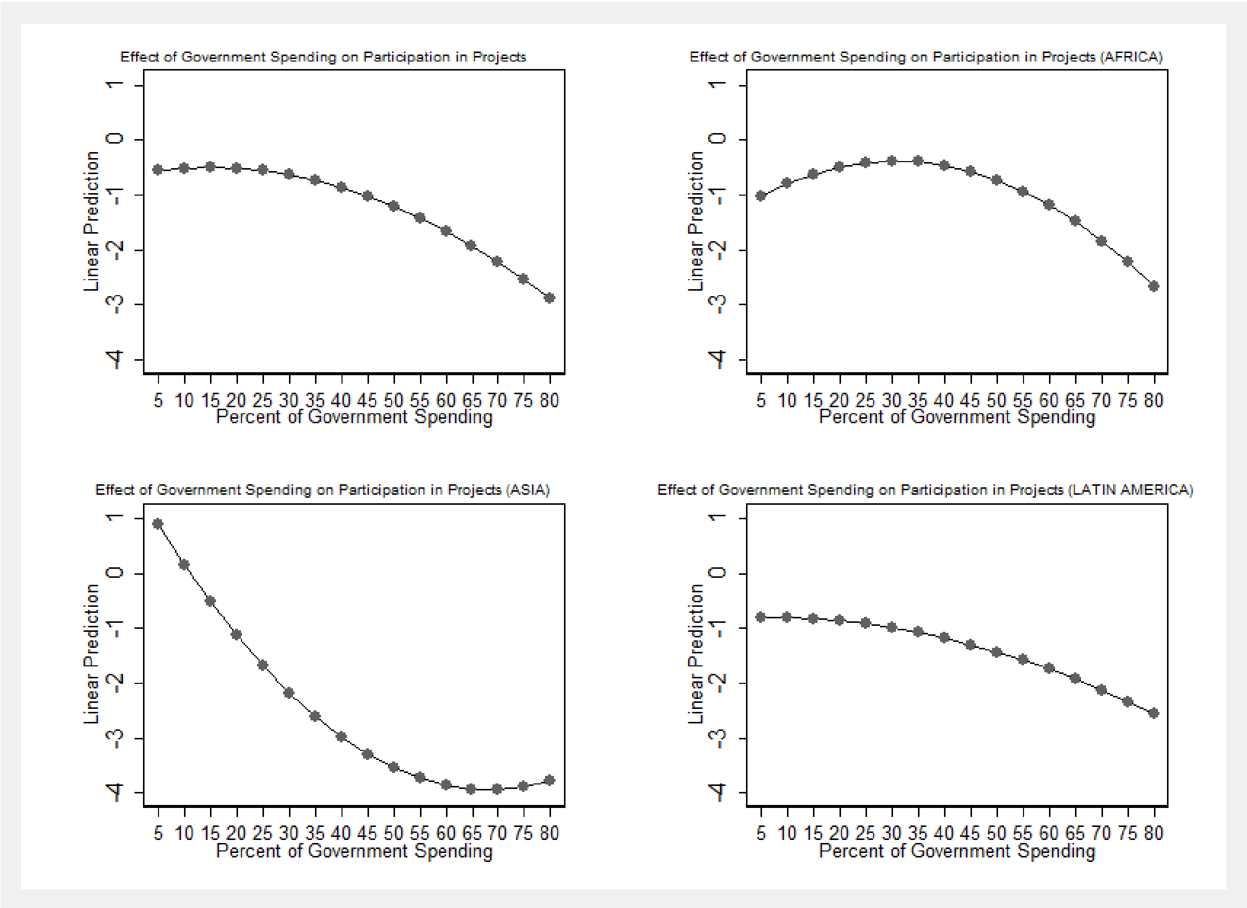
Results also show that projects that transfer general skills increase participation significantly. In all models, nuclear agencies increase the odds of participation by approximately 80% in those projects. Results also support the hypothesis that more developed nuclear programs are considerably more likely to participate in NEST projects. Each unit increase in the number of scientific publications increases the odds of participation in cross-national projects by 16% and 25%, $\exp(.227)$ and $exp(.154)$. Collaboration also increases when the state institution in charge of the sector is technical and when it is specialized in nuclear science. However, these last results are not robust under some specifications. Variables that increase the availability of resources in the domestic economy reduce collaboration in nuclear networks. That is the case for increases in consumption and investment, as well as for more resources accrued through international technical cooperation agreements. Finally, larger, democratic, and more economically-developed countries are more likely to be active collaborators in the NEST networks as shown by the population, polity, and GDP variables.

Table 4: Participation in Collaborative Projects in NEST

	Model A	Model B	Model C	Model D
Technical Agency	1.259***	0.399	-0.184	0.051
	(0.3014)	(0.5039)	(0.4915)	(0.4903)
Nuclear Agency	0.547**	0.646	0.477	0.556
	(0.2374)	(0.4144)	(0.3931)	(0.3927)
Government Spending (%)	-0.044***	-0.027***	-0.013**	0.046**
	(0.0058)	(0.0076)	(0.0077)	(0.0186)
Square Government Spending (%)				-0.001***
				(0.0003)
Investment (%)	0.005	0.02***	0.013**	0.027***
	(0.0049)	(0.0062)	(0.0065)	(0.0069)
Consumption (%)	-0.001	0.007*	0.012***	0.016***
	(0.0035)	(0.0044)	(0.0046)	(0.0049)
Project Skill Content	0.592***	0.638***		0.593***
	(0.0443)	(0.0506)		(0.0515)
Multilateral Financing		0.014	0.024*	0.01
		(0.0119)	(0.0129)	(0.0138)
Number of Scientific Publications (LN)		0.264***	0.087	0.141*
		(0.0558)	(0.0730)	(0.0764)
Number of Technical Cooperation Agreements		-0.223***	-0.319***	-0.337***
		(0.0779)	(0.0758)	(0.0810)
Asia		-0.793	-1.115**	-0.99**
		(0.4865)	(0.4687)	(0.4676)
Latin America		-2.599***	-2.61***	-2.573***
		(0.3633)	(0.3501)	(0.3520)
GDP (LN)			0.478***	0.357***
			(0.1254)	(0.1338)
Openness			-0.002	-0.003
			(0.0019)	(0.0021)
Population (LN)			0.374***	0.302**
			(0.1396)	(0.1434)
Polity Score			0.005**	0.004
			(0.0025)	(0.0026)
Constant	-0.941**	2.204	-1.696	-2.002
	(0.4340)	(1.4722)	(2.1000)	(2.0995)
Alpha(LN)	-0.11	0.633**	0.464*	0.396
	(0.1695)	(0.2660)	(0.2778)	(0.2779)
N	11320	8842	8398	8398
Groups	83	69	66	66
LogLik	271.2	282.08	280.19	288.86

Note: Cross-Sectional time series regression models with random effects by country. Baseline region is Africa. Standard errors in parentheses with confidence levels reported as follows: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Figure 3: Effect of Government Spending on Participation in Collaborative Projects



Note: Plots describe marginal effects of government spending on the decision to participate in cross-national NEST projects. The line describes quadratic specifications for the full sample and for each of the three regions.[33]

The quadratic specification provides some further insight into the effect of government spending on the nuclear sector. Figure 3 describes the marginal effect of government spending on program participation for the whole sample (upper left plot) and for each of the three regions. As it is possible to observe, the effects are more pronounced for Asia and more moderate for Africa. The negative effect of government spending on participation increases at very high levels

[33] Models with quadratic specifications for each of the regions are available upon request.

of government spending but is more moderate at low levels of spending. As expected, in countries were the government is the main engine of the economy, declines in government spending have a more pronounced effect on participation.

Dyadic Models: Discussion

Participation models describing the effect of government spending and other variables on participation in nuclear projects do not speak to the choice of partners. To test for partnerships in nuclear collaboration I now estimate dyadic models that take the value of 1 if a pair of countries joins in a project and 0 otherwise. Different from the previous model, the objective of these alternative specifications is to incorporate information about the relative dissimilarity between potential partners. As described before, the models include all covariates from Table 4 and also four new terms measuring the degree of similarity between the expert communities (measured by the differences in the total number of publications), differences in the number of technical agreements, and, as a placebo, inter-country differences in GDP.

The proposed specifications seek to test not only the effects of government spending and demands for skills on cooperation, but also to test whether scientific communities that are similar (dissimilar) are more (less) likely to cooperate. That is, I test for homophily effects (e.g. "birds of a feather flock together").

Table 5 presents three models of joint collaboration: a restricted model measuring the effect of government spending (Model A); a "skill" model testing for the effect of spending and the demand for skills (Model B); and the full model which includes also the three similarity/dissimilarity terms. I expect differences in the level of development of the scientific community (as described by differences in the number of publications) to reduce cooperation. I also expect differences in the technical treaties to reduce cooperation. Finally, I consider differences in GDP as a placebo control, given that it should not affect the level of cooperation.

Overall, models in Table 5 are consistent with those presented in Table 4. The effect of government spending on joint collaboration is negative and statistically significant, once again supporting expectations of a substitution strategy of transgovernmental cooperation for domestic funding. Every 1 % increase in government spending decreases the odds of collaboration, from -5.4% in Model A to -1.8 in the Model C. Countries with technical agencies and/or nuclear agencies are also more likely to partner up, with the effect being very large and statistically significant for the technical agency and more modest for the nuclear one.

Parameters that describe the demand for skills are large and statistically significant, with projects that transfer general skills being more likely to elicit cooperation and more developed scientific communities being more active partners. Indeed, the total number of scientific publications (LN) of a community increases the odds of cooperation by 25% in Model B—i.e. $exp(.226)$—and 14% in Model C—i.e. $exp(.129)$.

Model results for the homophily parameters are in the expected direction, although only the parameter describing differences in the number of scientific publications reaches statistical significance. By contrast, the variable “difference in technical cooperation agreements” is negative but statistically insignificant. As expected, differences in overall GDP are of no consequence for cooperative behavior once we control for overall income effects. In all, results of the model strongly confirm expectations in regards to governments spending and demands for skills. Homophily effects are consistent with the hypothesis but the effect is only significant for one of the two terms.

Table 5: Joint Collaboration in NEST Projects

		Model A	Model B	Model C
Spending	**Government Spending (%)**	-0.056***	-0.029***	-0.018***
		(0.0010)	(0.0012)	(0.0014)
	Investment (%)	0.002***	0.014***	0.014***
		(0.0008)	(0.0011)	(0.0014)
	Consumption (%)	-0.008***	0.008***	0.011***
		(0.0006)	(0.0007)	(0.0009)
	Asia	-0.403***	0.235***	-0.207**
		(0.0571)	(0.0575)	(0.0809)
	Latin America	-0.686***	-0.189***	-0.293***
		(0.0642)	(0.0485)	(0.0572)
Demand for Skills	**Technical Agency**		1.169***	0.744***
			(0.0629)	(0.0827)
	Nuclear Agency		0.207***	0.091
			(0.0481)	(0.0570)
	Proyect Skill Content		0.627***	0.777***
			(0.0089)	(0.0107)
	Number of Scientific Publications (LN)		0.226***	0.129***
			(0.0084)	(0.0141)
Access to Resources	**Multilateral Financing**		0.009***	0.007**
			(0.0020)	(0.0032)
	Number of Technical Cooperation Agreements		-0.103***	-0.183***
			(0.0132)	(0.0159)
	GDP (LN)			0.289***
				(0.0253)
	Openness			-0.0002
				(0.0004)
	Population (LN)			0.431***
				(0.0249)
	Polity Score			0.0076***
				(0.0020)
Homophily	**Difference in Total Scientific Publications (LN)**			-0.098***
				(0.0098)
	Difference in GDP			0.004
				(0.0221)
	Difference in Technical Cooperation Agreements			-0.07
				(0.0606)
	Constant	1.019***	-0.933***	-5.216***
		(0.0633)	(0.2368)	(0.3899)
	Sigma(u)	0.585***	-0.259***	-0.331***
		(0.0285)	(0.0357)	(0.0422)
	Rho	0.353***	0.19***	0.179***
		(0.0065)	(0.0055)	(0.0062)
	N	489650	286260	198750
	Groups	3058	2244	1676

Note: Cross-Sectional time series regression models with random effects by collaborative dyad. Baseline region is Latin America. Standard errors in parentheses with confidence levels reported as follows: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Model results also show that more populated, wealthier, democratic countries are more likely to cooperate in nuclear projects. The effect is large for populated and wealthier countries and more modest for democratic ones.

Centrality Models: Discussion

These models explain a country's position in the transgovernmental NEST network, which is a function of economic, political, and social factors at both the country and international level. The main covariates of this analysis include government spending (or government consumption) as a share of GDP, the level of insertion in international organizations (IO membership), the level of economic openness, education spending as a share of GDP, GDP growth, military capability, and the level of democracy.[34] In addition, I use a variable capturing the effect of IO membership from the Correlates of War database. To deal with problems common to cross-sectional time's series data I estimate a variety of random effects and fixed effects model, as in the previous section.

Table 6 presents the results of four different specifications. Model A estimates mean differences in degree centrality for countries of different regions, with Latin America as the baseline region. In all models I find higher mean degree centrality for countries of Africa and Asia. Model estimates from government consumption, education spending, and growth are negative and statistically significant. As expected, declining government spending and education spending activates nuclear collaboration as a mechanism to pool common resources. A decrease in government spending, consequently, leads to a decline in a country's centrality in AFRA, ARCAL, and RCA. Also, membership in international organizations increases network

[34] Variables are from the Penn World Table at http://pwt.econ.upenn.edu/php_site/pwt62/pwt62_form.php; World Bank http://www.worldbank.org/ ; Polity IV http://www.systemicpeace.org/polity/polity4.htm; and the Correlates of War Project http://www.correlatesofwar.org/ .

centrality. However, once countries are sufficiently linked to a core group of international organizations (around 50), IO membership has no further effect on the centrality of nuclear collaboration networks. Results also show that higher levels of democracy increase centrality in NEST networks. Other controls are statistically significant and in the expected direction: network centrality increases with trade openness. By contrast, higher military capability is negative, leading to lower degree centrality. However, the results for military capability are not statistically significant.

Table 6: Explaining Degree Centrality in NEST Networks

	Model A	Model B	Model C	Model D
Middle East	0.0351	-0.1748**	-0.21*	-0.2124**
	(0.0359)	(0.0778)	(0.1109)	(0.0870)
Africa	-0.0208	-0.0225	-0.0643	-0.1121
	(0.0317)	(0.0533)	(0.0684)	(0.0996)
South Asia	0.101	0.2528***	0.3193***	0.2714***
	(0.0881)	(0.0902)	(0.1007)	(0.0878)
North East Asia	0.1036***	0.0897**	0.0552	0.1106**
	(0.0305)	(0.0400)	(0.0462)	(0.0475)
Europe	-0.143***	-0.1694***	-0.214***	-0.4169***
	(0.0246)	(0.0327)	(0.0408)	(0.0583)
Government Consumption		-0.0092***	-0.0089***	-0.0075***
		(0.0020)	(0.0020)	(0.0021)
Openess		0.0022***	0.0027***	0.0027***
		(0.0003)	(0.0003)	(0.0004)
Education Spending		-0.0091*	-0.0112**	-0.0144***
		(0.0050)	(0.0048)	(0.0044)
GDP Growth		-0.0025***	-0.0022***	-0.0032***
		(0.0007)	(0.0007)	(0.0007)
Military Capability			-1.5592	0.8416
			(2.0134)	(2.2121)
Democracy (Polity IV)			0.0028**	0.0046***
			(0.0011)	(0.0012)
GDP(LN)				-1.122**
				(0.4902)
GDP(LN)^2				0.0745**
				(0.0303)
IO-Membership				2.455**
				(1.0957)
IO-Membership^2				-0.2623**
				(0.1108)
Constant	0.143***	0.2358***	0.24***	-1.29
	(0.0246)	(0.0516)	(0.0593)	(3.0453)
N	1512	498	488	483
N-Groups	54	27	25	24
Chi-Square	313.3	244.0	240.4	261.4

Note: Cross-Sectional time series regression models with random effects by country. Baseline region is Latin America. Standard errors in parentheses with confidence levels reported as follows: * p < 0.1, ** p < 0.05, *** p < 0.01.

Concluding Remarks

A recent piece on National Public Radio asked: "What do you do when you are a scientist and you have no money for your research?" The report featured a molecular biologist who studied the effects of addiction on the brain: "He's interested in doing something about mental illness and addiction, but he needs a lot more basic information about the brain before he can invent a new drug or treatment. Now, most of the time the federal government funds the basic biomedical research in this country. But it's getting harder and harder to snag one of those government research grants." So, the story continues, the scientist took matters into his own hands by crowdsourcing: he organized a campaign using different types of social media to ask the public to fund his research project. His goal was to raise the equivalent to a small seed grant, which he did. Like this professional, other American scientists are networking in new and resourceful ways to cope with widespread government spending cuts, which tend to disproportionately affect Research and Development (R&D) budgets. Crowdsourcing has enabled the implementation of projects that tend to be low on costs but high on innovation. Thus, soliciting "ideas, skills, or participation" from a wide network is one strategy scientists follow in the face of declining state sponsorship.[35] More critically, as monies raised through this networking method are typically supplemental to the level that is needed to support a science research program, the most significant contribution of crowdsourcing is the access it provides to innovation and expertise. In the developing world, where R&D budgets turn on a dime, state scientists have been "crowdsourcing" for decades. Accustomed to regular cuts in government spending, which can quickly derail research programs, state experts network with peers outside their agencies to pool scarce resources, access new technology, and keep up with professional best practices. In non-OECD countries a majority of scientists work in government agencies, as

[35] "What is Crowdsourcing?" at http://dailycrowdsource.com/training/crowdsourcing/what-is-crowdsourcing

employment alternatives for them in the private sector or university are few and rare (Solingen 1994). Thus, for this kind of expert, networking to access new skills and know-how in response to the withdrawal of state support often entails going beyond national borders.

In all, analyses provide support for main hypotheses presented in this article. First, study findings show that when government spending decreases expert bureaucrats intensify international cooperation with peers as a compensatory strategy. Second, models also show that impoverished bureaucrats favor those projects that provide the highest returns for a career in the bureaucracy: general skills. Finally, collaboration is more likely to develop between true peer programs with similar levels of development (i.e., homophily). This result is consistent with the qualitative evidence presented in previous sections drawn from numerous interviews with expert bureaucrats. These findings also contribute to our understanding of the political economy of skills. Workers incentives to invest themselves in general skills hold under conditions of competition *and* cooperation. Also, high skilled workers are more likely to access training whether they are from competing firms or state bureaucracies. Given these findings, the question remains: how effective is transgovernmental cooperation to deepen and improve bureaucratic expertise? Anecdotal data and elite interviews confirm that accessing international resources have a strong impact on the career path of individual bureaucrats. The next step would be to be able to measure the impact of this strategy on the state's *institutional* expertise.

Appendix

Table A.1: Participating Countries in RCA, AFRA, and ARCAL

RCA		AFRA		ARCAL	
Country Name	Country Code	Country Name	Country Code	Country Name	Country Code
Australia	AUS	Algeria	DZA	Argentina	ARG
Bangladesh	BGD	Angola	AGO	Bolivia	BOL
China	CHN	Benin	BEN	Brazil	BRA
India	IND	Botswana	BWA	Chile	CHL
Indonesia	IDN	Burkina Faso	BFA	Colombia	COL
Japan	JPN	Cameroon	CMR	Costa Rica	CRI
Mongolia	MNG	Central African Republic	CAF	Cuba	CUB
Myanmar	MMR	Democratic Rep of Congo	ZAR	Dominican Republic	DOM
New Zealand	NZL	Egypt	EGY	Ecuador	ECU
Pakistan	PAK	Eritrea	ERI	El Salvador	SLV
Philippines	PHL	Ethiopia	ETH	Guatemala	GTM
Republic of Korea	KOR	Gabon	GAB	Haiti	HTI
Singapore	SGP	Ghana	GHA	Jamaica	JAM
Sri Lanka	LKA	Ivory Coast	CIV	Mexico	MEX
Thailand	THA	Kenya	KEN	Nicaragua	NIC
Vietnam	VNM	Libyan Arab Jamahiriya	LBY	Panama	PAN
Nepal	NEP	Madagascar	MDG	Paraguay	PRY
		Mali	MLI	Peru	PER
		Mauritius	MUS	Uruguay	URY
		Morocco	MAR	Venezuela	VEN
		Namibia	NAM		
		Niger	NER		
		Nigeria	NGA		
		Senegal	SEN		
		Sierra Leone	SLE		
		South Africa	ZAF		
		Sudan	SDN		
		Tunisia	TUN		
		Uganda	UGA		
		United Republic of Tanzania	TZA		
		Zambia	ZMB		
		Zimbabwe	ZWE		

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