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State Stem Cell Policies and the Geographic Preferences of U.S. Stem Cell Scientists

Aaron Levine
Ph.D. Candidate in Public Affairs
Program in Science, Technology and Environmental Policy
Woodrow Wilson School of Public and International Affairs
Princeton University
Princeton, NJ 08544-1013
(717) 856-4181
adlevine@princeton.edu

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Introduction

Since human embryonic stem cells were first successfully isolated in 1998 (Thomson et al. 1998), a number of states have enacted policies governing research in this promising but controversial field. These policies vary widely from state to state. Six states, led by California, explicitly support human embryonic stem cell research. In contrast, twelve states clearly restrict some research in this field and a number of others have policies that may potentially hinder research. New laws, some aiming to support and others to restrict research, are currently under consideration in statehouses across the country.

This state interest in biomedical research policy is quite unusual. In the United States, research policy is typically a federal concern, either determined directly by congress or through policies promulgated by executive agencies responsible for funding scientific research (For an overview, see Smith 1990). For biomedical research, this effort is typically driven by the U.S. National Institutes of Health (NIH).

In the case of human embryonic stem cell research, the Federal Government has largely abdicated its traditional leadership role. In August 2001, George W. Bush dedicated the first primetime address of his presidency to announce a new policy limiting federal funding to research using human embryonic stem cell lines derived prior to August 9, 2001 (Bush 2001). While the NIH has funded important research using some of the 21 so-called “Presidential” cell lines,[1] the funding restrictions have isolated the NIH from the cutting-edge of the field and greatly reduced its policy-making leverage.

[1] See the NIH Stem Cell Registry (http://stemcells.nih.gov/research/registry/) for more details on the approved lines.

State interest in the field reflects, at least in part, action to fill this policy-making void. States supporting human embryonic stem cell research aim to circumvent federal funding restrictions and support what many see as medically-promising research. These states also aim to spur economic development and recruit and retain scientists and biotechnology firms (e.g. Baker and Deal 2004; Seneca and Irving 2005). States restricting research in the field typically aim to restrict this research in a more comprehensive manner, often by explicitly banning specific research practices regardless of funding type.

Of the states explicitly supporting stem cell research, California's program is the largest. Approved by voters in November 2004, it calls for the state to provide three billion dollars for new facilities and research grants over ten years (Murphy 2004). Although the California initiative – Proposition 71 – originally called for funding to be dispersed in mid 2005, litigation has hindered implementation of the state's plans and, thus far, blocked issuance of bonds (Somers 2005). In February 2007, the California Institute for Regenerative Medicine (CIRM), the new state agency created by the passage of Proposition 71, was expected to award its first research grants – totaling approximately $24 million. The bulk of this money has come from a loan of $150 million from the state general fund, approved by Governor Arnold Schwarzenegger in the hope of tiding CIRM over until the ongoing litigation is resolved (Somers 2006).

Connecticut also has a long-term plan to support stem cell research. A bill signed into law in June 2005 calls on the state to provide $100 million for research over a ten year period (Conn. Gen. Stat. §19a-32d to 32g). In November 2006, Connecticut announced its first round of grants under this program, awarding approximately $20 million for 21 different projects (Hathaway 2006).

New Jersey, Illinois and Maryland have also committed state funding to stem cell research, although these states have offered less substantial research funding. New Jersey is a bit of an exception. State lawmakers approved $270 million for new stem cell research facilities in New Brunswick, Newark and Camden in December 2006, but have not, thus far, made a long-term commitment to provide research grants (Chen 2006). Lawmakers plan to ask New Jersey voters to authorize $230 million in bonds for research grants in November 2007. Massachusetts has not provided any state funding for stem cell research but has passed legislation explicitly legalizing human embryonic stem cell research.

The varied state policies in effect or under consideration today reflect the nuances of embryonic stem cell research. The field inspires both hope and controversy for at least two reasons. Human embryonic stem cells are derived from the inner cell mass of five to six day old embryos. In normal development these cells go on to give rise to every cell type in a mature organism, a property scientists refer to as pluripotency. This ability raises hopes that these cells may one day be crucial to a variety of transplant-based therapies. However, the derivation of an embryonic stem cell line typically prevents the embryo from continuing development. Because these embryos are potentially viable if presented with the right environment – a surrogate womb – opponents of this research liken the derivation of a human embryonic stem cell line to abortion.

The second controversy arises over the potential link between human embryonic stem cell research and cloning. Immune rejection, a response that occurs when a recipient’s immune system recognizes a transplant as foreign and mobilizes to attack it, is a key complication of many transplant therapies. The combination of cloning and embryonic stem cell research may, however, allow scientists to sidestep this challenge. The idea is fairly simple. Scientists, using a technique pioneered to clone Dolly the sheep in 1997 (Wilmut et al. 1997), would create a cloned human embryo and allow it to develop to the blastocyst stage, typically reached at five days of age. They would then isolate human embryonic stem cells from this cloned embryo. These cells would be genetically matched to the patient and transplants derived from these cells should not trigger an immune response. This protocol has been deemed “therapeutic cloning” and, in the long-term, may offer significant health benefits. Therapeutic cloning is controversial both because it requires the deliberate creation and use of a human embryo and because it may open the door to the cloning of humans for reproductive purposes. If scientists aiming to produce patient-matched embryonic stem cells for medical therapies optimize the protocol for creating cloned human embryos, this would facilitate the creation of cloned human embryos for reproductive purposes. Because of the controversy surrounding human reproductive cloning, some states have chosen to explicitly ban the creation of cloned human embryos, thereby blocking research aimed at therapeutic cloning.

Although the impacts of state bans on certain lines of research are fairly clear, the impact of policies designed broadly to encourage human embryonic stem cell science are less straightforward. These states hope their policies will attract scientists and help build their biotechnology sectors. Yet the extent to which supportive state research policies impact stem cell scientists’ geographic preferences remains an open question. This study attempts to address this question. To do so, it compares survey responses indicating the preferred states of stem cell scientists and other biomedical scientists working in less contentious fields.

Scientists may prefer working in a specific state for a variety of reasons. Many of these reasons (high salaries, temperate climate, etc.) are likely shared by many, if not all, scientists, while others may be field-specific. By comparing stem cell scientists with similar biomedical scientists working in less contentious fields, this study aims to focus on field-specific reasons that stem cell scientists might prefer or dislike specific states.

In short, the analysis reported here indicates that U.S. stem cell scientists' preferences are significantly skewed toward the small number of states that explicitly support stem cell research and that the existence of a permissive policy in a state is a large and statistically significant predictor of the difference in preferences for that state between the two groups of scientists. Awareness of state efforts to support stem cell research was a statistically significant predictor of stem cell scientists' likelihood to rank California, Connecticut and New Jersey among their top three preferred states.

Methodology[2]

During September and October 2005, a survey was administered to stem cell scientists working at academic and non-profit medical research institutions in the United States. The survey was administered over the Internet, using the Princeton University web survey facility. The survey was pre-tested on a group of stem cell scientists, and, following revisions, sent to a larger sample of 1,033 stem cell scientists. This list of

[2] This methodology section is copied nearly verbatim from prior analyses of other datasets generated by these surveys (Levine 2006, In Press) These analyses focused on related but distinct questions

scientists was derived from three sources: *Who's Who in Stem Cell Research* (DataTrends Publications 2005), PubMed literature searches and the member directory of the International Society for Stem Cell Research. This participant list was designed to cover, as comprehensively as possible, the active U.S. population of stem cell scientists and contained scientists working with both adult and embryonic stem cells. Each potential participant was contacted first by mail and then by email.

Responses were defined as usable if both an initial demographics section and at least a portion of a section on future plans were completed. A total of 365 responses met these minimal criteria, yielding an overall response rate of 35 percent. The actual number of responses varied by question as item non-response was permitted and a small number of respondents completed only a portion of the survey, but each question analyzed here was answered by at least 92 percent of these 365 respondents. Fifty seven percent of respondents were principal investigators and 35 percent were either post-doctoral researchers or advanced graduate students. Respondents came from 39 states and their distribution closely paralleled the distribution of academic biomedical research in the United States, as measured by the NIH's fiscal year 2004 extramural budget. Thirty-five percent of principal investigators and 58 percent of post-doctoral researchers and graduate students were born outside the United States. Nearly 35 percent of the respondents indicated that they had worked with human embryonic stem cells and 58 percent of those who had not worked with these cells believed they were likely (six or higher on a ten-point scale) to do so in the future. A total of 265 respondents (73 percent) used or were likely to use human embryonic stem cells. These respondents are categorized as human embryonic stem cell scientists in the analysis that follows.

A similar survey of other biomedical scientists working in less contentious fields was conducted in January 2006. The survey was also administered on the Internet, using the same university-based web survey facility. The survey was sent to a random sample of 1,847 regular academic members of the American Society for Biochemistry and Molecular Biology (ASBMB) and 1,904 regular academic members of the American Physiology Society (APS). Each potential participant was contacted by email. These two societies were selected because together their members cover a wide range of biomedical research fields and it seemed unlikely that many of their members used stem cells in their research.

A total of 1,029 usable responses were received, yielding an overall response rate of 27 percent. The number of responses varied by question, but each question analyzed here was answered by at least 95 percent of these 1,029 respondents. 551 respondents were from the list of APS members and 478 were from the list of ASBMB members. Eighty seven percent of respondents were principal investigators. Respondents came from all fifty states and the District of Columbia. Twenty percent of principal investigators and 46 percent of post-doctoral researchers and graduate students were born outside the United States.

Both surveys included screening questions to ensure respondents were active researchers. The number of usable responses reported above only includes respondents who passed all relevant screening questions. For the stem cell survey, respondents were included in the final dataset only if they had, in the last six months, participated in a research project using or relating to stem cells. For the survey of non-stem-cell scientists, two screening questions were used. Respondents were included in the final dataset only if they had worked on a biomedical research project in the last six months and if they did not study or use stem cells of any type in their research. Both surveys contained both closed and open-ended questions, although the analysis reported here focuses on the closed-ended questions. Both survey protocols were approved by the Princeton University Institutional Review Panel for Human Subjects.

Results

Although states that have adopted policies supporting human embryonic stem cell research have done so in the hope that scientists will notice these policies and be attracted to their states, such an outcome is not guaranteed. While California and Connecticut have established programs supporting stem cell research for a ten-year period, other states offer shorter programs and continued funding may be subject to the whims of state legislators. Some states have attached intellectual property restrictions to their funding, potentially reducing its desirability and, at a minimum, adding to the bureaucratic red-tape associated with its use (See Noll 2006 on intellectual property issues associated with state support for stem cell research). Despite these challenges, state funding does allow scientists to pursue work not currently supported the NIH. This incentive, in addition to the benefit of competing for research funding among a smaller pool of scientists within a single state, may skew stem cell scientists' preferences to those states that offer supportive research environments.

To help determine the extent to which, if at all, state stem cell policies affect the geographic preferences of stem cell scientists, both groups of scientists were asked about their preferred states for research. Specifically, scientists were asked "if they could choose to work in any state to pursue human embryonic stem cell research / research in your field, what would be your top three states?" In the analysis that follows, responses to this question will be compared for two groups of scientists. The first group is U.S. stem cell scientists who either use human embryonic stem cells in their work today or indicated they expected to in the future. This represents approximately 73 percent of the stem cell scientist sample and are, presumably, the group of scientists most likely to be affected by the state policies. The second group consisted of biomedical scientists who indicated they did not use stem cells of any type in their research.

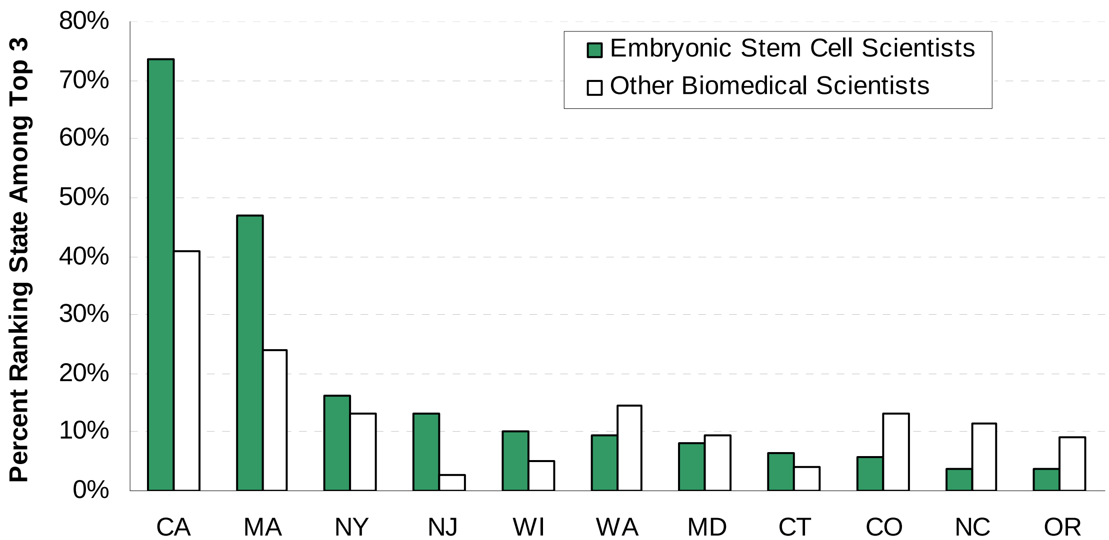

Figure 1 – Differences in preferred states. The percentage of U.S. human embryonic stem cell scientists and other biomedical scientists ranking a state in their top three is shown for the eleven states most frequently ranked by stem cell scientist respondents. Home state preferences excluded. N= 250 stem cell scientists, 983 other biomedical scientists.

If state stem cell policies have no effect, the stated preferences of both groups of scientists would be expected to be similar. This is not the case. Figure 1 and Figure 2 illustrate clear differences between the two groups of scientists. Figure 1 shows the percentage of each group of scientists ranking a state as one of their top three destinations. States disproportionately preferred by stem cell scientists include California, Massachusetts and New Jersey, all states with supportive stem cell research policies, and Wisconsin, where James Thomson's groundbreaking work isolating human embryonic stem cells occurred.

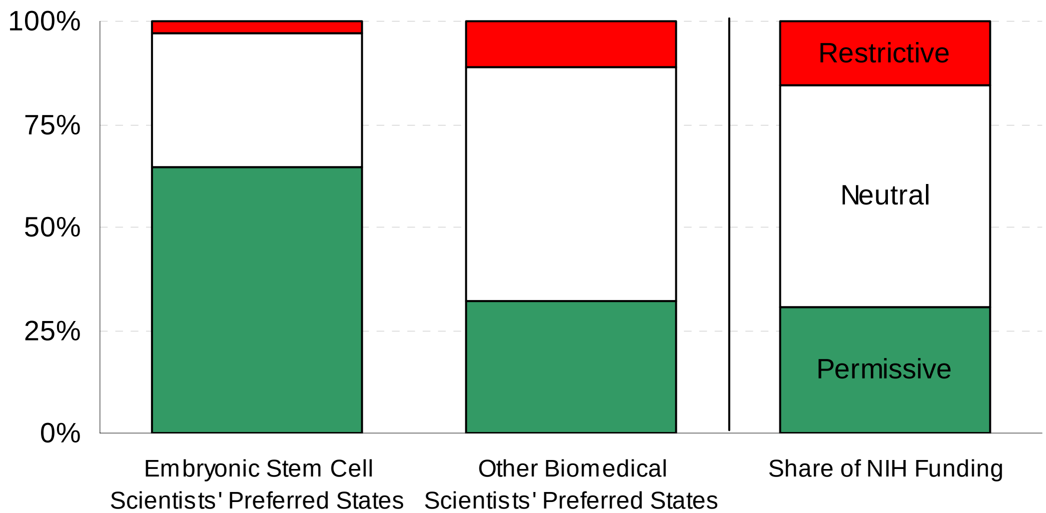

Figure 2 – Policy classification of preferred states. States ranked among scientists' top three destinations are classified according to their stem cell policies. NIH extramural funding is shown for fiscal year 2005. N= 2818 preferences.

To further clarify the role of state policy on these stated preferences, Figure 2 classifies these self-reported preferences on the basis of each state's policy toward stem cell research. Five states (CA, CT, IL, MA, NJ) are classified as permissive. (MD is considered neutral because legislation supporting stem cell research had not been enacted at the time of the survey.) Ten states are considered restrictive. These include states that explicitly ban all embryo research (LA, MI, SD) or restrict the creation of cloned human embryos for research purposes (AR, IN, IA, MI, ND, SD) as well as states where laws that either pre-date embryonic stem cell research or are ambiguously worded appear to hinder or restrict this research (MN, PA, VA). While the classification of permissive states is straightforward, restrictive states cannot be unambiguously identified. The classification used here largely agrees with existing policy interpretations (e.g. Andrews 2004; Stone 2006; Vestal 2006) and readings of the relevant statutes . In any case, the perception of restrictiveness may be as important as the presence of actual legal restrictions.

When all reported preferences were classified, permissive states made up 66 percent of the states listed by stem cell scientists, compared with 32 percent of the states ranked by the group of biomedical scientists in less contentious fields. Chi-square testing rejects the null hypothesis that these preferences share the same distribution ($P < 5e^{-40}$, $n = 2,818$ reported preferences, $df = 2$). The biomedical scientists' preferences closely parallel the distribution of NIH grant funding to permissive, restrictive and neutral states. Together, these results suggest that stem cell scientists' preferences are influenced by the heterogeneous policy environment their research faces, while the other biomedical scientists' preferences are representative of academic biomedical research as a whole.

To further investigate the relationship between state policies and the geographic preferences of stem cell scientists, regression analysis was utilized. Two analytic strategies were used. The first analysis was conducted at the state level, allowing the introduction of independent variables for permissive and restrictive state policies. The dependent variable for this analysis was the difference in the percent of stem cell scientists and other biomedical scientists ranking a state among their top three. This variable ranges from – 8 percent (NC) to + 33 percent (CA). This particular dependent variable eliminates from the analysis much of the variability in state preferences due to general factors unrelated to stem cell policy. Given the small number of states included in this analysis (many states are not particularly appealing to either group and were, thus, excluded), this dependent variable allows for the inclusion of fewer independent variables and reduces overspecification concerns. A small number of independent variables that could plausibly affect one group of scientists disproportionately were included in the analysis. These included measures of the strength of the scientific community in the states (NIH funding and biotechnology firms) and measures of the political and religious climate (Kerry voters and weekly church attendance).

	OLS (Initial)	**OLS (Final)**	**WLS (Initial)**	**WLS (Final)**
Permissive state policy	0.10** (0.04)	0.11*** (0.04)	0.13*** (0.04)	0.14*** (0.04)
Restrictive state policy	-0.01 (-0.03)	-0.01 (-0.03)	-0.00 (0.03)	-0.00 (0.03)
NIH grant funding (100 $M)	0.005*** (0.002)	0.007*** (0.002)	0.006*** (0.002)	0.008*** 0.001
Biotechnology firms (100s)	0.003 (.0003)		0.003** (0.001)	
Kerry voters in 2004 (%)	0.05 (0.08)		0.06 (0.09)	
Weekly church attendance (%)	-0.24 (-0.24)	-0.26 (0.20)	-0.25 (0.19)	-0.28* (0.16)
Constant	-0.02 (0.12)	0.02 (0.07)	-0.03 (0.10)	-0.00 (0.06)
N F P > F R^2	19 7.82 0.0014 0.78	19 9.73 0.0006 0.77	19 95.08 0.0000 0.95	19 69.48 0.0000 0.94

Table 1 – Regression analysis examining the influence of stem cell policies on the difference in state preferences. Dependent variable is the percentage of human embryonic stem cell scientists ranking a state among their top three – the percentage of other biomedical scientists ranking the state among their top three. Home state preferences were excluded. Only states which at least three stem cell scientist respondents ranked among their top three were included. WLS regression was weighted based on the number of respondents from the group of biomedical scientists ranking a state among their top three. State policy variables were constructed as described in the main text. Counts of biotechnology firms came from BIO (Batelle Technology Partnership Practice and SSTI 2006), Kerry voters from CNN and Church attendance from (San Diego Union Tribune 2006). *** P < 0.01, ** P < 0.05, * P < 0.10

Two ordinary least squares (OLS) regression models are presented in Table 1. The first contains the full set of regressors, while the second presents a reduced model with two independent variables removed due to high pair-wise correlation with other regressors. In both models, the coefficient on the permissive state stem cell policy indicator was large, positive and statistically significant. Indeed, all else equal, the presence of a permissive policy leads to a ten or eleven percentage point increase in the difference between the percentage of stem cell scientists and other biomedical scientists ranking a state among their top three. The restrictive state indicator variable had no impact, but this is not particularly surprising, since many states with restrictive policies were not popular with either group of scientist and, thus, failed to meet minimum standards for inclusion in the analysis. The point estimates of the variables measuring the strength of the biomedical research community in the state were positive, and the coefficient on NIH funding in a state was significant, suggesting that stem cell scientists disproportionately value being part of a large research community. Point estimates also suggest that stem cell scientists prefer democratic-leaning states and states with less religious citizens, although these coefficients did not reach standard significance levels.

If each scientist had ranked a full slate of fifteen states, both groups of scientists' relative preferences would be estimated with the same precision for each state. Because time constraints limited the survey to asking only about scientists' top thee states, however, more data is available for some states than others. This creates several challenges. Firstly, estimates of the percent of stem cell scientists preferring relatively unpopular states are based on a small number of respondents. This challenge was partly addressed by excluding any states ranked by less than three stem cell scientists from the analysis. It merits attention, however, since five of the nineteen states included in the regression were ranked by between three and five stem cell scientists.[3]

Heteroskedasticity is another potential concern arising from the varying precision of the dependent variable. Heteroskedasticity does not affect the point estimates of OLS regression, but does impact the standard errors and can lead to inefficient estimation. Although the OLS regressions presented in Table 1 were calculated using heterskedasticity-robust standard errors, this estimation routine is not well-defined with small datasets (White 1980). For this reason, weighted least squares (WLS) regression, in which each state is given a weight inversely proportional to its variance, has also been utilized. By giving more emphasis in the regression to observations that are estimated with more certainty, WLS can correct for some heterskedasticity. In this case, the number of respondents in the other biomedical scientists group ranking a state among their top three was used as the weight. WLS regressions are presented in the two right-most columns of Table 1. Estimated coefficients and statistical significance levels are quite similar in this model.

The permissive state indicator variable was statistically significant in both models, suggesting it is an important determinant of the differences in preferences observed between the two groups of scientists. In addition, the R^2 for both models is high indicating that a large portion of the variation in the dependent variable is accounted for by the independent variables. Together these results strongly support the contention that permissive policies have shaped the preferences of stem cell scientists in the United

[3] Notably, the OLS regression analysis presented in table 1 is robust to the exclusion of these five states. The coefficient on the permissive state indicator variable remains essentially unchanged and significant.

States. These results are robust to several alternative specifications, including limiting the data to principal investigators – a subset of the scientists who lead research groups. They are also robust to excluding California from the analysis, suggesting the results seen here are not merely a Proposition 71 effect (data not shown).

State	Awareness Level
California	91%
Massachusetts	60%
New Jersey	59%
New York	29%
Wisconsin	28%
Connecticut	20%
Illinois	20%
Maryland	13%
Michigan	10%
Minnesota	8%
Washington	8%
Florida	7%
Pennsylvania	6%
Ohio	6%
Oregon	4%
Texas	3%
North Carolina	3%
Indiana	2%
Colorado	2%
Missouri	2%
Virginia	2%

Table 2 – Stem cell scientists' awareness of state efforts to support stem cell research. Only states indicated by at least six stem cell scientists are included in the table. N=344. Data are reprinted from (Levine In Press).

State policies can only sway scientists' geographic preferences, as the above analysis suggests, if scientists are aware of these policies. To address this issue, stem cell scientists taking the survey were asked to indicate which states they believed were attempting to support stem cell research. This was a deliberately broad question designed to determine awareness not just of fully-implemented policies, but also plans or attempts to support this research which may be indicative of a supportive research environment in the long-term. As expected, states with permissive policies and those debating such policies (e.g. New York and Wisconsin) were at the top of the list. However, awareness tailed off rapidly after the top three states and only one out of five stem cell scientists was aware of the ten-year-long program enacted in Connecticut. These data also highlight how state support can materialize in short order. At the time of this survey, only two percent of stem cell scientists were aware of any effort to support stem cell research in Missouri, yet approximately a year later stem cells were the subject of the most-expensive ballot initiative in the state's history (Franck 2006).

To explore the impact of awareness on scientists' preferences, four state-specific probit regression analyses were completed. The analyses focused on California, Connecticut, Illinois and New Jersey. Each analysis used a binary dependent variable indicating whether or not a given stem cell scientist ranked the state among his or her top three choices. The key independent variable was also binary and indicated whether or not the scientist was aware of the state efforts to support stem cell research. Other independent variables controlled for whether or not a respondent used or expected to use human embryonic stem cells, the policy environment in the respondent's current state and the distance between respondent's current state and the state of interest.[4] For three of the analyses (CA, CT and NJ), awareness of the permissive policy in the state was a strong and statistically significant predictor of a stem cell scientists' likelihood of ranking each state among his or her top three. With all other independent variables at their mean value, a stem cell scientist who was aware of California's supportive policy environment

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[4] Distance was approximated based on the distance between the two state capital cities. For Connecticut, Illinois and New Jersey, distance was included in the analysis through the use of an indicator variable (Close States) that was equal to 1 for states where the capital to capital distance was less than 200 miles. For California, the actual distance (measured in miles) was used.

was 35 percentage points more likely to rank California among his or her top three preferred states. Stem cell scientists aware of Connecticut's and New Jersey's programs were 18 percentage points and 16 percentage points more likely to rank these states among their top three preferences, respectively. Point estimates of the coefficients on the distance variables had the expected signs (scientists were more likely to rank nearby states highly) in all four cases and were statistically significant in two cases (CT and IL). Stem cell scientists currently working with human embryonic stem cells or likely to do so in the future were statistically significantly more likely to rank California among their top three, but this variable was not significant for the other states.

	California	Connecticut	Illinois	New Jersey
Aware of policy	0.35***	0.18***	-0.002	0.16***
Human embryonic stem cell scientist	0.14***	0.006	0.003	-0.03
Distance	-0.00003			
Close states		0.05*	0.34***	0.04
Permissive state	0.02	-0.02	0.02**	0.03
Restrictive state	-0.05	0.06**	0.003	-0.04
N	317	357	352	353
Pseudo R^2	0.10	0.23	0.22	0.09

Table 3 – Probit regression analysis examining the influence of policy awareness stem cell scientists' likelihood to rank a state among their top three destinations. Values reported are the marginal effect of an infinitesimal change in continuous variables and a discrete change from zero to one for binary indicator variables (with all other independent variables held at their mean value). Home state preferences are excluded. *** P < 0.01, ** P < 0.05, * P < 0.10

These analyses indicate that in California and Connecticut, the two states with long-term stem cell programs in place, as well as in New Jersey, awareness of state policy efforts is an important determinant of scientists' likelihood to rank these states highly. This conclusion lends support to the conclusion from the OLS and WLS analyses that stem cell policy plays an important role shaping the geographic preferences of scientists in this controversial field.

Discussion

The analysis reported here identifying the role played by permissive state policies in shaping the geographic preferences of U.S. stem cell scientists complements other analyses of the role of policy in this field. In particular, it reinforces the finding (from another analysis of these same surveys) that U.S. stem cell scientists were more likely than their peers in less contentious fields to receive job offers to move to new positions (Levine 2006). This relationship help true for positions both inside and outside of the United States and, notably, domestic job offers received by stem cell scientists were skewed toward California, Massachusetts and New Jersey – the same states these scientists report disproportionately preferring here.

Previous analysis has also indicated that stem cell scientists in restrictive states believe they are more likely to move to pursue their research elsewhere in the near future (Levine In Press). This finding – that restrictive policies push scientists away – nicely parallels the results reported here – permissive policies attract scientists – and clearly illustrates the impact of the “regulatory patchwork” governing this field (Knowles 2004).

A pressing question for states currently considering support for stem cell research is whether these findings will generalize to new states or are more reflective of a first-mover advantage already captured by the handful of states with permissive policies today. Clearly states acting now to support research in this field face a very different landscape than did New Jersey or California when they became the first states to formally announce their support for embryonic stem cell research in 2004 (Murphy 2004; Washburn 2004). If New York was to enact legislation supporting stem cell research, as recently proposed by Governor Spitzer (Confessore 2007), it would be thrust into competition with the other permissive states, including neighbors New Jersey and Connecticut, as well as California, in its effort to attract researchers.

The impact of state stem cell policies and, particularly, the decision to initiate new policies may also be influenced by the uncertain future of the federal funding restrictions. At the moment, congressional attempts to overturn some of the federal restrictions appear unlikely to muster sufficient votes to overturn a veto. Thus, restrictions are likely to persist through 2008. Most of the leading presidential candidates – both Democratic and Republican – have indicated their support for increased federal funding for human embryonic stem cell research, however, calling into question the long-term future of these restrictions. The prospect of an improved federal funding environment may deter scientists from moving to permissive states and, thus, limit the impact of state programs.

The observation that permissive state policies are shaping the geographic preferences of stem cell scientists within the United States begs the question of how the international policy patchwork is influencing these scientists. Anecdotal reports suggest a number of permissive countries, such as the United Kingdom, Singapore and China, are appealing destinations for some subsets of U.S. stem cell scientists (Arnold 2006; Birmingham 2001; Dennis 2002; Dyer 2002; Mann 2003; Murray and Spar 2006; Normile and Mann 2005, 2005; Salter, Cooper, and Dickins 2006; Yang 2004). Furthermore quantitative data indicates that U.S. stem cell scientists have received more job offers for positions outside the United States than similar biomedical scientists working in less contentious fields, suggesting that international recruitment is a factor (Levine 2006). Analyses of publications related to human embryonic stem cell research suggest that the United States produces an atypically small share of research in this field (Levine 2005; Owen-Smith and McCormick 2006) and identifies the United Kingdom, Israel, and South Korea as major players in the field (Guhr et al. 2006).

It has long been known that biomedical research output tracks research funding (Frame and Narin 1976). This relationship suggests that restrictions on federal funding should, all else equal, lead to a reduction in research output by scientists typically funded by the federal government. States, however, may confound this equation. To the extent that state funding (or other private funding) substitutes for missing federal funding (Holden 2006), U.S. scientists may remain active in human embryonic stem cell research and continue pushing the boundaries of the field. The results presented here, verifying that the presence of permissive policies in a number of states is influencing the geographic preferences of U.S. stem cell scientists, suggest that this substitution may be in progress. Many stem cell scientists are aware of permissive state policies and these policies may well attract some scientists to these states. At the very least, these permissive policies can be expected to moderate the impact of the restrictive federal funding environment and reduce the lure of moving to other supportive nations.

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