Project Description: Spatial-Econometric Models for Political & Social Sciences

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1. Introduction: The Theory and Substance of Interdependence

(This introduction follows the structure of, but considerably condenses, Part 1 of the broader project that outlined briefly in the *Project Summary* and more thoroughly in sections 2 and 3 of this *Project Description*.)

Until recently, empirical analyses of spatial interdependence in the social sciences remained largely confined to specialized areas of applied economics (e.g., environmental, urban/regional, and real-estate economics) and sociology (i.e., network analysis). However, social-scientific interest in and applications of spatial modeling have burgeoned lately, due partly to advances in theory that imply and methodology to address interdependence, partly to global substantive developments that have raised at least the perception of and attention to interconnectivity, and likely the actual degree and extent of it, at all levels, from micro/personal to macro/international, and partly to advances in technology for gathering and working with spatial data. This is a welcome development as many phenomena that social scientists study entail substantively important spatial interdependence, and, as previous grant-work showed, omitting such interdependence empirically biases inferences badly.

Some of the most extensive classical and contemporary interest in spatial interdependence surrounds the diffusion of policy and/or institutions across national or sub-national governments. The study of policy-innovation diffusion among U.S. States has deep roots and much contemporary interest, with sustained attention between,[1] and similar policy-learning mechanisms underlie some comparative studies of policy diffusion.[2] Interest in institutional or regime diffusion is likewise long-standing and recently much reinvigorated.[3] In comparative and international political economy perhaps especially, interdependence is often substantively large and central. Indeed, globalization and international economic integration, arguably today's most-notable (and indisputably its most-noted) political-economic phenomena, imply strategic and/or non-strategic interdependence of domestic politics, policymakers, and policies.[4,5] The substantive range of notable interdependence effects extends well beyond these more-obvious contexts of intergovernmental diffusion, however, to span the political and other social sciences. Inside democratic legislatures, e.g., representatives' votes depend on others' votes or expected votes (e.g., Lacombe & Shaughnessy 2005); in electoral

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[1] Crain 1966; Walker 1969, 1973; Gray 1973; Knoke 1982; Caldiera 1985; Lutz 1987; Berry & Berry 1990; Case et al. 1993; Berry 1994; Rogers 1995; Mintrom 1997ab; Brueckner 1998; Mintrom & Vergari 1998; Mossberger 1999; Berry & Berry 1999; Godwin & Schroedel 2000; Balla 2001; Mooney 2001; Wejnert 2002; Coughlin et al. 2003; Bailey & Rom 2004; Boehmke & Witmer 2004; Daley & Garand 2004; Grossback et al. 2004; Mencken 2004; Berry & Baybeck 2005; Garrett et al. 2005; Costa-Font & Ons-Novell 2006; Karch 2006; Rincke 2006; Shipan & Volden 2006; Volden 2006; Werck et al. 2006; Woods 2006; Volden et al. 2007.

[2] Schneider & Ingram 1988; Rose 1993; Bennett 1997; Dolowitz & Marsh 2000; True & Mintrom 2001; Tews et al. 2003; Jensen 2004; Meseguer 2004, 2005; Brooks 2005, 2007; Gilardi 2005; Gilardi et al. 2005; Murillo & Schrank 2005; Weyland 2005; Braun & Gilardi 2006; Linos 2006; Parys 2006; Ermini & Santolini 2007; Moscone et al. 2007.

[3] Dahl's 1971 classic *Polyarchy*, e.g., implicitly references international interdependence among the eight causes of democracy he lists; Starr's 1991 "Democratic Dominoes" and Huntington's 1991 *Third Wave* accord it a central role; Beissinger 2007 and Bunce & Wolchik 2006, 2007, *inter alia*, emphasize it in the context of post-communist democratic transitions in Eastern Europe, and Hagopian & Mainwaring 2005 among others in the Latin American context; finally, O'Loughlin et al. 1998, Brinks & Coppedge 2006, and Gleditsch & Ward 2006, 2007 estimated empirically the extent, paths, and/or patterns of international diffusion of democracy. Kelejian et al. 2007 give institutional diffusion general theoretical and empirical treatment.

[4] Simmons & Elkins 2004 and Simmons et al. 2006, e.g., stress cross-national diffusion as the main force behind recent economic liberalizations, as do Eising 2002; Brune et al. 2004; Brooks 2005, 2007; Jordana & Levi-Faur 2005; Way 2005; Lazer 2006; Prakash & Potoski 2006; Brune & Guisinger 2007; and many others.

[5] Empirical work on globalization-induced interdependencies includes Genschel 2002; Guler et al. 2002; Franzese & Hays 2003, 2004b, 2005a, 2007abc, 2008c; Badinger et al. 2004; Basinger & Hallerberg 2004; Heichel et al. 2005; Henisz et al. 2005; Holzinger & Knill 2005; Knill 2005; Polillo & Guillén 2005; Elkins et al. 2006; Jahn 2006; Lee & Strang 2006; Manger 2006; Swank 2006; Baturo & Grey 2007; Cao 2007; Cao et al. 2007; Coughlin et al. 2007; Garretsen & Peeters 2007; Mosley & Uno 2007; Mukherjee & Singer 2007.

studies, citizens' votes,[6] election outcomes,[7] or candidate qualities, contributions, or strategies[8] in some contests depend on those in others. Outside legislative and electoral arenas, the probabilities and outcomes of coups (Li & Thompson 1975), riots (Govea & West 1981), civil wars (Murdoch & Sandler 2004, Buhaug & Rød 2006) and/or revolutions (Brinks & Coppedge 2006) in one unit depend on those in others. As for international relations, the interdependence of states' actions essentially defines that subject. States' entry into wars, alliances, treaties (Murdoch et al. 2003), or organizations, e.g., heavily depend on how many and who (they expect to) enter. Empirical attention to the inherent spatial interdependence of international relations has been greatest in the work of Ward, Gleditsch, and colleagues[9] and of Signorino and colleagues.[10] In micro-behavioral work, too, much of the surging interest in contextual or neighborhood effects surrounds effects on respondents of aggregates of others' behaviors and opinions—e.g., those of the respondent's community or social network. Huckfeldt & Sprague 1993 review the large literature on contextual effects in political behavior;[11] Sampson et al. 2002 and Dietz 2002 review the parallel large literature on neighborhood effects in sociology. At and beyond other disciplinary borders of political science, subjects where interest in interdependence, networks, or contagion has burgeoned include: social-movements;[12] microeconomic preferences;[13] macroeconomic performance;[14] technology, marketing, and other firm strategies;[15] violence and crime;[16] fertility, birthweight, child development, and child poverty;[17] and across all of public health and epidemiology. Perhaps more exotic topics where contagion has been studied include ordainment of women (Chaves 1996), right-wing extremism (Rydgren 2005), marriage (Yabiku 2006), national identity (Lin et al. 2006), and research faculty (Weinstein 2007).

Spatial interdependence is, in sum, ubiquitous and often quite central throughout the social sciences. As *Tobler's Law* (geographer Waldo Tobler: 1930-) aptly states: "Everything is related to everything else, but near things are more related than distant things." What's more, as Beck et al.'s (2006) pithy title stresses: "Space is More than Geography." I.e., the substantive content of the proximity in *Tobler's Law*, and so the pathways along which interdependence between units may operate, extend well beyond simple physical distance and bordering (as several examples above illustrate). Indeed, following Elkins and Simmons (2005) and Simmons et al. (2006), e.g., we may note at least four mechanisms by which spatial interdependence may arise: *coercion*, *competition* (to which we add *cooperation* and *externality*), *learning* and *emulation* (which we combine as one), and *migration* (which we add).[18] More generally, following Brueckner (2003), one can show that

[6] Huckfeldt & Sprague 1991; O'Laughlin et al. 1994; Pattie & Johnston 2000; Beck et al. 2003; Calvo & Escolar 2003; Kim et al. 2003; Schofield et al. 2003; Lacombe & Shaughnessy 2007.
[7] Shin & Agnew 2002, 2007; Hiskey & Canache 2005; Wing & Walker 2006; Kayser 2007.
[8] Goldenberg et al. 1986; Mizruchi 1989; Krasno et al. 1994; Cho 2003; Gimpel et al. 2006.
[9] Shin & Ward 1999; Gleditsch & Ward 2000; Gleditsch 2002; Ward & Gleditsch 2002; Hoff & Ward 2004; Gartzke & Gleditsch 2006; Salehyan & Gleditsch 2006; Gleditsch 2007.
[10] Signorino 1999, 2002, 2003; Signorino & Yilmaz 2003; Signorino & Tarar 2006.
[11] Contextual-effect works that stresses interdependence include Straits 1990; O'Loughlin et al. 1994; Knack & Kropf 1998; Liu et al. 1998; Braybeck & Huckfeldt 2002ab; Beck et al. 2002; McClurg 2003; Huckfeldt et al. 2005; Cho & Gimpel 2007; Cho & Rudolph 2007.
[12] McAdam & Rucht 1993; Conell & Cohn 1995; Giugni 1998; Strang & Soule 1998; Biggs 2003; Browning et al. 2004; Andrews & Biggs 2006; Holmes 2006; Swaroop & Morenoff 2006.
[13] Akerloff 1997; Postlewaite 1998; Glaeser & Scheinkman 2000; Manski 2000; Brock & Durlauf 2001; Durlauf 2001; Glaeser et al. 2003; Yang & Allenby 2003; Sobel 2005; Ioannides 2006; Soetevent 2006.
[14] Fingleton 2003; Novo 2003; Kosfeld & Lauridsen 2004; Maza & Villaverde 2004; Kelejian et al. 2006; Mencken et al. 2006.
[15] Abramson & Rosenkopf 1993; Geroski 2000; Strang & Macy 2001; Holloway 2002; Bradlow 2005; Autant-Berard 2006; Mizruchi et al. 2006.
[16] Grattet et al. 1998; Myers 2000; Baller et al. 2001; Morenoff et al. 2001; Villareal 2002; Baker & Faulkner 2003; Oberwittler 2004; Bhati 2005; Mears & Bhati 2006; Brathwaite & Li 2008.
[17] Tolnay 1995 and Montgomery & Casterline 1996; Morenoff 2003; Sampson et al. 1999; Voss et al. 2006.
[18] *Migration* involves a direct and mechanical interdependence—specifically: some components of some units move directly into other units, the most obvious examples being human emigration and disease contagion—but entails also the consequent strategic or idea-dissemination channels, and competition, cooperation, and

strategic interdependence arises whenever the actions of some unit(s) *i* affect the marginal utility of other unit(s)'s alternative actions. Consider units (*i*,*j*) with indirect utilities, (W^i,W^j), over actions or policies, (p_i,p_j), that they may choose. Due to externalities, *i*'s utility depends on both its policy and that of *j*. E.g., imagine two countries with homogenous populations regarding, say, their economic and environmental preferences. Due to environmental externalities (e.g., from pollution) and economic ones (e.g., from costs of environmental regulations), domestic welfare (i.e., net political-economic benefits/utilities to policymakers) in each country will depend on both countries' actions:

$$W^i \equiv W^i(p_i, p_j) \;\; ; \;\; W^j \equiv W^j(p_j, p_i) \qquad (1).$$

When the government in country *i* chooses its policy, p_i, to maximize its own utility, this alters the optimal policy government *j*, and *vice versa*. For example, *i* implementing more/less effective anti-pollution policy produces environmental spillovers that reduce/increase the need for/value of anti-pollution policy in *j*. A pair of best-response functions, giving *i*'s optimal policies, p_i*, as a function of *j*'s chosen policies, and *vice versa* can express such strategic interdependence of *i* and *j* usefully:

$$p_i^* \equiv \text{Argmax}_{p_i} W^i(p_i, p_j) \equiv R^i(p_j) \;\; ; \;\; p_j^* \equiv \text{Argmax}_{p_j} W^j(p_j, p_i) \equiv R^j(p_i) \qquad (2).$$

The slopes of these best-response functions indicate whether actions by *i* induce *j* to move in the same direction, in which case the actions of *i* and *j* are called *strategic complements*, or in opposite directions, in which case they are *strategic substitutes*. For example, anti-pollution policies are strategic substitutes in terms of their environmental effects as described above. The slopes of these best-response functions depend on the following ratios of second cross-partial derivatives:

$$\frac{\partial p_i^*}{\partial p_j} = -W^i{}_{p_i p_j} / W^i{}_{p_i p_i} \;\; ; \;\; \frac{\partial p_j^*}{\partial p_i} = -W^j{}_{p_j p_i} / W^j{}_{p_j p_j} \qquad (3).$$

If the government is maximizing, the second-order condition implies negative denominators in (3), so the slopes depend directly on the signs of the second cross-partial derivatives in the numerators. If $W^{i,j}_{p_i p_j} > 0$, i.e., if policies are strategic complements, reaction functions slope upward. Regarding the economic costs of anti-pollution regulation, e.g., increased (reduced) regulation in *i* lowers (raises) the costs of regulation in competitors *j*, and so spurs *j* to increase (reduce) regulation too. If $W^{i,j}_{p_i p_j} < 0$, policies are strategic substitutes, so reaction functions slope downward as regarding the environmental effects of anti-pollution policies. If these terms are zero, strategic interdependence does not materialize and best-response functions are flat. Generally speaking, then, positive externalities induce strategic-substitute relations, and policies will move in opposite directions as free-rider dynamics obtain. Franzese & Hays (2006b) argue and find such free-riding dynamics in EU active-labor-market policies, for example. Notice, furthermore, that free-rider advantages also confer late-mover advantages and so war-of-attrition (strategic delay and inaction) dynamics are likely. Conversely, negative externalities induce strategic complementarity, with policies moving in the same direction. The common example of tax-competition has these features. Tax cuts in one unit have negative externalities for competitors, who are thereby spurred to cut taxes as well. These situations advantage early movers, so competitive races can unfold. Other good examples here are competitive currency-devaluations or trade-restrictions. Economically, earlier movers in these contexts reap disproportionate benefits, so races to be first are likely. Thus, positive and negative externalities induce strategic-complement and -substitute relations, respectively, which spur competitive-races and free-riding, respectively, with their corresponding early- and late-mover advantages, and so strategic rush to go first on the one hand and delays and inaction on the other.

2. Project Overview: Substantially Completed and Proposed Further Research

In a series of articles, chapters, papers, and (in progress) a draft book-manuscript yielded from previously funded research (NSF 0318045), we (Franzese & Hays 2003, 2004ab, 2005ab, 2006ab, 2007abcde, 2008abc) have demonstrated this ubiquity and prominence of spatial interdependence

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externalities or learning and emulation covers only some of these effects.

across the theory and substance of political science. We also found, however, that most previous empirical work had neglected interdependence or treated it solely as nuisance, to the serious detriment of sound inference. Project work under this previous grant explored spatial or spatio-temporal interdependence almost exclusively in the linear-regression context. For those classes of models, we 1) derived analytically in simple cases the biases under interdependence of non-spatial and spatial least-squares (LS), 2) explored in simulations under richer, more-realistic, and limited-sample circumstances the properties of the biased non-spatial LS and spatial-lag LS estimators and of the consistent and asymptotically efficient spatial method-of-moments (MoM: IV, 2SLS, GMM) and spatial maximum-likelihood (ML) estimators, and 3) showed how to calculate, interpret, and present effectively the estimated spatial/spatio-temporal effects and dynamics of such models, with appropriate certainty-estimates (i.e., standard errors, confidence intervals, etc.) as well.

The central findings so far are that non-spatial LS ignores spatial interdependence and suffers omitted-variable biases fostering overestimation of non-spatial unit-level (domestic, individual) and contextual (exogenous-external) effects as a result. These biases quickly become substantively sizeable at even very modest interdependence-strength ($\rho>.1\pm$) and gargantuan at greater ρ. The biases concentrate in common shocks for homogenous diffusion processes. Standard errors for these overestimated effects are also dramatically underestimated in these ranges, and PCSE offers only limited amelioration. In short, given any noticeable interdependence, non-spatial LS is an unmitigated disaster. Spatial-lag LS, conversely, suffers simultaneity biases that, typically, foster overestimation of interdependence-strength, inducing underestimation of non-spatial factors' roles. However, these simultaneity biases generally remain mild at small-to-moderate interdependence ranges ($\rho<.3\pm$). Spatial-LS is also rather efficient, so only its problems with standard-error accuracy in smaller-T samples weigh against it as a simple effective option for mildly spatially interdependent contexts. Programs and instruments to implement spatial-ML or spatial-2SLS, each asymptotically normal, unbiased, and efficient under its assumptions, and each of which proved sufficient redress of spatial-LS's simultaneity problems, are available to handle other contexts.[19] As these programs become more accessible for practitioners, argument for the simpler spatial-LS will diminish.

The research proposed for this grant would, first, complete as described below the expanded exploration of spatial linear-regression specification, estimation, interpretation, and presentation for the social sciences and, second, undertake a like set of tasks for qualitative-, categorical-, and limited-outcome (*QualDep*) models (e.g., spatial probit: McMillen 1992,1995; Bolduc et. al. 1997; Pinkse & Slade 1998; LeSage 1999, 2000; Beron et al. 2003; Beron & Vijverberg 2004)[20] and systems-of-equations (*Systems*) models (Kelejian & Prucha 2004). New research would also explore prospects for parameterizing and estimating the spatial-connectivity matrix, a consensus priority for spatial-econometric research but one that raises thorny complications and so not yet far-advanced.

The expansions of the project to explore spatial/spatio-temporal *QualDep* and *Systems* models and parameterization and estimation of the spatial-connectivity matrix, $\mathbf{W}$, whose elements w_{ij} give relative strengths of connections from units *j* to *i*, raise severe empirical-methodological challenges. In brief and in general, difficulties arise for *QualDep* models as the endogenous spatial and/or temporal lags of latent-outcomes, y_j^* and/or y^*_{t-1}, on their right-hand sides (RHS) are (in most such models) converted to observed quantities by computation of an integral (e.g., the cumulative normal in probit). Since observations are spatially and/or temporally interdependent, the log-likelihoods (or log-posteriors) for realized data (times priors) are non-separable logs of single *n*-dimensional

[19] Simulations show spatial-2SLS admirably unbiased in both parameter and standard-error estimation even in smaller sample-sizes, but inefficiency is an issue. Spatial-ML, for its part, weakly dominates or nearly so across sample-dimension and parameter-value conditions in mean-squared-error terms, especially and importantly so in smaller sample-size, smaller-ρ conditions.

[20] Models of spatial sample-selection (i.e., spatial Tobit or Heckit: McMillen 1995, Smith & LeSage 2004, Flores-Lagunes & Schnier 2006), spatial multinomial-probit (McMillen 1995, Bolduc et al. 1997), and spatial discrete-duration (Phaneuf & Palmquist 2003), all three of which closely resemble the spatial probit, and models of survival with spatial frailty (Banerjee et al. 2004, Darmofal 2007) and of spatial count (Bhati 2005), including a zero-inflated-count model (Rathbun & Fei 2006) have also been suggested and will be covered.

integrals rather than the sums of logs of n unidimensional integrals as in the common case of conditionally independent observations. The n-dimensional cumulative-normal of the spatial-probit model, e.g., is exponentially (to power n) more intense to compute than its non-spatial counterpart, prohibiting direct likelihood/posterior maximization at even moderate sample sizes.[21] Bayesian (Metropolis-Hastings-within-Gibbs-sampling: see LeSage 2000) or simulated-likelihood (recursive importance-sampling: Beron et al. 2003) techniques can do the calculations in acceptable, if still somewhat burdensome, time. Likewise, to estimate spatial effects, dynamics, and multipliers, and calculate corresponding certainty estimates, in terms of *QualDep* outcomes, rather than in parameter or latent-variable terms as is current practice, requires calculation of these same n-dimensional integrals. Similar integration-by-simulation strategies will assist there. Alternative approaches apply approximate respecifications of *QualDep* models, e.g., (non)linear probability models (Fleming 2004) to allow spatial (generalized) linear-modeling, and/or apply the concept of generalized-residuals to allow (for spatial-error *QualDep* models only) spatial-GMM strategies (Pinkse & Slade 1998), either of these evades the computational intensity of the fuller simulation-based techniques.[22] This project will explore these estimation options for social-science applications and will redress a current important lack in the literature by providing comparisons of their relative performance. In *Systems* models, similarly, the spatial and other simultaneities of RHS variables intertwine (i.e., interact complexly) across variables and units, which creates analogous challenges and so suggests analogous estimation strategies may hold promise (Kelejian & Prucha 2004). Finally, parameterizing and estimating the connectivity matrix, however desirable analytically, raises even higher hurdles practically because the w_{ij} that one would like to relate parametrically to covariates for estimation are themselves elements of the crucial $\mathbf{W}$ term involved in the Jacobian transformation, $|\mathbf{I}-\rho\mathbf{W}|$, that is what complicates any spatial-model estimation in the first place. The relative lack of progress on this front is thus easily understood,[23] but some networks scholars and spatial analysts have seen the empirical question usefully differently with respect to this issue. From this view, the connectivity matrix, i.e., the network, *is* the observed outcome to be modeled. Exponential-family random-graph (*ExFRaG*) models (Hunter 2007), *inter alia*, seem promising in this direction, and the proposal here is to explore the possibility of embedding *ExFRaG* estimations in spatial-ML models. Appropriate tests for spatial interdependence in *QualDep*, *Systems*, and estimated-**W** models will also be explored, and effective tabular, graphical, and cartographical presentation of spatial-effect estimates in these kinds of models will again be emphasized.

To summarize, then, the project whose expansion and completion this grant would fund covers specification, estimation, interpretation, and presentation of empirical social-science models under spatial/spatio-temporal interdependence, including *QualDep*, *Systems*, and *Estimated*-**W** models.

Part 1 of the project gives overview of the substance and theory of interdependence in the social

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[21] Spatial logit has also been suggested (e.g., Dubin 1997; Lin 2003; Autant-Bernard 2006), but spatial probit dominates the methodological and applied literatures, and will receive primary focus here, given the relatively greater feasibility of working with n-dimensional normal, as opposed to extreme-value, distributions.

[22] McMillen 1992 first suggested an EM algorithm, which innovation allowed maximization of the spatial-probit log-likelihood for the first time, but the strategy also did not provide standard-errors for the crucial spatial-dependence parameter and required arbitrary parameterization of the heteroscedasticity induced by that dependence and has been superseded. McMillen 1995 and Bolduc et. al. 1997 applied simulated-likelihood strategies to estimate their spatial-multinomial-probit models, and Beron et al. 2003 and Beron & Vijverberg 2004 advanced a recursive-importance-sampling (RIS) estimator in that line. LeSage 1999, 2000 introduced a Bayesian strategy of Markov-Chain-Monte-Carlo (MCMC) by Gibbs and Metropolis-Hastings sampling. Fleming 2004 reviews these two families and simpler, if approximate, strategies of estimating linear or nonlinear probability models by nonlinear least-squares (NLS), generalized linear-models (GLM), or generalized linear-mixed-models (GLMM). Pinkse & Slade's 1998 two-step GMM estimator has also seen some use in the applied literature, but the RIS and Bayesian strategies have dominated applications. This project will focus on those and approximate-respecification strategies like the ones Fleming reviewed.

[23] Unfortunately, even qualitative discussion of **W**-specification is relatively light in the literature (but see Leenders 2002 and Wejnert 2002), which is less understandable and to be partially redressed in this project.

sciences, with some emphasis (to be lessened) on political science and especially comparative and international politics and political economy. It first surveys the broad substantive range in which, and the multifarious mechanisms by which, spatial interdependence arises across these subjects. It then offers a general theoretical model demonstrating that and showing how interdependence arises whenever the marginal utility to unit *i* of its actions depends on the actions/outcomes of/in some unit(s) *j*. The model illuminates the theoretical connections from positive externalities to strategic-substitute relations, free-rider incentives, first/early-mover advantages, and strategic-delay/war-of-attrition dynamics on the one hand, and from negative externalities to strategic-complement relations, beggar-thy-neighbor incentives, last/late-mover advantages, and competitive-race (e.g., race-to-the-bottom) dynamics on the other. It then briefly presents, and derives empirically testable propositions from, several more-specific theoretical models across the social sciences, first reviewing theories and models of globalization and international tax-competition and then offering similarly brief reviews of theories and models of interdependence in other substantive areas from across the social sciences. The previous grant-work completed most of this part of the project, but expanding the substantive range of topics and theoretical models across the other social sciences and to *QualDep* outcomes of interest to political and other social scientists mostly remains.

Part 2 explains the serious challenges for empirical analysis that interdependence poses. It first contrasts the three possible sources of spatial correlation—spatially correlated unit-specific factors, common or correlated exogenous-external factors, and true interdependence—distinguishing between which is the essence of the famous *Galton's Problem*. In modern conceptualizations, an additional complication of considerable importance arises in that these spatial interdependencies or correlations may occur in the stochastic and/or systematic components of the model, and these alternatives imply notably different spatial dynamics with substantively distinct interpretations. It then introduces several measures and tests of raw spatial-correlation (e.g., Moran's *I*) and discusses other basic empirical observations often seen to imply interdependence (e.g., S-shaped patterns of policy-adoption, temporal fixed-effects, or regional dummies) and explains how these, unlike well-specified spatial-lag models, cannot distinguish the possible sources of spatial correlation. Previous grant-work completed most of Part 2, but expansion of the set of raw tests and further discussion of the basic empirical observations that do not necessarily imply interdependence remain.

Part 3 turns to technical specification and estimation of empirical models of interdependence. It begins by presenting a generic empirical model with unit-specific and exogenous-external factors, their interaction, and a spatial lag. Such a model corresponds to typical modern theoretical and substantive expectations in social science—namely, that domestic/unit-level factors and exogenous-external/environmental conditions interact to shape outcomes—and in so doing highlights both the empirical difficulty and the substantive importance of distinguishing the possible sources of spatial correlation. It then introduces and explains four common estimation strategies for such spatial-interdependence models: non-spatial LS (or ML), LS (or ML) with spatial lags, spatial method-of-moments (MoM: IV/2SLS/GMM), and fully specified spatial-ML. It next identifies four classes of spatial-interdependence model—spatial-error, spatial-lag, and spatio-temporal-lag models, and spatial- and spatio-temporal *QualDep* models. Then it discusses, more technically than did Part 2, the challenges for these estimators in such models: omitted-variable and simultaneity biases for non-spatial LS/ML and spatial-lag LS/ML; specification and measurement error for all estimators; and, for the three spatial ones, several key issues surrounding the all-important spatial-connectivity matrix, **W**. These include 1) the pre-specification of **W**, which is current empirical-spatial-analysis practice and is the most crucial stage of that current practice;[24] 2) how estimators' properties and performance can vary, often in complicated fashion, with the nature of **W**;[25] 3) complications raised by multiple-**W** models;[26] and 4) some inroads into the parameterization and estimation of **W**.[27]

[24] *Inter alia*, this part explains and explores *Achen's Problem* with lagged-dependent-variable (LDV) models (Achen 2000)—that insufficiently accurate dynamic specifications push the LDV toward "stealing explanatory power" from the other regressors—as it manifests in the spatial context.
[25] This is what necessitates the many repeated sets of simulations in Part 4.
[26] Used in the literature, e.g., to evaluate the strength of alternative mechanisms of interdependence.

Finally, several nested and non-nested post-estimation tests, some of which can distinguish spatial-correlation sources, are introduced. Previous grant-work has completed almost all of this, but, as noted above, *QualDep*, *Systems*, and *Estimated*-**W** models will add significant complications to these discussions, and all of that work remains for the current proposed research.

Part 4 considers the properties and performance of the estimators and tests. It first derives analytically, in simple cases, the asymptotic omitted-variable bias of non-spatial LS/ML on the one hand and the simultaneity biases of LS/ML with spatial lags, spatial and temporal lags, or multiple spatial-lags on the other. It then evaluates by simulation the bias, efficiency, and standard-error-accuracy performance of all the estimators in richer, limited-sample contexts. The simulations explore empirical-model specifications matching the generic empirical model of Part 3 and consider first data-generating processes matching those specifications, with common exogenous-external shocks and uniform interdependence among spatial units. The spatial lag is thus the simple average of the dependent variable in other units, representing a "rough-and-ready" interdependence pattern to which empirical researchers may often resort. *Galton's Problem* manifests severely here, given the close similarity of uniform interdependence and common exogenous-external shocks. Across simulations, the estimators are evaluated first with empirical specifications matching the true data-generating process; then with measurement-cum-specification error in the empirical model of the exogenous-external conditions or in the spatial-interdependence pattern, **W**; and then, for the spatial-MoM estimators, with imperfectly exogenous instruments under varying degrees of spatial correlation and endogeneity among RHS and LHS variables and, for the fully specified spatial-ML estimators, with varyingly sizable violations of their strong distributional assumptions. For the spatio-temporal models, the simulations also explore *Achen's LDV Problem* in the spatio-temporal context. This battery of simulation experiments are then repeated for several realistically non-homogenous patterns of spatial-interdependence, some literally drawn from substantive literatures (i.e., the w_{ij} of the experimental models are drawn randomly from actual **W** in applied literature). One set of patterns is intended to reflect economic relations among the units (e.g., trade flows); another to reflect *co-memberships* (e.g., in organizations, language or cultural groups, etc.; shared borders, dyads, etc.) among units; a third to reflect geographic, Euclidean, or network distances between units; and the fourth to reflect strategic-complement (cooperative) and strategic-substitute (competitive) relations among the units. The next several sections conduct like sets of simulations for multiple-**W**, spatial-*QualDep*, spatial-*Systems*, and estimated-**W** models. Finally, tests' size-accuracy and power performance are likewise simulated. The current grant-work explored the case of linear regression with a single **W** reflecting a uniform pattern of interdependence across most of these experimental conditions, but robustness to measurement-*cum*-specification error and to violations of spatial-MoM and spatial-ML assumptions requires further exploration. Most of the non-homogenous **W** simulations and those for the tests remain for the currently proposed research, as do all of the *QualDep*, *Systems*, and *Estimated*-**W** simulations, of course.

Part 5 shows how to calculate (by simulation and, where possible, by delta-method analytic asymptotic-approximation), and offers suggestions on presenting (via tabular feedback grids, spatio-temporal response-path graphs, and maps) estimates and standard errors of estimates of spatial and spatio-temporal multipliers, effects, dynamics (response paths), and long-run steady-states. Work applying the delta method in the linear-regression cases is complete, but that for the simulation methods, in linear and in the *QualDep*, *Systems*, and *Estimated*-**W** cases, remains.

Part 6 illustrates all this via replications and extensions of existing work using spatial lags or failing to do so when theory and substance clearly imply them. The reanalyzed works presently include Swank & Steinmo (2002), Hays (2003), Basinger & Hallerberg (2004), Beck et al. (2006), Volden (2006), and Franzese & Hays (2006b). Further (re)analyses will be required to illustrate the wholly new components of the expanded project (*QualDep*, *Systems*, and estimated-**W** models).

Two supplements will provide Stata™ code to implement all specification, estimation, testing, and presentation procedures described in the project, and all data and code to replicate the

[27] As noted, a widely agreed critical future direction for spatial-econometric modeling, but plagued by thorny complications and so not yet far-advanced.

empirical work. At present, MatLab™ code and data exist for all completed parts of the project; the translation thereof and of code and data for the currently proposed expansions remains.

3. Proposed New and Further Research

In addition to the proposed new research on *QualDep, Systems,* and *Estimated-**W*** models described above, this proposal includes considerable work to complete the exploration of spatial linear-regression specification, estimation, interpretation, and presentation for political and social science begun under the previous grant. The best way to describe both these aspects of the proposal is to outline the entire project, noting the parts where further or wholly new work is required. The current proposal also includes an interdisciplinary workshop gathering for synergistic interchange the disparate sets of spatial scholars studying primarily social-scientific substance and theoretical models of interdependence or of networks or primarily spatial econometrics, spatial statistics, or network analysis. Plans for that workshop are briefly described after the project outline.

I. (PART 1) The Substance & Theory of Spatial Interdependence

A. The Broad Substantive Range of Spatial Interdependence

1. *Topical Survey:* Further expansion across the social sciences (see introductory section).
2. *Mechanisms:* Review network and interdependence literatures beyond political science for other useful classifications or additional channels. Solid and thorough understanding of the possible mechanisms is especially critical to the crucial stage of pre-specification or parameterization of **W** in empirical spatial-analysis.
3. *Tobler's Law* with *Beck et al.'s Corollary:* Discussion completed.

B. Theoretical Models Strategic Interdependence:

1. *General Theoretical Models of Interdependence:* This section is substantially complete (see introductory section), but the alternative general theoretical models of Brock & Durlauf 2001 and of Glaeser & Scheinkman 2000, being written more with QualDep outcomes and social preferences and contextual/neighborhood effects in mind, also bear exploring.
2. *Specific Theoretical Models of Interdependence:* Theoretical models and arguments in the globalization, international tax-competition, and domestic-policy autonomy context are complete (see Franzese & Hays 2003, 2004b, 2005a, 2007abc, 2008c). Plans to explore a few further models in other contexts include models of learning, perhaps working from Meseguer 2004, 2005 and/or Gilardi 2005, Gilardi et al. 2005, and Braun & Gilardi 2006, and of social movements, perhaps following Biggs 2003 and Andrews & Biggs 2006.

II. (PART 2) The Empirical Challenge of Spatial Interdependence

A. *Galton's Problem, 3 Sources of Spatial Correlation and a Modern Complication:* This section of the project is substantially complete.

B. *Basic Empirical Observations Taken (Problematically) as Evidence of Interdependence*: These include dummies for groups/regions, time dummies, *S*-shaped adoption patterns and clusters, and (error) covariance or correlation matrices, and this section of the project is largely completed, although some further discussion of especially the last is needed.

C. *Measures & Tests of Raw Spatial Correlation/Clustering:*

1. *Introduced & Evaluated:* Breusch and Pagan's (1980: 247) LM test: $LM = T\sum_{i=2}^{N}\sum_{j=1}^{i-1} r_{ij}^2$.
2. *Introduced:* Greene's (1997: 661) LR test comparing sums of logged diagonal elements of the residual variance-covariance matrix under a restriction fixing off-diagonal elements to zero with the log of the unrestricted variance-covariance matrix's determinant.
3. *Introduced & Illustrated:* Moran's I, in row-standardized and non-standardized forms: $I = \frac{\boldsymbol{\varepsilon}'\mathbf{W}\boldsymbol{\varepsilon}}{\boldsymbol{\varepsilon}'\boldsymbol{\varepsilon}}$ standardized, and $I = \frac{N}{S}\frac{\boldsymbol{\varepsilon}'\mathbf{W}\boldsymbol{\varepsilon}}{\boldsymbol{\varepsilon}'\boldsymbol{\varepsilon}}$, where $S = \sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}$ non-standardized
4. *Proposed Further Research on Raw Spatial-Correlation Measures and Tests:*
   a) *Anselin's LISA (Local Indicators of Spatial Association) require exposition.*
   b) *Simulations to gauge small-sample performance of these tests.*

III. (PART 3) Specifying & Estimating Empirical Models of Spatial Interdependence

A. *Generic Empirical Model* ($y_{it} = \rho \sum_{j \neq i} w_{ij} y_{jt} + \mathbf{d}'_{it}\boldsymbol{\beta}_{\mathbf{d}} + \mathbf{s}'_t\boldsymbol{\beta}_{\mathbf{s}} + \left(\mathbf{d}'_{it} \otimes \mathbf{s}'_t\right)\boldsymbol{\beta}_{\mathbf{ds}} + \varepsilon_{it}$): Section done.

B. Estimators: Specification and Estimation

1. Non-Spatial LS or ML: introduced; shown inconsistent; and its (omitted-variable) bias derived analytically for the spatial and spatio-temporal linear-regression cases.
2. Spatial-Lag LS and (Quasi) ML: introduced; shown inconsistent; and its (simultaneity) bias given analytically for spatial, spatio-temporal, and multiple-**W** linear-regression cases.
3. Spatial Method-of-Moments, for the linear-regression cases:
   a) Spatial 2SLS: introduced; shown consistent; noted that inefficient.
   b) Spatial GMM: introduced; shown consistent and asymptotically efficient.
4. (Fully Specified) Spatial-ML: introduced and shown asymptotically unbiased, normal, and efficient for spatial, spatio-temporal, and multiple-**W** linear-regression cases.

C. Spatial-Econometric Model-Classes: Specification and Estimation

a) Spatial-Error, Spatial-Lag, and Spatio-Temporal-Lag Linear-Regression Models: introduced and discussed.
b) Spatial-Error & Spatial-Lag Probit Models: introduced & discussed (see Franzese & Hays 2007e, 2008b).

D. Proposed Further Research on Specification and Estimation:

1. *Spatial-GMM for the Spatial-Error Probit Model (following Pinkse & Slade 1998)*
2. *Approximate Respecification Approaches to Spatial QualDep Models (Fleming 2004 is a starting point)*
3. *(Temporal- and) Spatio-Temporal-Lag Probit Model*
4. *Other Spatial/Spatio-Temporal QualDep Models (see notes 20 and 21)*
5. *Spatial Systems Models (Kelejian & Prucha 2004 provide a start)*
6. *Parameterized-and-Estimated-***W** *Models (Hunter 2007 is one possible starting point)*

E. Challenges for Estimation and Inference

1. Omitted-Variable Bias and Simultaneity of LS/ML and S-OLS/Quasi-ML: Section substantially complete; biases shown analytically and implications discussed.
2. Specification & Measurement Error in all cases: Issues of (relative) measurement-error/misspecification in the spatial and non-spatial components of the model have been introduced and extensively discussed, but further exposition and discussion of issues with moment exogeneity-assumptions and ML distributional ones required.
3. **W**: The Spatial-Connectivity Matrix of Relative Interdependence: All of these sections, especially the last two have been only briefly introduced in previous grant-work, so most of these important discussions remain for the current proposal.
   a) **W** commonly pre-specified; crucial stage of spatial analysis
   b) Estimators' properties tend to vary, often in complicated fashion, with **W**
   c) Multiple-**W** Models: raise issues beyond those always associated with controls (e.g., interpretation, colinearity) due to simultaneity and "overlap"
   d) Inroads into parameterization and estimation of **W**.

F. Post-Estimation Tests of Spatial Dependence and/or Spatial-Model Specification

1. LM Tests for Spatial-Error or Spatial-Lag Models: A family of LM tests of non-spatial linear-regression models against alternatives of spatial-error, $LM_\lambda = \left(\hat{\boldsymbol{\varepsilon}}'\mathbf{W}\hat{\boldsymbol{\varepsilon}} / \hat{\sigma}^2_\varepsilon\right)^2 \Big/ T$, or of spatial-lag, $LM_\rho = \hat{\sigma}^2_\varepsilon \left(\hat{\boldsymbol{\varepsilon}}'\mathbf{W}\mathbf{y} / \hat{\sigma}^2_\varepsilon\right)^2 \Big/ \left(G + T\hat{\sigma}^2_\varepsilon\right)$, or robustly against those alternatives,

$$LM^*_\lambda = \frac{\left(\hat{\boldsymbol{\varepsilon}}'\mathbf{W}\hat{\boldsymbol{\varepsilon}} / \hat{\sigma}^2_\varepsilon - \left[T\hat{\sigma}^2_\varepsilon\left(G + T\hat{\sigma}^2_\varepsilon\right)^{-1}\right]\hat{\boldsymbol{\varepsilon}}'\mathbf{W}\mathbf{y} / \hat{\sigma}^2_\varepsilon\right)^2}{T\left[1 - \frac{1}{\hat{\sigma}^2_\varepsilon}\left(G + T\hat{\sigma}^2_\varepsilon\right)\right]^{-1}} \text{ or } LM^*_\rho = \frac{\hat{\sigma}^2_\varepsilon\left(\hat{\boldsymbol{\varepsilon}}'\mathbf{W}\mathbf{y} / \hat{\sigma}^2_\varepsilon - \hat{\boldsymbol{\varepsilon}}'\mathbf{W}\hat{\boldsymbol{\varepsilon}} / \hat{\sigma}^2_\varepsilon\right)^2}{G + T(\hat{\sigma}^2_\varepsilon - 1)}$$, or of

against those alternatives jointly, $LM_{\rho\lambda} = LM_{\lambda} + LM^{*}_{\rho} = LM_{\rho} + LM^{*}_{\lambda}$, have been given, their properties noted, and their use illustrated. Simulations to explore their performance remain.

2. *Proposed Further Research on Post-Estimation Tests*
   a) *Non-nested testing strategies would seem promising; their exploration remains.*
   b) *Specification tests for the* QualDep*,* Systems*, and* Estimated-**W** *models.*

IV. (PART 4) Properties and Performance of Spatial Estimators and Tests

A. *Analytic Results for Spatial Linear-Regression Simple-Contexts:* This section substantially complete; few analytic results exist for the corresponding *QualDep*, *Systems*, and *Estimated*-**W** cases. The proposed research would generate/report what results may be obtained/found.

1. Omitted-variable bias (OVB) in non-spatial LS and simultaneity bias in spatial-lag LS
   a) In the two-variable, two-unit case (and so in scalar expression):
      (1) the OVB in β for non-spatial LS
      (2) for spatial-lag LS, the simultaneity bias in ρ and the bias that it induces in β
      (3) The OVB in ρ for spatial-lag LS excluding relevant exogenous-external factors.
   b) These biases are also derived generally for *k*-variate, *n*-unit case for the spatial, spatio-temporal, and multiple-**W** models.

B. *Simulations:* All simulations are based on the generic empirical-model of Part 3 and explore bias, efficiency, and standard-error accuracy. In addition to sample-dimensions and strength of interdependence (i.e., ρ), the sets of experiments vary all of these conditions:

1. Interdependence Processes/Patterns of Interdependence (i.e., **W**):
   a) Uniform/Homogenous Interdependence:
   b) Interdependence proportional to some economic/strategic connection; w_{ij} drawn from actual datasets in literature: trade/capital flows, trade/capital mobility,
   c) Strategic complements/substitutes (cooperation/competition) relations between units; w_{ij} drawn from uniform-distribution {-1…1}.
   d) Unit interdependence due to "co-membership" (borders, organizations, culturo-linguistic-religious groups, dyads, etc.); w_{ij} drawn from actual datasets in literature. Considerations in exploring this parameter space:
      (1) Overlapping v. non-overlapping group-memberships.
      (2) Complete group membership (no isolates)
      (3) Size & number of these groups relative to totals
   e) Unit interdependence proportional to geographic or Euclidean distance b/w units; drawn from actual datasets in the literature.
2. Specification and Measurement Error:
   a) Fully accurate specification and measurement.
   b) Measurement/specification error in exogenous-external factors
   c) Measurement/specification error in **W**
   d) For the MoM estimators only: imperfect instruments, i.e., varying endogeneity from LHS to RHS with varying magnitudes spatial interdependence within LHS and RHS.
   e) For the ML estimators/models only: varying violations of distributional assumptions
   f) For spatio-temporal models only: varying magnitude of errors in the specification of spatial or temporal dynamics (to explore Achen's LDV Problem).
3. *Proposed Further Research on Estimator and Test Properties/Performance:*
   a) *This battery of simulation experiments has been substantially completed for all four estimators (S-2SLS representing S-MoM) in the linear and single-, uniform-**W** case without measurement/specification error. Exploration of the first two forms of measurement error and of imperfect instruments in the S-2SLS case have also begun, as have a few of the tests. All of the rest is proposed.*
   b) *The entire battery for the proposed wholly new research on* QualDep, Systems, *and* Estimated-**W** *models of course remains also.*

V. (PART 5) Calculation, Interpretation, & Presentation of Spatial & Spatio-Temporal Effects & Dynamics:

A. *Calculating Spatial and Spatio-Temporal Multipliers, Effects, Dynamics (Response-Paths and Long-Run Steady-States)*

1. These components are complete for the linear spatial, spatio-temporal, and multiple-**W** cases, but not for the *QualDep*, *Systems*, and *Estimated*-**W** cases.

B. Calculating Standard Errors for S and ST Multipliers, Effects, and Dynamics

1. Delta Method: This is complete for the linear spatial, spatio-temporal, and multiple-**W** cases, but not for the *QualDep*, *Systems*, and *Estimated*-**W** cases.
2. Simulation Methods: This remains both for the linear spatial, spatio-temporal, and multiple-**W** cases and for the *QualDep*, *Systems*, and *Estimated*-**W** cases.

C. Presenting Estimates of Spatial and Spatio-Temporal Effects and Dynamics

1. Short- and Long-Run Spatial and Spatio-Temporal Effects Feedback-Grids/Tables
2. Plotting Spatio-Temporal Response-Paths
3. Maps (and Dynamic Maps) of Spatial and Spatio-Temporal Effects
4. These components are complete for the linear spatial, spatio-temporal, and multiple-**W** cases (excluding the possibility of dynamic maps), but not for the *QualDep*, *Systems*, and *Estimated*-**W** cases.

VI. **(PART 6) Empirical Applications:** Illustrative replications & extensions

A. Substantially Completed:

1. Competition: Globalization, Capital-Tax Competition for Investment, & Domestic-Policy Autonomy (Swank&Steinmo APSR '02; Hays WP '03; Basinger&Hallerberg APSR '04)
2. Learning & Emulation: Volden (AJPS 2006) on US State Adoption of Policy Innovations
3. Competition & Negative Externalities: Beck et al. (ISQ 2006) on International Conflict and Trade
4. Cooperation & Positive Externalities: Franzese & Hays (EUP 2006) on ALMP in the EU

B. Further illustrations will be required, obviously, as the new research is completed.

VII. **Supplements:** Stata™ code to implement all of the procedures of the project. Data and code in Stata™ format to replicate all of the estimation results of the project. As noted elsewhere, these exist for currently completed components in MatLab™ format, so translations of those and of the code and data from new-research components remains.

The grant-project would conclude with an international, interdisciplinary workshop (likely in Ann Arbor in the summer of 2010) gathering synergistically the disparate sets of spatial scholars studying primarily the social-scientific substance and theoretical models of interdependence or of networks or primarily spatial econometrics, spatial statistics, or network analysis. As drawn perhaps most sharply into relief by the lack of progress on parameterizing and estimating **W** in models of spatial interdependence, the relative isolation of these groups of scholars has greatly retarded the advancement of spatial analysis. Theoretical modeling of interdependence seems to have advanced furthest in the topical areas of (microeconomic) preference interdependence, policy or social learning, and (macro)economic interdependence. Empirical methodologies have advanced furthest, but unfortunately quite separately, in three separate traditions of networks scholars, geographical-spatial scholars, and interdependence scholars. Meanwhile, as illustrated by the introduction to this *Project Description*, substantive interest in and applications of interdependence models seem to be exploding almost everywhere across the social sciences. Thus, while our theoretical- and empirical-methodological capacity has grown rapidly, it faces some bottlenecks due in some considerable extent to the relative isolation of these groups, and it has been exponentially outpaced by the growth in substantive interest and applications. Accordingly, a conference-workshop gathering leaders from these disparate groups to present to each other their work and advancements, but also their puzzles and challenges and needs, could open some of those bottlenecks.

4. Results of Prior Support

The co-PI's have received prior support from NSF #0318045, "Diagnosing, Modeling, Interpreting, and Leveraging Spatial Relationships in Time-Series-Cross-Section Data," originally funded in 2003, and in a total amount of approximately $285,000. The substantive content of the research products of that grant have been extensively described above—in our reference list here, they are Franzese & Hays 2003, 2004ab, 2005ab, 2006ab, 2007abcde, 2008abc: a draft book manuscript, three journal articles, three book chapters, a working paper, and seven conference papers (that are cited here; over twice that number of presentations). We have worked closely with four graduate students over this period: one US citizen (Bryce Corrigan), one Japanese (Aya Kachi), one Chinese (Xiaobo Lu), and one South Korean (Nam Kyu Kim); three male and one (Kachi) female; three at the University of Michigan and one (Kachi) at the University of Illinois. We expect the work of this grant to be completed, and its funds depleted thereby, in the summer of 2008, before the requested start-period of the current grant-proposal.

The first co-PI of this proposal (Franzese) has also received prior support in connection with and as a co-PI (with James Alt, Henry Brady, and John Aldrich) of NSF # S137-245-01, "Empirical Implications of Theoretical Models (EITM) Summer Training (Political Science Program: EITM Competition IIIa)." NSF award # S137-245-01 funded a series of four summer training institutes (2002-2005) in EITM, hosted at Harvard, Michigan, Duke, and Berkeley, respectively, for about 25 advanced graduate students and early junior faculty. To be exact, the co-PI served as one of about 15 faculty lecturers at the first institute and served as one of about 20 faculty lecturers and as the institute director in second, summer 2003, program at Michigan. Only in this last role, representing approximately one-fourth of the total grant, did he receive and manage any support directly (approximate amount: $175,000). Thus, results of funding here will refer to that year of the grant. That EITM program also received NSF award #0215621 to fund a fifth, supplemental summer training institute, which was held at Michigan with the first co-PI of this proposal again serving as director (approximate amount: $175,000). Each EITM summer institute recruits about 15-20 faculty to lecture, lead discussion, and design projects over a four week training session, each offering from half a day to five days instruction. Large numbers of students apply, primarily from US graduate programs but also from abroad, and the PI's select about 25 participants. Participant evaluations have consistently enthusiastically agreed on the overall quality of the experience, which concludes with a web-simulcast of student project proposals, with feedback from faculty in attendance and watching on the web. All lecture, assignment, and related material is recorded and made publicly available in various forms. In addition to program participants, one graduate student serves as primary assistant to the institute director, gaining also thereby not only from program-instruction as do participants, but also from a tremendous amount and degree of exposure to the program faculty. In the Michigan years of the program (2003, 2006), two graduate students have had this opportunity and experience: one Japanese citizen (Kenichi Ariga), one Spanish (Carolina de Miguel Moyer); one male, one female.

Finally, the first co-PI on this grant is also PI on NSF #0340195, "Empirical Implications of Theoretical Models of Effective Democratic Representation—Electoral- and Party-Systemic Institutions, Structures, and Strategic Contexts," awarded in 2004 in the approximate total amount of $200,000. The research product so far of this grant, which is not expected to be completed or depleted fully before the spatial-econometric project winds down, includes an article in review (co-authored with two, at the time, graduate students: Irfan Nooruddin and Karen Long Jusko), a book chapter, a working paper, and at least twelve conference presentations (most with Nooruddin and/or Long Jusko co-authoring). In addition to the two co-authors, the project has also worked extensively and closely with two other graduate students (Kenichi Ariga, Nam Kyu Kim); of the four: three are male, one female; one Indian citizen (Nooruddin), one Canadian (Long Jusko), one Japanese (Ariga), and one South Korean (Kim).