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Toward Understanding Teacher Supply and Demand

Priorities for Research and Development

Interim Report

Panel on Statistics on Supply and Demand for
Precollege Science and Mathematics Teachers

Committee on National Statistics *and*
Committee on Indicators of Precollege Science
and Mathematics Education
Commission on Behavioral and Social Sciences and Education
National Research Council

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Contents

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Daniel Levine, study director for the Committee on National Statistics' Panel to Evaluate the National Center for Education Statistics, provided valuable information on the Center's programs and kept us informed of that panel's recommendations. We have endeavored to take cognizance of their report in developing our own recommendations directed to the Center.

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us more than amply supplied with information on work in progress, drafted text for materials to be included in the report, provided rapid turnaround on panel requests for information and materials, kept the chairman fully apprised of what had to be done next, and in general provided the kind of staff support that was indispensable to completion of the project and that made life tolerable for the chairman.

Agnes Gaskin served ably as administrative secretary for the panel. She made admirable logistical arrangements for panel meetings and cheerfully and competently coped with multiple rounds of revisions to sections of the report. Lee Paulson contributed expert assistance in preparing the report for publication.

Finally, I would like to thank the panel members themselves for their generous contributions of time and expert knowledge. Of course, no individual panel member should or would want to be held responsible for every word or idea expressed, but the report does reflect the collective thinking of the panel to date on the issues addressed. Thus far it has been a pleasure to work together, and I look forward to continuing the effort of the panel to evaluate statistics and models on supply and demand for precollege teachers of science and mathematics.

F. Thomas Juster, *Chair*
Panel on Statistics on Supply and
Demand for Precollege Science
and Mathematics Teachers

Summary

The scientific and popular press in the past few years have sounded alarms regarding the quality of instruction in mathematics, science, and technology in the nation's elementary and secondary schools. Numerous articles and papers have reported shortages of qualified teachers of mathematics and science (as well as teachers in other fields), and have predicted that shortages will become worse over time as enrollments rise and the supply of new teachers falls. Education policy makers have responded to these reports through a variety of initiatives, including teacher salary increases and tuition support for teacher training and retraining in technical subjects.

A small but growing number of articles and studies have questioned the quality of the data that underlie reports of teacher shortages and the adequacy of the models that are used to estimate and project teacher supply and demand. These concerns are important to investigate, because of the likelihood that policies developed on the basis of inadequate data and models will be irrelevant at best and counterproductive at worst. The National Science Foundation and the Center for Education Statistics of the U.S. Department of Education commissioned the National Research Council to convene a panel to evaluate available data and models on teacher supply and demand and to recommend needed improvements.

The Panel on Statistics on Supply and Demand for Precollege Science and Mathematics Teachers has completed the first year of a projected 30-month study and prepared an interim report of findings. The panel was asked in this first phase to review teacher supply and demand models in selected states and the national model maintained by the Center for Education Statistics and suggest improvements in state and national models. The panel was also asked to

identify information on teacher qualifications that could be collected for use in descriptive profiles and in supply and demand models.

In its second phase of work, the panel is charged with continuing its investigation of statistics and models on teacher supply and demand. The panel plans to conduct case studies in a small sample of school districts of the entry and exit of mathematics and science teachers in the teaching force, carry out a comprehensive review of data resources on teachers at the national and state levels and assess their utility to support needed research, and further explore methodological issues in the development and evaluation of useful models of teacher supply and demand.

The panel expects that its second-phase activities will result in fuller comprehension of what can and should be done to improve the ability to model the forces that influence the demand for and supply of qualified science and mathematics teachers. Nonetheless, we believe that the timeliness of our initial recommendations in this interim report is important. It is clear even at this stage that available data on teacher labor markets and on the qualifications of the teaching force are inadequate. Consequently, it is impossible to assess the condition of teacher labor markets or to target policies to address possibly emerging supply and demand imbalances. Education, especially in science and mathematics, is so critical to the nation's future that policy should not be formulated in the statistical dark. Hence, we urge an immediate start on the research and development agenda outlined in this report.

The need for teacher supply and demand models is clear. The panel identified a wide range of questions frequently asked by policy makers that could be addressed by accurately specified models. These include questions about the future supply-demand balance, overall and for specific subjects and geographic areas; the sources of future teacher supply; and "what if" questions about the likely impacts of various education policy actions and socioeconomic forces on prospective teacher supply and demand.

"What if" questions are some of the most important and also most difficult questions to deal with, because they require a capacity to project supply and demand under varying assumptions about future circumstances. In turn, this capability requires the development of models that are both behavioral and dynamic. By this we mean models that capture relationships between variables in the environment and the behavior of actors in the educational system and in particular capture relationships between changes in circumstances and subsequent changes in the numbers and kinds of

people interested in obtaining teaching positions or in the numbers and kinds of teachers demanded by school systems.

The recognition that teacher labor markets are responsive to changing market conditions, on both the demand and supply sides, is central to development of improved models and to proper understanding of model projections. Warnings of impending teacher shortages that take no account of various market adjustment mechanisms are unrealistic and misleading. Faced with fewer applicants than openings, school systems may opt over the long term to increase salaries or improve working conditions. In the short term, they may decide to recruit more aggressively over a wider area or to increase class size or cancel course offerings. Frequently, the adjustment mechanism operates through changes in quality; that is, school systems hire people who are relatively less well trained for their assignments. Hence, there is no supply-demand imbalance in a quantitative sense but instead a change in the quality characteristics of the teaching force.

When measured against the need for dynamic models with serious behavioral content to address important policy needs, the panel finds that current teacher supply and demand models are seriously deficient. Demand projections, which current models derive from enrollment trends together with assumed pupil-teacher ratios, have a reasonably good track record for short-term projections, but are increasingly less reliable over longer periods. Supply projections, however, have proven totally inadequate. Moreover, current models do not deal in a satisfactory manner with the issue of quality. Where models consider this dimension at all, the definition of a qualified teacher is equated with certification.

The major shortcoming of current models is on the supply side, where most models consider two main sources: (1) teachers continuing in the system from last year, and (2) new graduates of teacher training programs or new certificate holders. Other sources of new entrants are generally ignored, even though statistics in many states indicate that newly hired teachers come from many different groups: experienced teachers on leave last year or recalled from layoffs; experienced teachers out of teaching for longer periods; substitute teachers; in-migrants (from other states, schools, subjects, etc., defined appropriately for the level of aggregation of the model); new graduates of teacher training programs; other new graduates who obtain certification; and persons hired on emergency certificates. Each of these groups has a very different probability of being attracted to teaching under current conditions and of responding to particular policy initiatives aimed at attracting teachers. Yet virtually nothing is known about these differences.

Some of the teacher supply and demand models that we examined incorporate useful refinements: for example, the use of age and field-specific attrition rates in projections of continuing teachers and consideration of a broader range of sources of new supply. However, even the more elaborate models are constrained in their usefulness--on both the demand and supply sides--because they consist of little more than plausible extrapolations of current conditions or historical trends. Such relatively simple and largely mechanical models permit only an evaluation of the continuation of the status quo, or, at best, minor variations on the status quo. Behavioral models, in contrast, would take into account the interaction and interdependence of a wide range of variables and could help answer such questions as how many teachers can be expected to quit in response to a change in retirement policy, how many former teachers can be expected to reenter if salaries are raised by a certain amount, or how many additional teachers will be needed if graduation requirements in science and mathematics are doubled--the kinds of questions to which reliable answers are badly needed.

RECOMMENDATIONS

The panel has identified both short-term goals for improvements in methodology of current models and in supporting data series, and long-term goals for model development based on further research. Recommendations for modest improvements to current models and data are clearly intended for implementation by the Center for Education Statistics and appropriate units in state education agencies. The panel urges cooperative efforts in this area between the Center and state agencies.

Recommendations that call for research and model development are directed to a wide range of organizations, including the National Science Foundation, the U.S. Department of Education, and others. In the panel's view, research on teacher labor markets needs the participation of investigators with a variety of backgrounds, perspectives, organizational affiliations, and approaches.

Considering the purely quantitative dimension, the panel believes that improvements in current models and data--on both the demand and supply sides--together with a comprehensive program of research on teacher supply are high priority areas. Research on the behavioral determinants of teacher demand is also important but less pressing, largely because existing models are reasonably adequate for current needs.

With regard to the equally important dimension of teacher quality, the panel confronted a basic problem. The literature does not furnish evidence of relationships between teacher characteristics and eduational outcomes that are strong enough or persistent enough to support the selection of variables to measure teacher qualifications. Further research in this area is urgently needed. At the same time, there is a pressing need for nationally representative time series on teachers. Drawing on the collective judgment of its specialists in this area, the panel has suggested qualification measures that could usefully be included in ongoing data collection efforts.

Improvements in Current Models and Data Series on Teacher Demand

To be useful for addressing policy questions about the demand for teachers, specifically teachers of mathematics and science, models should incorporate appropriate levels of disaggregation by geographic area and subject field.

Recommendation 1. We recommend that the key components of current models of teacher demand--enrollment projections and pupil-teacher ratios--be disaggregated by state and important substate teacher labor markets. For middle and secondary grades, these projections should be further disaggregated by broad subject categories.

Research on Behavioral Aspects of Teacher Demand

Research on behavioral factors that influence the demand for teachers, particularly teachers of mathematics and science in the higher grades, is needed to permit the development of improved models that will support longer-term projections.

Recommendation 2. We recommend that research pertinent to teacher demand be conducted--in order of priority--on:

(a) The behavioral determinants of student selection of science and mathematics courses at the secondary school level, including the effects of changes in graduation requirements and of student preferences for subject areas;

(b) The behavioral determinants of parental and student preferences for private and public schooling;

(c) The determinants of pupil-teacher ratios, especially the adjustment lags in those ratios as enrollments change and/or the teaching force changes in demographic composition;

(d) The impact on high school dropout rates of such factors as changes in graduation requirements, labor market conditions, and the demographic composition and family circumstances of the school-age population; and

(e) The relationship of changes in demand for courses to changes in pupil-teacher ratios and the resulting derived demand for full-time-equivalent teachers of mathematics and science at the secondary school level.

Improvements in Current Models and Data Series on Teacher Supply

Timely, detailed data are needed to improve projections of the proportions of teachers who can be expected to stay versus those expected to leave (defined appropriately for the level of aggregation of the model).

Recommendation 3. We recommend that the Center for Education Statistics surveys of schools and teachers regularly obtain data on teacher retention and attrition. The Center should also obtain and analyze existing data from states, where available, on retention and attrition rates by age or experience and subject field. Such data are essential to improve projections of continuing teachers--by far the largest component of teacher supply.

Newly hired teachers come from many sources, including new college graduates, former teachers, and teachers who change residence or subject field. It is important to have detailed information on the components of new hires.

Recommendation 4. To provide needed data on new hires, we recommend that the Center for Education Statistics stratify the sample for its teacher surveys into teachers who are new and those who were teaching last year. For a given overall sample size, the sampling ratio for new hires should be higher than the ratio for continuing teachers.

Data on the pool of applicants for teaching positions would be valuable for understanding new teacher supply, particularly from sources other than new graduates, and to permit comparisons of potential supply and actual hires.

Recommendation 5. We recommend that the Center for Education Statistics explore with the states possible ways of systematically obtaining data on applicants for teaching positions.

Research on Behavioral Aspects of Teacher Supply

Research on behavioral factors that influence the supply of teachers is essential to improve understanding of teacher labor markets and to support the development of useful and realistic models.

Recommendation 6. We recommend that research pertinent to teacher supply be conducted--in order of priority--on:

(a) The behavioral determinants of major components of new entrants, including new graduates, former teachers, and persons hired on emergency certification;

(b) The forces underlying teacher migration (among states, school districts, schools, and subjects); and

(c) The linkage between the decision of teachers to stay or leave and behavioral and environmental factors related to that choice. The research should stratify teachers by subject field and other characteristics.

Research on Teacher Qualifications

Short-term adjustments between teacher supply and demand frequently occur through redefining the acceptable level of teacher qualifications. We need to know more about how these adjustments take place.

Recommendation 7. We recommend that research be undertaken on the linkage between the qualifications of the teaching force and changing market conditions.

Further research on the relationship of measurable characteristics of teachers of mathematics and science to educational outcomes in these subjects is needed to identify teacher characteristics that should be regularly collected in surveys in order to monitor the qualifications of the teaching force.

Recommendation 8. We recommend that further research be conducted on the relationship of measurable characteristics of teachers of mathematics and science to educational outcomes of students in these fields. In order to permit comprehensive and methodologically appropriate research on this issue, the National Education Longitudinal Study of 1988 should include appropriate measures of student outcomes together with a rich set of teacher characteristics and characteristics of schools and districts. Teacher characteristics should include measures of academic training, in-service training, general intellectual ability, and teaching styles and attitudes. To the extent possible, measures should be obtained through administrative records, such as transcripts, rather than through survey questions.

Ongoing Collection of Data on Teacher Qualifications

We believe that the Center for Education Statistics surveys of teachers could usefully include, for mathematics and science fields, a number of measures of teacher qualifications related to general intellectual ability, academic preparation, in-service preparation and commitment, and certification. For meaningful assessment of mathematics and science education, particularly at higher grades, we note that measures of teacher qualifications should be reported, not as percentages of teachers per se, but as percentages of students being taught by teachers with specific characteristics.

Recommendation 9. We recommend that the Center for Education Statistics surveys of teachers regularly include measures of general intellectual ability and of academic preparation to teach mathematics and science fields, particularly for new entrants, in order to provide time series for monitoring and analysis. These measures should be obtained to the extent possible from transcript records rather than through survey questions.

Recommendation 10. We recommend that the Center for Education Statistics surveys of teachers regularly include, for experienced teachers, measures of recent in-service preparation and participation in professional activities in mathematics and science fields. These surveys should also obtain measures of years of teaching mathematics and science distinct from total teaching experience.

Recommendation 11. We recommend that the Center for Education Statistics surveys of teachers regularly include measures of certification (type and subject fields) and that

the Center obtain and disseminate available information on state certification policies and practices.

Introduction

Debate in recent years concerning the nation's elementary and secondary education system has focused on problems in the quality of instruction in mathematics, science, and technology. The discussion is frequently framed in the context of the necessity for the United States to maintain and, in many areas, to regain its economic competitiveness and leadership in high-technology industries and innovations. One fear widely expressed in both popular and scientific reports (see, for example, National Science Foundation, 1983; National Commission on Excellence in Education, 1983) is that there are too few qualified teachers at the elementary and secondary school levels to meet the nation's instructional needs in technical areas. Rumberger (1985:355) sums up the prevailing opinion as follows:

> All the major education reports issued over the last two years have pointed out that a severe shortage of qualified mathematics and science teachers currently exists in the United States. Numerous articles have appeared in the popular press and the educational press reporting the problem of shortages. Congressional testimony by various educational associations has further substantiated the acute problem of teacher shortages in these areas. A shortage of mathematics and science teachers is now accepted as conventional wisdom.

Yet, as a number of recent reports point out (Barro, 1986; Champagne and Hornig, 1986; Gilford and Tenenbaum, 1985; Raizen, 1986; Raizen and Jones, 1985; Rumberger, 1985), it is very difficult to know from hard data what is meant by "shortages" of "qualified" teachers. The available statistics and models used to estimate and project the supply and demand for mathematics and science teachers at the elemen-

tary and secondary school levels have many problems and weaknesses. In fact, on the basis of our review to date, the panel concludes that current publicly collected statistics on science and mathematics teachers are so inadequate that it is impossible to say whether there is an existing or impending shortage. Furthermore, on the dimension of quality--which is critical for assessing the adequacy of teacher supply--there are virtually no useful statistics at all.

The problems inherent in current data and models mean that the nation lacks the knowledge on which to assess precollege mathematics and science education and thus to implement sound policy decisions. Policy makers at all levels of government have responded to perceived existing and future shortages of qualified teachers through a variety of initiatives, including teacher salary increases, merit pay plans, tuition support for teacher training and retraining in technical subjects, and innovative recruitment and certification procedures (see Education Commission of the States, 1984, 1985; Feistritzer, 1985). Some of these initiatives may prove very effective in expanding the supply of good teachers; others may turn out to be ineffective at best or entail burdensome social costs at worst. Improved statistics and models are imperative to permit education leaders to develop cost-effective policies and programs directed to the nation's teaching force in science and mathematics. The goal of this interim report is to identify priorities for research and development activities that would enhance understanding of teacher supply and demand.

ORIGINS AND SCOPE OF THE STUDY

The National Academy of Sciences (NAS) and National Academy of Engineering (NAE) have a long history of involvement in issues of precollege mathematics and science education. A convocation held at the Academies in the early 1980s drew attention to the lack of adequate information about mathematics and science teaching in the elementary and secondary schools. The resulting report (NAS/NAE, 1982) provided impetus for the formation of the Committee on Indicators of Precollege Science and Mathematics Education in 1983 within the National Research Council (NRC). The committee's initial report (Raizen and Jones, 1985) reviewed the problems and gaps in analyses and data on supply and demand for mathematics and science teachers and discussed the critical issue of defining qualifications.

At the request of the National Science Foundation (NSF), the NRC Committee on National Statistics convened a planning conference in August 1984 for a study on statistics on

supply and demand for precollege science and mathematics teachers. Subsequently, in early 1986, our panel was organized to carry out the work outlined in the planning conference report (Gilford and Tenenbaum, 1985). The panel's activities were planned in two phases extending over a 30-month period.

The project sponsors--the Directorate for Science and Engineering Education in NSF and the Center for Education Statistics (formerly the National Center for Education Statistics) in the U.S. Department of Education--asked the panel initially to carry out two tasks and prepare an interim report of findings at the end of its first year:

(1) Review teacher supply and demand models in selected states and the model maintained by the Center for Education Statistics and suggest improvements in state and national models; and

(2) Identify information on the qualifications of teachers of science and mathematics that could be collected for use in descriptive profiles and in supply and demand models.

We underscore the point that the panel was not asked to develop estimates of teacher supply and demand; our task is more basic: to recommend improvements in data and methodology that would provide meaningful estimates.

This interim report provides an assessment of the adequacy of current data and models on teacher supply and demand, gives suggestions for improvement, and indicates some of the research activities that need to be undertaken in order to enhance the structure and performance of these models and the data that support them. The report also focuses on the measurement of teacher qualifications and considers how they could be better measured in the future.

In its second phase of work, the panel is charged with continuing its investigation of statistics and models on teacher supply and demand. Two specific tasks that are planned for the second phase are:

(1) Conduct case studies of teacher flows in a small sample of school districts to determine the entry and exit of science and mathematics teachers in the teaching force; and

(2) Carry out a comprehensive review of data resources on teachers at the state and national levels, assess their utility to support research needed to improve understanding and models of teacher supply and

demand, and recommend new or modified data collection as necessary.

The panel also hopes to evaluate data on the nation's institutions of higher education that are pertinent to understanding the supply of precollege mathematics and science teachers. Finally, the panel will give more detailed consideration to methodological issues in the development and evaluation of useful models, such as appropriate measures of error, tradeoffs in the choice of variables to include inside or to treat as outside models, and problems and strategies for developing disaggregated models.

The panel expects that its second-phase activities will provide important additional knowledge and insight to support recommendations for improving data and models of teacher supply and demand. The case studies of teacher flows will serve to identify additional variables that should be included in models to enhance their realism with respect to the operation of teacher labor markets and hence the usefulness of the models for education policy making. The review of data bases will permit the panel to develop a more detailed research agenda. Although available statistics on teacher supply and demand are inadequate to sustain models or to give us a comprehensive picture of the teaching force, there are many data bases, particularly at the state level, that can support needed research and model development activities. Several states, for example, have detailed personnel files that could usefully be mined to further understanding of teacher supply, and other states might well be able to develop files of similar usefulness.

The panel expects in its final report to build on and expand the initial set of recommendations presented here. We expect to be more specific regarding the topics that merit research, variables that should be examined, and sources of useful data. We also expect to be more specific regarding promising methodological improvements in models and enhancements to data series pertinent to teacher supply and demand. We do not expect, however, to alter the basic framework or set of priorities that we have outlined in this interim report for critically needed research on supply and demand for precollege science and mathematics teachers.

We are very much aware that pursuit of the research recommended here may not result in fully developed models of teacher supply and demand that reliably generate useful results. Indeed, given the absence of well-established supply and demand models in other occupational fields, the probability of developing good models for teacher labor markets may be low. Nonetheless, we believe that the research we recommend is of great importance given the large gaps in current

knowledge. The added insight gained from such research and the effort to express the results in terms of models should be very helpful to education policy planning even if highly developed models in the formal sense are not achieved. We encourage the research community to make an immediate start on the agenda that we propose. Education, especially in science and mathematics, is so critical to our nation's future that we need the best possible information base for informed policy choices.

ORGANIZATION OF THE REPORT

The panel's interim report is organized as follows. Part I presents an overall assessment of current data, concepts, and models of teacher supply and demand. We begin with a discussion of policy uses of models that must be kept in the forefront in considering needed model development. The next section is a brief history of attempts to measure shortages and qualifications of precollege mathematics and science teachers in the decade of the 1980s. We then provide our overall assessment of current models and go on to review concepts that have been the source of considerable confusion in discussions of teacher supply and demand. We end Part I by presenting the panel's view on basic characteristics of useful teacher supply and demand models: namely behavioral content, disaggregation, and quality measurement. Our assessment of current models and data is succinct and intended to provide an overall picture. The detailed information that supports this assessment is provided in Part III, which incorporates material excerpted from reports prepared for the panel on selected state and national models.

Part II presents the panel's recommendations. We begin by discussing the role of the Center for Education Statistics and the counterpart units of state education agencies in implementing certain of the recommendations, and the role of the National Science Foundation and other organizations in the possible implementation of other recommendations. The recommendations are then grouped, for convenience of exposition, into two sections: a section on models of teacher supply and demand per se and a section on measures of teacher qualifications that are needed for models and for descriptive profiles of the nation's teaching force. Many of the recommendations refer to precollege teachers in general and not just teachers of mathematics and science. In some cases, this is because the recommendation is generally applicable across subject fields; in other cases, it is because we lack the knowledge base to make a specific recommendation.

Finally, Part III provides descriptions, drawn from our consultants' reports, of the Center for Education Statistics national model of teacher supply and demand and the models and data bases of selected states. This material, together with the observations and suggestions contained in the full text of the consultants' reports (Barro, 1986; Cavin, 1986; Popkin and Atrostic, 1986), proved invaluable to the panel in assessing the current state of supply and demand models for teachers at the precollege level.

Part I
An Overall Assessment of Current Models, Data, and Concepts

The panel's review of current models of teacher supply and demand and of the supporting data reveals many important shortcomings. Current models, particularly on the supply side, are not adequate to address the questions that they purport to answer or that arguably need answers. Indeed, lack of explicit consideration of the goals and utility of models of teacher supply and demand has undoubtedly hindered their development. Fuzzy concepts and an absence of agreed-upon terminology have also greatly hampered understanding of teacher labor markets and the development of meaningful projections of teacher supply and demand.

In Part I, we first consider relevant policy questions that models and data could usefully address. With these uses in mind, we briefly review the history in recent years of attempts to measure "shortages" of "qualified" teachers and to develop models of teacher supply and demand. We then provide a brief overall description and assessment of current models, followed by a discussion of conceptual issues relevant to models that have been the source of much confusion in the past.

Finally, we discuss the necessity for useful models to incorporate three major characteristics. The first is behavioral content, by which we mean models of relationships between variables in the environment and the behavior of actors in the educational system. An example of a behavioral component in a model of teacher supply would be the estimated impact of salaries and working conditions on the decision of teachers to continue or to leave teaching. The second major characteristic of useful models is disaggregation by geographic area and subject field, and the third is quality measurement.

As background on the scope of the problem, there are currently about 2.5 million teachers responsible for providing

instruction to 45 million students enrolled in precollege grades in the nation's public and private schools. Of the total number of teachers, 48 percent are teaching in public school elementary grades, 38 percent in public school secondary grades, 10 percent in private school elementary grades, and 4 percent in private school secondary grades. (These figures are based on the latest available data for the 1983-1984 school year--see National Center for Education Statistics, 1985a:Tables 1.1, 1.8.) The majority of the 1.4 million elementary school teachers have responsibility for teaching mathematics and science subjects for some portion of the class day. Of the other 1.1 million secondary school teachers, 10 percent are estimated to be teaching science subjects and 11 percent mathematics (National Science Foundation, 1985:Table 6.8).

USES OF TEACHER SUPPLY AND DEMAND MODELS*

Models for projecting teacher supply and demand are supposed to be practical tools for planning and policy. Their usefulness depends on whether they can provide valid answers to questions that policy makers or policy analysts are likely to have.

Today, the most often-heard questions about teacher supply and demand concern the future supply-demand balance, or adequacy of supply:

- Will there be enough teachers in the coming years to staff the schools? Is there likely to be a general teacher shortage?

Increasingly, such questions are combined with concerns about quality:

- Will there be enough certified, qualified, or, "high-quality" teachers to meet the expected demand?

Frequently, the questions pertain not to teachers in general but to particular categories of teachers, especially teachers in "critical" fields believed to be threatened by shortfalls in supply:

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*This section is drawn from the paper prepared for the panel by Barro (1986:5-7).

- Will there be enough science teachers, mathematics teachers, teachers of special education, teachers of bilingual education, etc., to serve the expected numbers of pupils in these areas?

Sometimes, questions pertain to particular geographic areas:

- Will there be enough qualified teachers in central cities, in rural areas, in the fast-growing Sunbelt states, or, more specifically, in Southern California or New York City?

To address such questions, one must be able to project demand and supply in appropriate detail and to assess the balance between the two.

Questions about future supply and demand for teachers generally or for particular categories have a somewhat different focus when asked from the point of view of those responsible for training, recruiting, or hiring teachers:

- How many job opportunities will there be for new graduates of teacher training programs, or how many such graduates will there be to fill the projected number of positions?

- To what extent can one count on the "reserve pool"--persons trained and/or certified to teach but not currently teaching--to meet the projected demand for teachers? What occupations compete with teaching for the services of members of this reserve pool?

- How many teachers will it be necessary to recruit from out-of-state to fill the expected vacancies?

- How many teachers may have to be hired under "emergency" certificates because of a lack of fully certified applicants?

To deal with such questions requires a capability to project the supply of teachers from particular sources as well as the supply in general.

Other policy concerns generate "what if" questions--questions about the likely effects of various education policy actions and economic or other external developments on prospective teacher demand, teacher supply, and the supply-demand balance. For example:

- How would the demand for teachers be affected by changes in the elementary-secondary curriculum or in the course requirements for high school graduation?

- How would a change in the teacher salary scale affect teacher retention and the supply of new entrants into teaching?

- How would new requirements for teacher certification, such as competency tests or longer periods of training, affect the supply of new teachers from various sources?

- How would an improvement in professional job opportunities outside teaching affect the attrition rate and the supply of new teachers?

These are clearly the most difficult types of questions to deal with, since they require a capacity not only to project demand and supply under the assumption that conditions will remain constant but also to estimate the effects on the projections of various changes in circumstances.

The panel recognizes that it is not feasible or even useful for all teacher supply and demand models to have the capability to answer the entire list of policy questions outlined above. Nor is it feasible or necessary for all models to incorporate the most sophisticated methodology. From a policy perspective, different kinds of models may be appropriate depending on whether they are at the school district, state, or national level and what the perceived needs or policy alternatives and relevant time horizons are at each level. The panel discusses the issues of level of aggregation and the implications for model development in the section below on basic characteristics of useful models.

We note that the objectives of the models that we reviewed are often not at all clear and that, moreover, documented uses of the projections from these models are rare (see discussion in Part III). As best we can tell, current models appear to have limited uses. The national model maintained by the Center for Education Statistics is designed to provide teacher supply and demand projections that can assist the education policy process at the federal level and inform the higher education community and young people regarding career prospects in the field of teaching. The Center's model does not at present purport to provide information that would help answer questions about supply-demand balances in particular regions of the country or particular subject fields. Similarly, the models and analyses of teacher supply and demand developed by state education agencies

appear often to have limited objectives, such as assessing the employment prospects for graduates of in-state teacher training programs or identifying subject fields with "critical shortages." However, models designed with such limited objectives in mind are greatly circumscribed in terms of the insights they can provide into important issues of public policy.

RECENT EFFORTS TO MEASURE "SHORTAGES" OF "QUALIFIED" MATHEMATICS AND SCIENCE TEACHERS

Initial efforts in this decade to measure teacher shortages relied on qualitative measures based on opinions of state administrators and teacher placement officers. For example, Howe and Gerlovich (1982) asked state science supervisors and teacher certification directors to assess supply and demand for secondary school science and mathematics teachers in their state on a five-point scale from 1, surplus, to 5, critical shortage: about 44 state authorities reported shortages or critical shortages of math, physics, and chemistry teachers. A more recent survey conducted by the Education Commission of the States (Flakus-Mosqueda, 1983), using similar methods, found that only 38 states reported shortages in either mathematics or the physical sciences. Some of the most populous states in the East and Midwest did not report shortages. The latest survey of teacher placement officers conducted by the Association for School, College and University Staffing (Akin, 1986) reported generally widespread shortages across the country of mathematics and physics teachers, but greater variation for chemistry teachers--shortages in the latter category were most severe in New England and least severe in the Far Northwest. However, it is not possible to use these kinds of opinion data in any way other than to supplement results based on more rigorous measurement methods.

The Center for Education Statistics took another approach to the measurement of shortages. Its surveys of Teacher Demand and Shortage conducted in 1979-1980 and again in 1983-1984 (National Center for Education Statistics, 1982; Gilford and Tenenbaum, 1985) asked school administrators to identify openings by subject area in the previous spring that had not been filled by the fall. In both survey years, the results showed very few shortages in mathematics or science fields (less than 1 percent overall).

However, the definition of shortage used in these surveys--unfilled vacancies--does not take into account the

universal preference on the part of school systems to hire someone to teach a class rather than to cancel it. Many states do not have laws or policies restricting "out-of-field" teaching--that is, teaching classes for which one is not certified. Other states permit teachers to teach one or two classes out of field. Yet other states permit emergency certification of applicants if a teacher with the needed subject certification is not available. Hence, school systems can make supply equal demand by changing the definition of a "qualified" applicant. The positions filled by uncertified or otherwise unqualified persons would not appear in the measures of shortage developed from the Center's surveys, even though meaningful measures of supply and demand need to specify the important dimension of quality.

The Center for Education Statistics and a number of state education agencies have developed models that attempt to project teacher supply and demand and the supply-demand balance. The Center developed its model in the mid-1960s. Currently, the model generates high, intermediate, and low projections year-by-year for 10 years into the future; the projections are updated every 2 years. Roughly speaking, the Center's model compares projections of the year t+1 demand for new classroom teachers, defined as the number of openings that result from the attrition of year t teachers adjusted for enrollment and teacher-pupil ratio changes, with the supply of new college graduates who received teacher training. The model is not disaggregated either by geographic area or subject field. The latest projections for 1992-1993 (National Center for Education Statistics, 1985b) indicate that demand for additional teachers could exceed the supply of new graduates nationwide by as much as 133 percent or that supply could exceed demand by as much 20 percent, depending on which assumptions the user considers to be most realistic at the time.

State efforts to model teacher supply and demand sometimes incorporate separate projections by locality or by subject area, particularly fields such as mathematics and science that are viewed as critical shortage areas. In other respects, state models bear many similarities to the Center for Education Statistics model, typically comparing projections of the demand for new teachers with the supply of graduates of in-state teacher training programs.

There are many deficiencies in concepts, methodology, and data in both the Center and the state models, which are discussed in detail in the next section. The concepts of supply, demand, and shortage embedded in the models are problematic. For example, not all new graduates of teacher training programs are in the new teacher supply, as some proportion do not apply for certification or a teaching job. There are

also many other sources of supply, such as persons with teaching experience who are on leave. The models employ a methodology that is relatively simple and mechanical in nature and does not incorporate behavioral components, such as supply responses to changes in salary schedules or other policy initiatives. Data for key model components, such as the turnover rate of the current teaching force, are often lacking in stratification by important variables, such as teaching experience, or are out of date.

Current models also handle poorly the dimension of teacher qualifications, which is as important a matter for public concern as the numbers of available teachers. The Center for Education Statistics model implicitly assumes that all continuing teachers and new graduates of teacher training programs, which constitute the supply components in the Center's model, are qualified. Some state models look at qualifications in terms of appropriate subject certification. Many estimates of shortages have incorporated estimates of out-of-field teaching, which in mathematics and science areas have been high. For example, analysis of data from a 1981 NCES survey indicated that only 53 percent of new mathematics and science teachers one year out of college were subject certified. The percentage with appropriate certification was higher (73 percent) for those teachers primarily teaching mathematics or science (Rumberger, 1985).

Although shortage estimates that incorporate measures of qualifications are a definite improvement over estimates that do not, a major drawback of estimates based on certification is that the level of qualifications or competence to teach implied by certification is hard to assess and in any case varies greatly across the nation. As of 1983, only 8 percent of the states required a major in mathematics or science for certification to teach these subjects at the high school level, and only about another 22 percent of states required as many as 30 credit hours (Raizen and Jones, 1985:Table 7).

It is certainly possible to collect more nearly comparable measures of teacher qualifications, such as percentage with a college major in their subject. Some studies have used as a measure the Scholastic Aptitude Test (SAT) scores of college students planning to enter teaching or the scores of teachers in specific states (Vance and Schlechty, 1982a; Weaver, 1978). Each measure one could suggest is subject to its own questions of interpretation (for example, college students who plan to enter teaching are not the same group as those who actually do). There is also the difficulty that data on alternative measures are not generally available nationwide for all components of teacher supply, but are available for only some components, some areas, and some points in time. There remains an even more fundamental problem. Ideally,

measures of qualifications should be good predictors of the quality or effectiveness of teaching. Unfortunately, the research literature on the relationship of teacher characteristics to educational outcomes (see the section below on basic characteristics of useful models) does not support the selection of specific measures on this basis.

OVERALL ASSESSMENT OF CURRENT MODELS

In general, the panel finds that current teacher supply and demand models at all levels are deficient in their ability to address important policy needs, even when measured against the apparently limited uses that the models are intended to serve. Current models are in most respects reasonably adequate on the demand side but in almost all respects totally inadequate on the supply side. We summarize the strengths and weaknesses of current models of teacher supply and demand below.

Demand Models

The central feature of the demand models that we have examined, both in the Center for Education Statistics national model and in most state models, is that demand is driven by enrollment projections plus an arbitrary assumption (sometimes adjusted for trends) about pupil-teacher (or teacher-pupil) ratios. Enrollment projections are typically based on a combination of projected births and historical analysis of birth cohort-to-grade survival and grade-to-grade retention ratios. These enrollment projection techniques, while completely mechanical, have a reasonably good track record, particularly for short-term projections (see Part III:Tables 1, 6).

However, the demand models and underlying methodology have important weaknesses. The reliance of the models on projection of current or historical trends means that any important change in behavior will make the projections increasingly unreliable. Changes in population fertility and migration, in parental preferences for private versus public schooling, and in school system policies and practices will affect teacher demand at all grades. In addition, changes in dropout rates and in choice of courses will affect demand at higher grades. Thus, the cohort-survival rates need to be checked periodically for validity.

From a policy perspective, one key problem is the lack of disaggregation needed to answer many of the most important questions being asked about teacher supply and demand today. Almost all the models that we have examined project demand for elementary and secondary school teachers separately, but they less commonly disaggregate by geographic area or subject field. The Center for Education Statistics model produces national total projections. About half the state models we analyzed disaggregate by substate area, typically counties--not necessarily the most useful representation of intrastate teacher labor markets. About half the states (not the same half) disaggregate by subject field, such as mathematics, science, foreign languages, etc. The technique used to develop subject-specific demand projections is to assume that historical proportions of teachers by field will hold for the future.

The projection methodology is not well suited to support model disaggregation. Historical analysis of grade-to-grade retention ratios, for example, does not distinguish between the effect of dropouts and the effect of net migration. By grade level, standard methods are least adequate for projecting secondary school enrollments, which in total are influenced by changes in dropout rates and in specific subject areas by many behavioral and school system factors.

A complicating problem is that demand models generally deal only with the public school sector. (This is true of all the state models that we examined; the Center for Education Statistics model develops separate private and public school demand projections.) Where private school enrollments are an important component of the total, switches between public and private schools need to be incorporated into demand models for public schooling. The statistics for private school enrollments are substantially weaker than those for public school enrollments.

Supply Models

The situation is much less satisfactory on the supply side. Supply can be thought of as consisting of two major components--continuing teachers and new entrants. The latter component in turn comprises several categories.

The most important element of teacher supply during year t+1 is the retention of people teaching during year t: to obtain that element of teacher supply, all we need to know is the attrition or turnover rate between years t and t+1. The method typically used in current models involves use of a single assumption about attrition rates, sometimes adjusted for trend and sometimes not. In the case of the Center for

Education Statistics model, moreover, the attrition rate in the intermediate set of projections is based on survey data that are more than 15 years old. In some state models, this component of supply is handled in a much more satisfactory way (see Part III), since forecasts of turnover are based on differential attrition rates for teachers in different age or experience categories and in different subject fields. (Evidence from these states shows that, as the teaching stock ages, the average attrition rate will change. Interestingly, attrition rates in these states for teachers of science and mathematics subjects are not noticeably different from rates of teachers in other fields. See Part III:Tables 4, 5.)

The more difficult part of modeling teacher supply consists of predicting the potential willingness to teach of people who were not in the teaching force last year. We have labeled all sources of teacher supply other than continuing teachers as "new entrants." Major categories under the new entrant heading include newly certified persons, persons with previous teaching experience and certification (i.e., reentrants), and persons hired through some alternative or emergency certification procedure. These categories can be broken down into yet finer components: newly certified graduates of teacher training programs; newly certified graduates with other majors; experienced teachers who were on leave or layoff; experienced teachers who resigned for long-term health reasons or to enter other careers, including homemaking; in-migrants, that is, teachers who were teaching last year but not in the particular jurisdiction or subject field for which the model is being estimated; persons who were teaching as substitutes; etc. In some states, virtually any college graduate, whether or not they have teaching certification or experience, can be in the supply of new entrants; these states permit certification on the basis of testing, permit hiring on an emergency certification basis, or use an apprentice teaching program.

The sources of new entrants listed above consist of different components that can be expected to behave in very different ways. For example, teachers on maternity or health leave during year t or laid off and expecting to be called back can plausibly be expected to return to the teaching pool in year t+1 at relatively high rates; teachers who are newly certified and in the job market during the last few years and who for one reason or another did not obtain teaching jobs can be expected to remain in the teacher supply pool with relatively high probability; teachers whose credentials are older and who have been out of the teaching market for several years have a lower probability of being in the pool; while people with teaching certificates who have followed a completely different career trajectory for many years have a

much lower probability of being in the supply pool. In some states, as we noted above, everyone with a bachelor's degree is potentially in the supply pool with some--arguably low--probability.

Virtually none of the state models nor the Center for Education Statistics model provides what we regard as a serious analysis of the contribution of these various types of potential teacher supply. Most of the models ignore everything in this area but newly certified teachers or some equivalent. The Center's model limits projections of new entrants to new graduates of teacher training programs. Other definitions that are used in state models include students enrolled in the state's education programs and newly certified persons.

The California PACE model (Cagampang, Garms, Greenspan, and Guthrie, 1985) represents the most ambitious effort we have seen on the supply side, with projections of the supply of new entrants from four sources: (1) new or recent graduates of California credential programs, (2) new credential holders from out of state, (3) teachers entering from the reserve pool of nonteaching credential holders, and (4) college graduates who pass the California Basic Educational Skills Test and obtain emergency credentials. However, because of inadequate data sources and the lack of knowledge of the supply behavior of the various new entrant components, the PACE model relied largely on extrapolations of historical hiring patterns in the state, which are not the same as projections based on supply relationships.

In stark contrast to the restricted definitions of new entrants used in most models, descriptive statistics in many states indicate that a substantial fraction of new hires do not consist of newly certified teachers, but of teachers that fit into some other category. For example, less than 30 percent of new hires of mathematics and science teachers in New York State were new certificate holders; the corresponding figure in Illinois is 40 percent (see Part III). These and similar figures from other states underscore the need to obtain data on all of the components that make up new teacher supply.

Overall, it is the panel's view that current models of teacher supply and demand are of very limited usefulness for education policy and consist of little more than plausible extrapolations of relationships that are largely based on cohort survival techniques on both the demand and the supply side. None of the models has any serious behavioral content--i.e., on the relationship between changes in circumstances and changes in the numbers and kinds of people interested in obtaining teaching positions or in the numbers and kinds of teachers demanded by school systems.

As we noted earlier, current models generally fail to deal with a critical component of teacher supply and demand--the quality or qualifications that school systems look for in teachers and that characterize persons who apply for teaching positions. Where models do consider this component, the definition of a qualified teacher is equated with certification. While certification may be a reasonable measure of qualifications from the perspective of a single state (in particular a state that restricts emergency certification), certification requirements vary too greatly among states to permit meaningful comparative analysis.

We discuss at greater length in the section on basic characteristics of useful models issues surrounding the need for behavioral modeling and the measurement of quality. Our recommendations in Part II include both short-term and long-term goals for improvement in models of teacher supply and demand and associated data series. We identify components of current models for which immediate improvements in methodology and supporting data are feasible and desirable, and we outline an agenda for further research. The research program is ambitious but essential to support the development of models that are fully adequate and useful for policy.

UNDERSTANDING CONCEPTS OF TEACHER SUPPLY AND DEMAND*

In economics, "demand" and "supply" refer to relationships, not numbers. The demand for teachers is a relationship between the number of teachers school systems want to employ and such determinants of that number as the salaries that must be paid for teachers and levels of funding for the schools. The supply of teachers is a relationship between the number of (eligible) persons willing to offer their services to teach and such factors as the salaries and working conditions offered by school systems and the alternative opportunities available in other lines of work. School systems are likely to demand more teachers if their funds are plentiful and fewer teachers if funds are tight. More people are likely to offer to teach if salaries are high and working conditions favorable. Consequently, any projection of numbers of teachers demanded or supplied must be conditional--

*This section is drawn from the paper prepared for the panel by Barro (1986:14-24).

implicitly, if not explicitly--on certain assumptions about future conditions.

Current projection models maintained by the Center for Education Statistics and state agencies do not incorporate explicit assumptions about future salaries, funding levels, and other conditions; nevertheless, such assumptions are implicit in the projections. But what assumptions are they? The most plausible answer is that the indefinite continuation of current conditions or of trends in conditions is assumed. It is essential to keep these implicit assumptions in mind in interpreting the projections and especially in assessing any supply-demand imbalances that the projections seem to imply.

An important issue bearing on the validity and proper interpretation of projections is the relationship of demand or supply to the actual number of teachers employed. In general, one cannot assume equality among the three, as in textbook models of supply and demand. The latter models apply to markets for well-defined homogeneous commodities, like red wheat number 2, for which price acts as a ready mechanism for adjustment of supply and demand. In the teacher market, adjustment processes are slow, especially on the supply side, and a supply-demand imbalance can persist for many years. Moreover, the adjustment process frequently operates by changing the definition of the "commodity," i.e., the qualifications and other characteristics of teachers. Hence, in any given year, actual employment equals the *lesser* of quantity demanded or quantity supplied. If school systems demand fewer teachers than are willing to supply their services (under prevailing salaries, working conditions, etc.), then only the number demanded will be hired--a condition of excess supply. If fewer teachers apply than are wanted, only the number supplied can be employed--a condition of excess demand.

But this apparent symmetry between excess supply and excess demand is misleading. For many years, the teacher market, nationally, and in many states, has been characterized by excess supply (the long-running "teacher surplus"). Consequently, it is reasonable to assume that the aggregate number of teachers employed in a state or in the nation approximates the number of teachers demanded. This rough equivalence between the number of teachers demanded and the number actually employed is essential to the validity of demand projection models. Invariably, such models project employment rather than demand per se. The implicit assumption is that current and historical teacher-pupil ratios reflect the number of teachers per pupil demanded. If this were not true, if the observed teacher-pupil ratios fell short of the desired ratio because of insufficient supply, projections based on them would not be demand projections at all but rather

projections of supply. Hence, the validity of the demand component of the models rests on the assumption that currently, or during the historical period on which the projections are based, there was either a supply-demand balance or a condition of excess supply.

The assumption of excess supply is less likely to hold for particular types of teachers than for teachers in the aggregate. Today, we hear frequently that there is excess demand for teachers in such fields as mathematics and science. It may well be that instead of hiring underqualified persons to staff classes in these fields, school systems reduce their hiring to match the qualified supply and reduce their course offerings to match. If so, it is incorrect to project future demand for mathematics and science teachers on the basis of current employment in those fields. For example, if the number of science teachers currently demanded were 5 per 1,000 high school students, but the actual number employed were only 4 per 1,000 because of a lack of qualified applicants, it is the former ratio rather than the latter that should be used to estimate future demand. Admittedly, this prescription is hard to implement, since the actual teacher-pupil ratio is directly observable, while unfilled demand is neither observable nor readily inferred. Nevertheless, the issue is unavoidable: one cannot logically project demand on the basis of current employment in a field already characterized by excess demand.

The same argument has even more troubling implications for projections of supply. In a situation of excess supply, current employment falls short of supply and, furthermore, the number of newly hired teachers each year falls short of the supply of applicants for teaching positions. How then can one project supply? The problem is that in the excess-supply case, the supply of teachers--the number that would have been willing to take jobs had openings been available--is not directly observable. Consequently, none of the simple, mechanical techniques of extant projection models is applicable. Teacher supply must be inferred indirectly rather than merely extrapolated, but such inference requires methods far more sophisticated and far more demanding of data than any currently employed.

These considerations explain why there is such evident confusion about what one should project under the heading of "supply." To produce valid supply projections, one would have to estimate, or infer, how many people would have been available to take teaching jobs at prevailing salary rates and employment conditions had there been no limit on employers' willingness to hire. Such estimation requires statistical models of teacher behavior, in which willingness to apply for

teaching jobs is linked to both job characteristics and characteristics of the teachers themselves.

Recently, several constructive steps have been taken toward the development of such models. In recent studies by Douglas and Bird (1985), Manski (1985), and Zarkin (1985), and in an earlier British study by Zabalza (1979), statistical relationships have been demonstrated between individuals' decisions to go into teaching and a number of personal and occupational characteristics, including the rewards in teaching relative to rewards in other occupations.* There is also a relevant literature from studies of occupational choice in other fields (see, for example, the work of Freeman (1975) on lawyers). Teacher supply behavior is not a unique phenomenon, and work on understanding the decision to go into teaching can benefit from behavioral analyses of choices of other occupations.

In any case, much remains to be done to bridge the gap between models of individual behavior and models of the supply of teachers to a state or district. Until this is accomplished, true supply models and supply projections are beyond the state of the art.

What then is one to make of the so-called projections of the supply of new entrants into teaching found in some current supply and demand models? Recall that such projections are constructed by applying current or extrapolated entry rates to projected numbers of new graduates of teacher training programs and, less frequently, to projected numbers of persons in the "reserve pool." But according to the foregoing argument, current and recent entry rates reflect demand rather than supply, and hence projections based on them cannot reasonably be construed as projections of supply. For example, the fact that only 30 percent of recent graduates of teacher training programs may be observed to enter teaching does not imply that only 30 percent were in the supply. The percentage willing to supply their services (under prevailing conditions) could have been 50 percent, 75 percent, or more; there is no way to know from data on the number of entrants alone. To project supply, one would have to estimate the percentages of new graduates or reserve pool members who would have entered teaching had there been no

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*An earlier model developed by Carroll and Ryder (1974) linked the supply of newly trained teachers, with a lag, to the supply-demand balance in the teacher market. This model, unlike extant mechanical models, correctly predicted the tighter market for teachers that has developed in recent years.

scarcity of positions, but this cannot be accomplished with the models, methods, and data at hand.

Teacher Shortage

"Shortage" is a most overused and abused term in discussions of teacher supply and demand. An imminent shortage is likely to be proclaimed whenever a projection of the number of teachers supplied is found to be smaller than a corresponding projection of the number of teachers demanded. Frequently, however, the so-called supply projections in these comparisons are not supply projections at all, for reasons discussed above, or the supply projections are incomplete, pertaining only to certain components of total supply. The Center for Education Statistics, for example, has often compared the projected demand for new teachers with the projected number of new graduates of teacher training programs and, finding the latter smaller than the former, has warned of a shortage.* Some state analyses have done the same. We know, however, that newly trained teachers often make up only a minor fraction of the annual flow of new entrants into teaching (see, e.g., Prowda and Grissmer, 1986; Illinois State Board of Education, 1985b; and Cagampang, Garms, Greenspan, and Guthrie, 1985).

A more fundamental problem with predictions of shortage is that they usually take no account of adjustment processes in the teacher market. What does it mean to project, as in the recent California analysis (Cagampang, Garms, Greenspan, and Guthrie, 1985), a shortage of more than 20,000 teachers by 1990? One thing it clearly does not mean is that there will be 20,000 teacherless classrooms in California in that year. It is generally recognized that adjustments will be made. Perhaps class sizes will increase or, more likely, the qualifications or quality standards required of new teachers will be reduced and/or salaries will rise by enough to generate the needed additional supply. The problem is that mechanical projection models, lacking the capacity to take market adjustment processes into account, predict quantitative supply-demand gaps that one can confidently predict will not occur. Moreover, these models do not provide the means

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*In its more recent discussions of the topic, the Center notes that new graduates are only one source of supply and acknowledges the role of the reserve pool, but it persists in its data tables in characterizing the projected number of new graduates as "supply" and expressing it as a percentage of projected demand (see, e.g., Moore and Plisko, 1985).

to evaluate supply responses to specific kinds of policy initiatives on the demand side, such as changes in salary levels or certification requirements.

This is not to imply that there are not and can never be teacher shortages defined in constant quality terms. Markets do not adjust instantaneously, and there are institutional impediments to some of the adjustment mechanisms. For example, when too few new teachers apply who are qualified, school systems may not be free to raise salaries quickly or to take other measures to attract additional qualified applicants. It is quite possible, therefore, for supply-demand gaps to emerge, particularly within fields such as science and mathematics, in the sense that not all classes are being taught by persons with a specified level of qualifications. Nevertheless, in the long run, markets do adjust, and models that make no allowance for adjustment are unlikely to produce valid supply, demand, or shortage estimates.

The Reserve Pool and the Dynamics of Supply

Recent studies of teacher supply and demand have given increasing attention to the reserve pool as a source of supply. This is a positive development in that it corrects for the excessive emphasis formerly placed on the supply of new graduates of teacher training programs. Yet the reserve pool concept is itself too narrow and static, and it reinforces an overly restrictive view of potential sources of future teacher supply.

The reserve pool is usually defined as the stock of persons certified to teach but not currently employed as teachers. This suggests a finite, clearly bounded inventory of potential teachers. That inventory is replenished by new graduates who do not immediately enter teaching and by former teachers who leave teaching; it is depleted as members take teaching jobs or as they move away, retire from the labor force, or die; conceivably, it could even be exhausted. But this definition ignores two important phenomena: first, people outside the system can become certified without undergoing conventional teacher training; second, prior certification is not always a prerequisite for obtaining a teaching job.

Access to teaching positions is potentially open to a broader segment of the population than the reserve-pool concept implies. Today, it is not necessary in all states to complete a multiyear undergraduate training program to become a teacher. In California, anyone with a bachelor's degree who completes one year of teacher training and passes a test can be certified to teach. Therefore, although the California

reserve pool today is fixed in size, the reserve pool two years from now is effectively unbounded. The notion of a fixed inventory does not apply. The relevant question, therefore, is not how many reserve teachers are currently in the inventory but how many would join the ranks of the certified in the future if conditions were right.

It should also be recognized that it is possible to enter teaching without first joining the certified pool. In California in 1984-1985, 30 percent of all new teachers entered under "emergency" certificates, issued on the basis of district-attested need. To be sure, this percentage is atypically high, and many states' rules limit emergency certificates tightly. However, New Jersey has recently institutionalized "alternative certification" without the "emergency" label, allowing holders of noneducation bachelor's degrees to become fully certified after a one-year teaching internship. Moreover, even where the rules appear restrictive, they are likely to be relaxed if and when shortage conditions materialize. Thus projections need not be restricted to the already-certified stock.

More generally, a model that purports to project teacher supply 5, 10, or more years into the future should be based on a dynamic concept of supply. The notion that teachers must be drawn from a pool of certified persons, expandable only by graduating more young people from teacher training programs, is far too restrictive. The emphasis should be redirected to the behavioral question of how many and what kinds of persons are likely to equip themselves to teach and offer their services to teach under various market conditions.

BASIC CHARACTERISTICS OF USEFUL MODELS

In considering research and development activities that would enhance understanding of teacher labor markets and lead to significant improvements in modeling of teacher supply and demand, the panel has identified several basic features that are essential for useful models and analyses. These include behavioral content, appropriate levels of disaggregation, and quality measurement. The panel discusses issues involved in each of these areas.

Need for Behavioral Responses in Supply and Demand Models

As we suggested above, existing models are largely mechanical extrapolations based on cohort survival methods or the equivalent. In no case is there a significant behavioral parameter in the model. For example, even though it may not be easy to demonstrate empirically, no one would quarrel with the proposition that the supply of new teachers would be greatly increased if teacher starting salaries and salary scales were doubled from their present levels. Under such circumstances, one could confidently predict that there would be a great influx of both young and older people seeking teaching positions. We do not suggest that such a policy response is plausible. Rather, we assert that knowing how teacher supply would react to various conditions associated with teaching--salary, work hours, school work environment, prestige, etc.--must have considerable relevance for developing teacher supply models that are relevant for policy.

We would note that the Center for Education Statistics model employs alternative projection assumptions for key model components, such as population growth and teacher-pupil ratios on the demand side and attrition rates and propensities of college students to graduate from teacher training programs on the supply side. The Center produces high, intermediate, and low projections of both teacher supply and demand. However, the pairing of scenarios, such as rising teacher-pupil ratios with the most rapidly rising enrollments and constant teacher-pupil ratios with the slowest rising enrollment, seems motivated more by a desire to form the widest "best case, worst case" bounds than to establish causal relationships among the model components. (In the example cited, rising enrollments have historically been associated with *falling* teacher-pupil ratios, as the supply response lags behind changes in demand--see further discussion in Part III.) The widely ranging alternative projections provided by the Center hence do not serve as useful guides for policy and can in fact be quite misleading. In any case, they are not a substitute for behavioral modeling.

The importance of having behavioral models that can provide policy assessment and guidance cannot be overemphasized. Consider the discussion by Levin (1985), who asserts that the presence of significant numbers of unqualified teachers in mathematics and science fields, based on estimates of out-of-field teaching, is not a new phenomenon but has characterized these subjects to a greater or lesser degree since the 1950s. He also asserts that policy initiatives currently in favor, such as scholarship support or loan forgiveness programs to encourage persons to enter or reenter

teaching fields with shortages, were tried in the post-Sputnik period but had very little demonstrable impact on the qualifications of the mathematics and science teaching force. In his view, the problem lies in the lack of differential salary schedules for shortage subjects and also compensation systems that generally cap teachers' salaries relatively early in their careers. Whether or not Levin is correct in his assessment of the effects of alternative policies, his argument underscores the point that better knowledge of the operation of teacher labor markets and the capability to model supply response to policy initiatives are needed for governments at all levels to be able to develop cost-effective programs for augmenting the supply of qualified teachers.

There has been very little research on what motivates the choice of a teaching career or the decision to return to the teaching force of nonpracticing teachers. Given the lack of knowledge about the variables that influence these decisions, we are not in a position to make detailed recommendations to the Center for Education Statistics or state education agencies for data collection that would permit behavioral modeling of teacher labor markets. The search for such behavioral relationships is clearly in the category of a research agenda that needs to be formulated rather than a well-defined set of statistics that need to be collected. An important feature of building behavioral responses into supply and also some demand components of teacher models is, as we just noted, that it is precisely in the behavioral component that public policy can influence both the quantity and quality of people in the teacher supply pool. Although it is nothing more than a commonplace, it needs to be emphasized that the supply of qualified teachers relates directly to the attractiveness of teaching careers.

Aggregation Issues

Some teacher markets are basically national markets for which one would model supply and demand phenomena at a national level. This is clearly true of the teacher markets for the major research-oriented universities--the Ivy League schools, the major public institutions, etc. But as one goes below national research universities, teacher labor markets are more apt to be regional than national, and at the precollege level may be largely local rather than regional. School districts can and do respond to shortage situations by expanding their normal area of recruitment and actively seeking teachers from other areas. However, it appears to be rare for districts to expand their recruitment efforts very far beyond their own state or neighboring states.

It is clear, moreover, that precollege teacher labor markets vary widely in both supply and demand characteristics from state to state--contrast the declining demand and adequate supply of teachers in New York and Illinois with the rising demand and the need to rely on migration from other states in Florida. (In 1984-1985, in-migrants acccounted for 65 percent of new applicants for certification and 35 percent of new hires in Florida--see Part III.) Markets also differ within states in many instances--for example, the Chicago district faces a very different set of problems in recruiting teachers than do downstate districts in Illinois, while the same is true comparing rural districts in eastern Oregon with urban and suburban districts along the Oregon coast.

Hence, for understanding teacher supply and demand issues at the precollege level, it seems reasonable that we should be concerned more about models of supply and demand at the state level than about models of national supply and demand, and perhaps even about models of supply and demand for substate markets. Since policy about precollege education is made largely at the level of states and localities rather than at the national level, that provides additional reason to be concerned with developing state and local models rather than expending efforts on developing a more sophisticated national model.

In addition to geographic disaggregation, policy considerations strongly support the need for models that are subject-specific. Many questions being asked today are not about the overall teacher supply-demand balance, but about the situation for specific fields, including mathematics and science (and other fields such as bilingual education). Disaggregating models by subject may well be a taller order than incorporating geographic disaggregation, entailing many more problems of data and methods, yet the need is at least as great.

Policy makers could benefit from information on teacher supply and demand for broad categories of mathematics and science at the high school level (grades 10-12 in some states and 9-12 in others). In addition, disaggregation by subject would be useful for middle school grades (7-8 or 7-9) in about half the states. These states organize classrooms for middle school grades by subject and train and certify middle school teachers accordingly. Other states organize their middle school grades similarly to elementary grades, in that the same teacher handles several subjects and receives a broad certification.

Closely tied to the question of appropriate level of aggregation is the treatment of migration in teacher supply and demand models. In national models, the relevant migration is to the United States from abroad or from the United States

to other countries. But in a model of school district supply and demand, migration includes movement from district A to district B as well as the reverse flow. And in the context of the particular focus of this panel--precollege instruction in mathematics and science--migration of teacher supply should also be defined to include migration across subject fields and across levels (elementary, middle school, secondary). For example, teachers who were trained in English but are teaching mathematics or science can be thought of as migrants from one discipline to another, and a thorough understanding of the quality of mathematics and science teaching needs to be able to comprehend migration of that sort.

Quality Measurement Issues

Information on the quality of the teaching force providing precollege instruction in mathematics and science is important to include in descriptive profiles of teachers and in time series for monitoring changes in teacher characteristics. Information on quality is also central to the proper modeling of teacher supply and demand.

Perhaps the best way to illustrate the importance of quality measurement is to note that one common way of thinking about shortage or surplus of mathematics and science teachers is to ask whether mathematics and science courses are being taught by someone. When demand exceeds supply, unless schools take the drastic step of canceling course offerings or the equivalent, the adjustments between the number of mathematics and science teachers demanded and the number of mathematics and science teachers supplied will be taken up by changes in quality--people will be induced to teach mathematics and science courses who are relatively untrained to do so. But there will be no supply-demand imbalance in numerical terms; rather, supply and demand will be equated by way of adjusting quality. Indeed, a major focus of this panel's concern is not whether there will be sufficient teachers of mathematics and science to enable such courses to be taught in the future, but whether and under what circumstances it will be possible to maintain the quality of mathematics and science teaching at acceptable levels.

We discuss at some length below the difficult and contentious issues in measuring the quality of precollege mathematics and science teachers. Our discussion specifically notes that practically one can at best measure only the *qualifications* of teachers rather than their quality in terms of demonstrated effectiveness in educating students in the classroom.

Relationships of Qualifications to Outcomes

It seems obvious that desired measures of teacher qualifications are those that relate to teacher "quality" or "effectiveness." Unfortunately, the extant literature does not indicate strong relationships of measurable qualifications with educational outcomes such as student performance on standardized tests. From the available studies, summarized in a comprehensive literature review by Darling-Hammond and Hudson (1986:24-32), it appears that the following teacher characteristics exhibit some positive relationship (often weak) to student performance:

- Verbal ability;
- Number of math credits (for math teachers);
- Educational background in science, particularly for science teachers in higher grades;
- Recent (particularly voluntary) educational experience;
- Active involvement in professional organizations (based on one study);
- Years of teaching experience; and
- Positive attitudes toward teaching, flexibility, and enthusiasm.

Other measures, such as IQ, National Teacher Examination (NTE) scores, and various measures of subject knowledge, have not shown any relationships to outcomes. Another comprehensive review of the literature by Blank and Raizen (1985) provides the same picture, but point outs a number of problems with the research to date on teacher effectiveness that preclude using the study results to justify choice of teacher qualifications measures:

- The degree of variation in the independent variable (e.g., NTE scores) is often so small that no effect on outcomes is measurable;
- Most studies have not included teachers with emergency certificates or low levels of training in the field in which they were teaching, so that strong relationships to outcomes of measures such as extent of subject preparation would be unlikely to result; and

- Most studies have used student achievement tests as the sole measure of outcomes. The tests themselves may not relate to the goals of the students' courses; moreover, other measures such as attitudes toward science or math might show different results.

Darling-Hammond and Hudson note that another problem with much of the teacher effectiveness literature is the failure to include mediating school and school system variables. The literature on effective schools has found that characteristics of the school and school system have considerable impact on student outcomes, both directly and through their effects on teachers' behavior and attitudes. For example, research has found that the presence of a collegial environment in which teachers have time and are encouraged to interact with colleagues in subject departments is beneficial for effective teaching (see discussion in Darling-Hammond and Hudson, 1986:41-55).

Finally, a recent review by Hanushek (1986) of 147 studies that correlate educational system "inputs" such as school expenditures and teacher characteristics with student achievement "outputs" confirms the picture outlined above. Hanushek states (p. 1162) that "the results are startlingly consistent in finding no strong evidence that teacher-student ratios, teacher education, or teacher experience have an expected positive effect on student achievement." For example, of 106 studies that included measures of teacher education, 32 found positive correlations with student achievement, but only 6 of these were statistically significant, while 37 found negative correlations, and the remainder had unknown signs. The results were only marginally stronger for measures of teacher experience.

In contrast, Hanushek states that the results of studies of the overall impact of teachers, based on comparing the average performance of groups of students who differ only in their teachers, and similar studies of schools, are "unequivocal: teachers and schools differ dramatically in their effectiveness" (p. 1159). The problem is that the readily observable measures of teacher characteristics that have been available have not been found to correlate systematically with the various attributes or skills that distinguish effective from ineffective teaching.

Characteristics of Useful Teacher Qualifications Measures

Our charge includes a task to recommend measures of teacher qualifications, particularly for mathematics and science fields, that can be incorporated in models and statistics on teacher supply and demand. The absence of a research base makes

this a very difficult mandate. Yet there is a pressing need to have available nationally representative time series that will permit monitoring the state of the teaching force on the vital dimension of quality. In Part II, we outline a research agenda directed to providing a sounder footing for identifying meaningful measures of qualifications. In addition, drawing on our collective judgment, we offer a few recommendations for measures to include in ongoing data collection efforts by the Center for Education Statistics and possibly state education agencies. We list below a number of attributes that we believe generally characterize useful measures of teacher qualifications, acknowledging that such measures are not necessarily related to teacher effectiveness in the classroom.

(a) *The measures should be feasible and relatively inexpensive to collect.* Operationally, this probably means that the measures should be obtainable either from administrative record systems and/or from surveys using conventional questionnaires administered via mail or telephone. Measures that involve classroom observation, for example, probably would not be feasible in terms of cost.

(b) *The measures should be comparable across school systems and political jurisdictions.* In other words, the measures should not have one meaning in state A and a different meaning in state B. Hence, measures limited to certification are not satisfactory because of the great variation in certification requirements among the states.

(c) *Measures should be obtained for all components of teacher supply, with somewhat different sets of measures developed for experienced compared with newly trained teachers.* As we have discussed previously, major components of teacher supply include persons newly certified to teach; continuing teachers who were employed last year; and persons with teaching experience who did not teach last year for one or another reason. For experienced teachers, in contrast to those newly trained, it is desirable to develop measures not only of preservice preparation but also of continued commitment and learning.

(d) *The set of measures should be more extensive for middle and secondary school compared with elementary school teachers.* Different criteria clearly are relevant for assessing the competence of teachers who are responsible for all subjects at elementary levels than for those who teach only one or two subjects at more advanced levels. It is important to obtain broad measures for elementary school teachers of their qualifications for teaching mathematics and science--lifelong

attitudes toward these subjects are often established at this level (Eccles and Hoffman, 1985). But specific and much more detailed measures are needed for teachers of mathematics and science at the secondary level. Measures are also needed at the middle school level, although different organizational arrangements among the states pose a problem in this regard: about half the states assign teachers to specific subjects in these grades while the other half assign teachers to handle most subjects, including science and mathematics.

(e) *Most measures should be tracked at regular intervals to permit analysis of trends over time.* Too often, in the field of education statistics, important data have been collected only once or a few times, and hence it has not been possible to determine trends.

(f) *The measures should plausibly relate to student mastery of the curriculum and other desired outcomes of the educational system.* Despite the lack of knowledge about the relationship of such teacher characteristics as subject matter knowledge to student outcomes, the panel accepts as a working assumption that qualifications such as academic training in mathematics and science fields are important for the quality of teaching in those areas and hence should be monitored.

(g) *The measures should in most instances be amenable to federal and state education policy.* For example, a measure of subject matter preparation, such as laboratory science courses, is susceptible to policy response through changes in certification requirements.

Part II
Recommendations for Improved Data and Models

In this part, we first discuss a key issue in the implementation of research and development activities leading to improved models and data on teacher supply and demand: the appropriate role for our sponsors, the Center for Education Statistics and the National Science Foundation, and for other organizations such as state education agencies and research institutions in government and academia. The recommendations that follow are divided into two major sections: a section dealing with models and data on the quantity dimension and a section dealing with measures that may begin to shed light on the important dimension of quality.

IMPLEMENTATION OF RECOMMENDATIONS

The panel's recommendations involve two different types of activities:

(1) Improvements in current models and ongoing data series, and

(2) Model development and research.

In the *first category*, we make recommendations in areas in which existing knowledge seems to be sufficiently well-defined to permit specifying modest improvements in ongoing data series and current models for implementation by the Center for Education Statistics and corresponding units in state education agencies. A major function of the Center is clearly the collection and reporting of data relevant to the condition of education in the nation. The states also without exception support and have an interest in collection of data that describe the condition of education in their own juris-

dictions. The areas where we recommend near-term improvements in models and data series include disaggregation of teacher demand by geographic area and subject, better specification of the continuing teacher component of supply, enhancement of data for new teachers, and collection of data on selected measures of teacher qualifications.

We note that the Center for Education Statistics is currently planning the next round of data collection for several major surveys that include data on teacher characteristics and teacher supply and demand. Specifically, the Center has contracted with the Rand Corporation to redesign its surveys of Teacher Demand and Shortage, Public and Private School Teachers, and Public and Private School Administrators and to design a new, possibly longitudinal survey of attrition and labor market outcomes of the current teaching force. The current design calls for these surveys, collectively renamed the Staffing and Schooling Surveys, to comprise an integrated set of data collection instruments administered more frequently to a larger sample of schools than was the case for prior survey efforts (Haggstrom, Darling-Hammond, and Grissmer, 1986).

The Center has also contracted with the National Opinion Research Center to design and field the National Education Longitudinal Study of 1988 (called NELS:88), which is the latest in a series of panel studies that provide important information for understanding many aspects of the educational system, including the impact of teachers on student outcomes. NELS:88 will obtain information from a sample of 8th graders, their parents, teachers, and schools and reinterview the sample in the 10th and 12th grades.

We should acknowledge the concerns that have been raised about the plans of the Center for Education Statistics to proceed at this time to redesign its major data collection programs. (These concerns are directed primarily to the Staffing and Schooling Surveys and related efforts to restructure the Center's Common Core of Data system for collecting basic information on precollege education from state and local education agencies.) The recent report of the Committee on National Statistics' Panel to Evaluate the National Center for Education Statistics (Levine, 1986) seriously questions the capabilities and resources available to the Center. The report strongly recommends that the Center focus on improving its current data collection activities before proceeding to redesign of major systems. The Council of Chief State School Officers' Committee on Evaluation and Information Systems (CEIS) has expressed similar reservations, specifically about implementing the Staffing and Schooling Surveys.

We believe that it is important that the Center put in place data collection systems that will regularly obtain data on teachers as well as the other components of our educational system. Our recommendations make specific suggestions for the kinds of data that are needed. However, we certainly agree with the view that major redesign activities should proceed with care and with primary consideration given to issues of feasibility and the capability within the Center for Education Statistics to carry out a high-quality effort. Since cooperation of the CEIS is essential for successful implementation of a new data system, our recommendations for the Center's teacher surveys should be interpreted as consequent upon an agreement by the CEIS that it is feasible to proceed with this major system redesign.

Finally, with regard to ongoing data collection and incremental improvements to current models, there is an important issue relating to the division of labor between the Center for Education Statistics and the state education agencies. (A similar issue also arises in some states in which major school systems in large metropolitan areas are carrying out their own work on teacher supply and demand.) Our recommendations support disaggregation of current models to a much greater degree than is done in the existing Center for Education Statistics model. While not prepared to make a definitive recommendation in this interim report regarding the role of the Center in developing disaggregated models, we suggest that work should go forward on model disaggregation both in the Center for Education Statistics and in state agencies. We urge cooperative efforts between the Center and state education agencies.

In particular, we encourage the Center to work actively with the states on technical aspects of model development and enhancement. We note that existing legislation, P. L. 93-380, calls for the Center "to assist state and local education agencies in improving and automating their statistical and data collection systems." We urge that the U.S. Department of Education seek and the Congress appropriate sufficient funds to permit the Center to undertake cooperative programs with states and school districts to develop improved data and analysis systems. An important component of such programs should be work on developing and improving models of teacher supply and demand.

The *second category* of the panel's recommendations concerns areas in which current knowledge is not sufficiently well-developed to specify a mandate for the Center for Education Statistics or statistical units in state education agencies that relates to clear-cut data requirements associated with well-defined models. These areas include the impact of

behavioral factors on longer-term changes in teacher demand, the effect of a variety of behavioral factors on the different components of teacher supply, and the relationship of measurable teacher qualifications to teaching effectiveness. Here we call for research and model development and strongly urge that it be a decentralized, widespread activity.

The National Science Foundation is clearly one organization that should play a role in sponsoring such research activities. Other organizations include the Center for Research in the U.S. Department of Education (the former National Institute of Education) and foundations concerned with education. The Center for Education Statistics and interested state education agencies could also sponsor useful research. We encourage a wide range of organizations and research analysts to pursue the research agenda outlined in this report and urge collaborative efforts with researchers and agencies working on questions of supply and demand in other fields. We believe it is important that investigators with a variety of backgrounds, perspectives, organizational affiliations, and approaches devote their attention to the issues in this area.

We argue throughout the report that research is needed to permit development of improved models of teacher labor markets, particularly on the supply side, that are useful for policy. This argument does not mean that we are necessarily sanguine that research will lead to greatly improved models in the near term. Indeed, given the absence of good models of labor supply and demand generally, the likelihood that fully satisfactory models can be developed for teachers may be small. Nonetheless, research is a necessary precondition for progress toward developing more useful models. Moreover, the understanding obtained from research about teacher labor markets and the further insights gained from the process of endeavoring to express research results in models should prove very helpful in education planning and evaluation of policy alternatives.

MODELING TEACHER SUPPLY AND DEMAND

The panel's recommendations for improving models of teacher supply and demand are grouped into two major categories, one dealing with the demand side of teacher labor markets and one dealing with the supply side. Within these major categories, we distinguish between recommendations relating to areas in which ongoing models with their explicit data requirements are appropriate and areas in which model development and research of a fundamental nature seem more

appropriate. The key issue of quality measurement is discussed in a separate section.

Teacher Demand

Improvements in Current Models and Data Series

We believe that the most important set of improvements needed in current teacher demand models and supporting data is to introduce appropriate levels of disaggregation into projections of the key components of these models--enrollments and pupil-teacher ratios. Disaggregation is needed both in terms of geographic areas and in terms of subjects. We are referring, in this context, to projections based on the relatively straightforward extrapolation methods of current models which have proven to be reasonably reliable for short-term periods of up to five years (or sometimes longer).

As we noted in Part I, labor markets for elementary and secondary school teachers in the United States largely operate as regional, state, and even substate markets that differ widely in both supply and demand characteristics. Moreover, states and school districts are largely responsible for setting policies and practices--ranging from certification requirements to the proportion of budgets devoted to science equipment--that influence teacher supply and demand. Hence, we believe that disaggregation by geographic area is necessary to permit demand models to provide projections that are useful for policy.

With regard to state-level projections, we note that there are a number of available data sources that could support disaggregation of the Center for Education Statistics demand model. Currently, the Center obtains grade-specific enrollment data from the states in the Center's Common Core of Data program that permit calculation of grade-to-grade retention rates by state. The Center also has state data on pupil-teacher ratios. Furthermore, we understand that all the states prepare their own projections of enrollment using some variant of the Center's method. We are not prepared, at this stage, to recommend the specific manner in which state models should be further disaggregated by substate market. We do recommend that states consider the appropriate level of disaggregation in light of both available data and the specific characteristics of the school districts in their jurisdiction.

Important policy questions in precollege education relate to the supply-demand balance not only for teachers in specific areas but also for teachers in specific subjects, such as mathematics and science. Answers to these questions require

demand projections by broad subject for high school grades, at a minimum, and, in some states, for middle school grades.

We recognize that adding subject disaggregation to demand projections, even defining subjects very broadly, is not an easy task. The Center for Education Statistics has only infrequently obtained data on course offerings. A few large states, including California, Florida, and New York, have (or will shortly have) data on subject enrollments that could support disaggregated projections. However, many states do not have these data.

We urge, however, that the Center and the states devote efforts to developing teacher demand projections that include subject disaggregation, specifically for broad categories of science subjects and mathematics. With regard to the grades for which subject-specific projections are needed, we note that disaggregation by subject would be useful for middle school in addition to high school grades in those states--about half--which organize classrooms for middle school grades by subject and train and certify middle school teachers accordingly.

Recommendation 1. To be useful for addressing policy questions about the demand for teachers, specifically teachers of mathematics and science, models should incorporate appropriate levels of disaggregation by geographic area and subject field.

We recommend that the key components of current models of teacher demand--enrollment projections and pupil-teacher ratios--be disaggregated by state and important substate teacher labor markets. For middle and secondary grades, these projections should be further disaggregated by broad subject categories.

Model Development and Research

The recommendations in this section pertain to research that would permit the development of more sophisticated models of teacher demand that incorporate important behavioral components. Given that current models handle demand much better than supply, we believe that research on teacher demand is less important in overall priority than research on supply or than improvements in current demand and supply models. However, the utility of demand models for addressing important policy questions, particularly for science and mathematics education over the long term, would be greatly enhanced by the development of more dynamic, behaviorally responsive models.

The deterministic methods employed in current teacher demand models, specifically the cohort-survival methodology used to project enrollments, have reasonably good track records, particularly for elementary grades. However, for longer-term projections extending for more than about five years, particularly at the high school level, and for specific subjects, the projections become increasingly less reliable due to the impact of changes in the behavior of students, parents, and school systems. We have identified several kinds of behavioral responses that we believe are particularly important to understand in order to develop more useful models of teacher demand. We discuss them in order of their priority in terms of improved demand models for science and mathematics teachers. Our assignments of priority are based on an assessment of the relative importance of each topic for teacher demand projections and also on an assessment of the current state of knowledge about each topic and hence the relative gains that could be expected from research.

First, research on the determinants of course selection by students is critical to the development of useful projections for broad subject categories, including science and mathematics, at the high school (and possibly middle school) level. This is also an area about which we know very little. Many factors can influence students' choice of courses, including high school graduation requirements, college entrance requirements, government (including federal and state) support for science and mathematics education that motivates schools to encourage enrollment in these subjects, and fashions or tastes on the part of students and their parents and peers for certain subjects.

Given that most current models focus on public school demand (the Center for Education Statistics model develops separate public and private school projections), another important area for research concerns the determinants of parental and student preferences for private and public schooling. Nationwide, private elementary and secondary school enrollment was only 11 percent of the total in 1980, but was as high as 17 to 19 percent in some states and undoubtedly even higher in some school districts (see Part III:Table 2). In these areas, changing preferences for private school enrollment, a topic about which almost nothing is known, can importantly affect public school demand. Particularly in today's educational climate, when private schools are perceived by some parents to offer a more attractive educational environment than public schools, research into the factors that influence the choice of type of school is needed.

Another area for research concerns the determinants of pupil-teacher ratios. In almost all demand models, pupil-

teacher ratios are estimated in a relatively arbitrary way. But we suspect that certain types of dynamics in teacher markets (e.g., declining enrollments, increases in school funding, or rising numbers of tenured teachers) will tend to be associated with declining pupil-teacher ratios, while other conditions (e.g., escalating enrollments, failure of a school bond issue) will tend to be associated with rising pupil-teacher ratios. Since that ratio is so critical to an assessment of teacher demand, our recommendation is for research on its determinants and for the development of methods that would permit obtaining confidence bounds for estimates.

We note in this regard that research conducted to date on pupil-teacher ratios indicates that short-term adjustments differ from longer-term adjustments (e.g., see Cavin, Murnane, and Brown, 1984). For example, a shortage situation may result in a relatively sharp increase in pupil-teacher ratios until the school system has had time to implement various kinds of responses. These can include measures designed to increase supply, such as active recruitment over a broader geographic area and salary adjustments, and measures designed to moderate demand such as greater reliance on teacher aides and computers. Consequently, it is important to use longitudinal data to carry out meaningful research on this topic.

Another type of response that affects demand projections at the high school level is the dropout rate. We know a good deal from previous research about why students drop out of school. Work is needed, however, on changes in dropout rates that can be expected in response to a variety of social, economic, and educational changes. For example, the changing ethnic composition of the school-age population in many areas of the country may dramatically affect dropout rates in those areas. Increased high school graduation requirements may increase dropout rates as a side effect of raising educational levels for those who stay in school.

Finally, research is needed on the interrelationships of changes in demand for courses and changes in pupil-teacher ratios. It is important to understand these relationships in order to derive the numbers needed for science and mathematics teacher demand models, namely full-time-equivalent teachers.

Recommendation 2. Research on behavioral factors that influence the demand for teachers, particularly teachers of mathematics and science in the higher grades, is needed to permit the development of improved models that will support longer-term projections.

We recommend that research pertinent to teacher demand be conducted--in order of priority--on:

(a) The behavioral determinants of student selection of science and mathematics courses at the secondary school level, including the effects of changes in graduation requirements and of student preferences for subject areas;

(b) The behavioral determinants of parental and student preferences for private and public schooling;

(c) The determinants of pupil-teacher ratios, especially the adjustment lags in those ratios as enrollments change and/or the teaching force changes in demographic composition;

(d) The impact on high school dropout rates of such factors as changes in graduation requirements, labor market conditions, and the demographic composition and family circumstances of the school-age population; and

(e) The relationship of changes in demand for courses to changes in pupil-teacher ratios and the resulting derived demand for full-time-equivalent teachers of mathematics and science at the secondary school level.

Teacher Supply

Improvements in Current Models and Data Series

We believe that current models are particularly weak on the supply side and that extensive research is required to support the development of improved teacher supply projections. Even more than on the demand side, it is imperative that supply models include behavioral components. Nonetheless, there are several improvements that can usefully be made in current models and data, specifically in projecting the supply of continuing teachers and in obtaining better data on new supply.

Continuing teachers represent by far the largest component of teacher supply in any year (typically 90 percent or more in the states we have examined--see Part III). Most current models include this component on the demand side (although, except for layoffs and firings, the choice of current teachers to stay or leave is largely a supply side phenomenon) and use a single constant attrition rate for projection. Moreover, the single rate used by the Center for

Education Statistics for its intermediate series of projections is more than 15 years out of date.

Some states have greatly improved their projections of continuing teachers by using attrition rates that are differentiated by age or teaching experience and by subject field. We strongly support the use of timely, disaggregated data to determine the proportions of teachers who can be expected to stay or leave. We believe it is important that the Center for Education Statistics surveys of public and private school administrators and teachers regularly obtain data on teacher retention and attrition that would be useful for the Center's model, although it may be that these surveys cannot provide highly disaggregated data. We note that there are tricky problems involved in using information on retention to project continuing teachers depending on the level of aggregation of the model. For example, teachers who leave one school may simply transfer to another; models for higher levels of aggregation such as a state or the nation need to subtract out this kind of mobility. In contrast, models for subjects such as mathematics need to be sure not to count as continuing teachers those who were teaching some other subject last year.

To the extent that available data permit, we encourage states that have not developed disaggregated models of teacher retention to follow the lead of states that have done so. We also encourage the Center for Education Statistics to obtain data on stayers and leavers from those states that have information. Analysis of state data could help the Center update and improve its projections of the continuing component of teacher supply.

Recommendation 3. Timely, detailed data are needed to improve projections of the proportions of teachers who can be expected to stay versus those expected to leave (defined appropriately for the level of aggregation of the model).

We recommend that the Center for Education Statistics surveys of schools and teachers regularly obtain data on teacher retention and attrition. The Center should also obtain and analyze existing data from states, where available, on retention and attrition rates by age or experience and subject field. Such data are essential to improve projections of continuing teachers--by far the largest component of teacher supply.

The other major component of teacher supply we have defined as "new entrants," who comprise a heterogeneous collection of individuals who come into teaching from a number of different backgrounds. In any one year, persons who are

newly hired by school districts from the new entrant supply make up a relatively small fraction of the total number of teachers (typically 10 percent or less), but changes in their characteristics over time will change the makeup of the teaching force. We believe it is important that the Center for Education Statistics teacher surveys oversample new hires relative to continuing teachers in order to provide much more reliable information about this critical component of teacher supply. The cost, in terms of smaller sample sizes of continuing teachers, seems small, since attrition rates for these teachers are relatively low in any one year.

Recommendation 4. Newly hired teachers come from many sources, including new college graduates, former teachers, and teachers who change residence or subject field. It is important to have detailed information on the components of new hires.

To provide needed data on new hires, we recommend that the Center for Education Statistics stratify the sample for its teacher surveys into teachers who are new and those who were teaching last year. For a given overall sample size, the sampling ratio for new hires should be higher than the ratio for continuing teachers.

As we discussed in Part I, employment cannot be equated with supply (or demand) in the teacher market. School districts generally want to have a large number of applicants for each opening, not just a sufficient number to meet their immediate needs. We believe that information on the applicant pool is important for understanding sources of supply and for comparing the characteristics of supply properly defined with the characteristics of actual new hires. We realize that the definition of an applicant is not straightforward and that there are problems in constructing an unduplicated sampling frame for surveys of applicants. In at least some school systems, we understand that a meaningful operational definition would be to consider as applicants those persons who filled out an application form and supplied a transcript. We urge investigation by the Center for Education Statistics and the states into the feasibility of obtaining information on applicants.

Recommendation 5. Data on the pool of applicants for teaching positions would be valuable for understanding new teacher supply, particularly from sources other than new graduates, and to permit comparisons of potential supply and actual hires.

We recommend that the Center for Education Statistics explore with the states possible ways of systematically obtaining data on applicants for teaching positions.

Model Development and Research

Teacher supply represents the least-developed component of current models and has benefited the least from in-depth research. Given the absence of even a reasonably well-developed base of knowledge, many of the panel's recommendations in this section are general in nature. They represent the thinking of the panel midway through its planned study.

The activities planned for the second phase of the panel's work are designed to provide information that will make it possible for us to develop more specific recommendations in this area. We will be conducting case studies of how teaching positions in mathematics and science are filled in a sample set of school districts. This activity should give us important insights into factors related to teacher supply and demand, into understanding how teacher quality can best be measured, and, most important, into understanding how school districts adjust teacher quality to market conditions. We will also review data sources that can support meaningful research on teacher supply at both the national and state levels. We believe that state data, such as administrative files on certifications and teaching personnel, represent a particularly rich resource for research that to date has been largely untapped. Finally, we will consider important methodological issues involved in the development of useful models based on research results. For example, one issue concerns tradeoffs in the choice of variables to include within a model, that is, to be generated by one or more relationships in the model, versus variables to be treated as outside or supplied to the model.

The recommendations for research on teacher supply are clearly pertinent for the research program of the National Science Foundation, as are the recommendations for research on teacher demand. They are also directed to other agencies and institutions involved in education research, including the Center for Education Statistics and corresponding units in state education agencies. We strongly encourage organizations in all sectors and at all levels of government concerned with precollege teaching to support the kinds of research that we believe are needed.

An implication of the recommendations on teacher supply is that current models should forego efforts to project supply from sources other than continuing teachers who taught last

year. It goes without saying that the Center and state agencies should maintain and enhance descriptive time-series statistics that are pertinent to the supply of new entrants, such as the sources of new teacher hires, numbers and characteristics of graduates from teacher training programs, etc. However, we believe that no useful purpose is to be served at this time by preparing "projections" of new teacher supply from the available data, given the current severe limitations of knowledge and methodology.

Turning to the research that we believe is required to improve understanding of teacher labor markets, we have emphasized throughout this report the importance of incorporating behavioral responses into teacher supply and demand models, particularly on the supply side. Supply behavior involves complex individual choices regarding occupation (teaching or some other field) and, for those who choose teaching, geographic location and specialization by school type (public or private), level, and subject field. Many factors influence these choices. They include personal attributes, including demographic characteristics, such as age and sex; labor force and training characteristics, such as educational background and skill level; career and salary expectations and tastes for market versus home labor; and family characteristics, such as family type and size and labor force characteristics of other family members. They also include attributes of schools and school systems, including salaries, working conditions, certification requirements, retirement provisions, and geographic location. Finally, they include comparable attributes of other types of employers and jobs along with general social and economic conditions.

Recently, many states and school systems have implemented new or modified policies and programs with regard to salary scales for teachers, methods of determining salary increases (e.g., merit pay plans), retirement provisions, certification requirements, and support for training or retraining in particular subjects such as mathematics and science. These policy initiatives afford opportunities for studying the supply response to variations in important factors such as salary levels. (We note that these policy changes are not independent of teacher supply and, indeed, in large part represent explicit responses to perceived teacher shortages. This poses methodological problems for research, but no more so than in other occupational fields.)

As a useful methodology for developing dynamic, behavioral models that can answer "what if" questions for policy purposes, we suggest the development and use of microsimulation modeling techniques. This is in part because we judge that teacher supply may be better represented by transition matrices from one status to another than by more conven-

tional analytic techniques, and in part because simulation methods are especially useful for examining the consequences of alternative public policy changes. Microsimulation models operate on large samples of individual-level microdata, which are manipulated to observe the response, both in aggregate terms and for subgroups of the population, to specified policy changes. (For example, a model that is currently used for welfare and tax program analysis simulates proposed changes in the rules for programs such as food stamps. The model estimates program costs and case loads under each alternative scenario, typically using the Current Population Survey household and person microrecords; see Beebout, 1984, 1986.)

It is important to bear in mind that microsimulation models are only as good as the underlying behavioral relationships that they incorporate. Indeed, microsimulation models without such behavioral components can be just as mechanical and deterministic as other kinds of models. Moreover, microsimulation models may not work as well for teacher labor markets as for other kinds of applications. The potential difficulty, technically referred to as a "dynamic sample selection" problem, is that the pool of available teachers changes across the years. To the extent that the changes arise for unobservable reasons and hence cannot be statistically controlled in the model, microsimulation techniques may have serious problems. Nevertheless, microsimulation techniques offer great flexibility for evaluating alternative policy scenarios. They seem very useful as a tool for helping federal and state education agency staff think in more sophisticated ways about supply and demand through working with the model and analyzing the results of various scenarios. Hence, we suggest that microsimulation techniques be investigated for their utility for modeling teacher supply responses to alternative policies and market conditions.

Turning to needed research, we have identified several kinds of behavioral responses that we believe are particularly important to understand in order to improve knowledge of teacher supply and ultimately to develop more useful models. We discuss them in order of the priority we believe should be attached to each in terms of the potential to develop improved understanding and models of the supply of science and mathematics teachers.

A critical failing of most current models of teacher supply is the failure to recognize that new supply, i.e., supply other than continuing teachers, includes many different kinds of persons whose probabilities of entering into the supply pool vary widely. Research is urgently needed on the behavioral determinants of the major components of new entrants to teaching. The relationships that need research include the determinants of the supply of persons newly certified to

teach; the relationship between the number of people newly certified to teach and the number who seek teaching positions; the relationship between those applicants who are unsuccessful and the likelihood of their applying for teaching positions in future years; the relationship between those currently on leave from teaching positions (for reasons of maternity, health, etc.) and the likelihood and time path of their return to teaching; the relationship between those teachers who resigned from teaching positions and the likelihood and time path of their possible reentry into the teaching supply pool; the relationship between people certified to teach but on different career paths and the likelihood of their entry into the teaching supply pool; and the relationship between college graduates generally and the likelihood of their being attracted to teaching under alternative programs of certification and hiring (such as emergency certification or apprenticeship programs). Current supply and demand models do not handle any of these major components of teacher supply in a satisfactory manner.

Another neglected aspect of teacher supply has to do with the migration or movement of teachers. In this context, we have in mind migration within a school but among levels and subjects or disciplines, within a school district but among schools, within a state but among districts, and within the country but among states. Current models handle this topic poorly. For example, most state models do not include out-of-state sources of supply even though in some states in-migrating teachers represent a large proportion of new hires each year. As we have noted before, it is important to define migration appropriately in terms of the model under consideration--for a state model, for example, migration among schools within the state does not affect supply, although interstate migration does.

Finally, there is a need for research on the behavioral determinants of the decision by teachers to stay or leave their subject, school, school district, or state, or to leave teaching entirely either on a temporary or long-term basis (including the decision to retire). We note that some states have developed useful data and analysis on attrition behavior for different types of teachers, such as those in different age cohorts or subject fields. Much more needs to be done using such data to fully develop needed knowledge of the supply behavior of the current teaching force.

Recommendation 6. Research on behavioral factors that influence the supply of teachers is essential to improve understanding of teacher labor markets and to support the development of useful and realistic models.

We recommend that research pertinent to teacher supply be conducted--in order of priority--on:

(a) The behavioral determinants of the major components of new entrants, including new graduates, former teachers, and persons hired on emergency certification;

(b) The forces underlying teacher migration (among states, school districts, schools, and subjects); and

(c) The linkage between the decision of teachers to stay or leave and behavioral and environmental factors related to that choice. The research should stratify teachers by subject field and other characteristics.

MEASURING TEACHER QUALIFICATIONS

We have stressed that satisfactory models of supply and demand for science and mathematics teachers must be specific regarding teacher qualifications. There is also a great need for nationally comparable time series on the qualifications of major components of teacher supply, including continuing teachers and the various components of new entrants. This is especially true for those teaching mathematics and science.

Unfortunately, review of the literature provides virtually no support for selecting variables to use as measures of qualifications, in the sense that the literature does not find strong relationships between teacher characteristics and educational outcomes. Some panel members are pessimistic that additional research on outcomes will yield any better results, even if the methodological problems plaguing previous studies are overcome. Other members are more optimistic that additional research will yield useful insights, particularly in fields such as science and mathematics.

Despite the absence of a research base for selecting measures of qualifications, there is no doubt that many participants in the educational debate will use such data as are available, independently of their probable validity or relevance, to draw conclusions about the quality of teachers. If Scholastic Aptitude Test (SAT) scores for entering college freshmen or newly certified teachers in specific states are available, these data will be used despite the problems they pose with regard to lack of representativeness and the fact that SAT scores capture at best only one dimension of qualifications.

In this context, the project sponsors asked that the panel draw on the knowledge and experience of its members, many

of whom have extensive experience in precollege science and mathematics education, to recommend a reasonable set of measures of teacher qualifications. The purpose of the recommendations would be to encourage the development of nationally representative series that would provide some sense of changes over time in qualifications of the teaching force and would provide a useful data base for research. (We note in this regard that the NSF-sponsored 1985 survey of mathematics and science teachers by Research Triangle Institute will provide valuable information on the current teaching force in these subjects. However, only limited time comparisons will be possible with earlier surveys.) The panel has done its best to respond to this inherently difficult mandate.

The recommendations in this section are divided into those that the panel believes warrant research and analysis and those that we believe should be implemented by the Center for Education Statistics in its ongoing survey programs. We suggest that recommendations for ongoing data collection also be considered for implementation by state education agencies, using a combination of administrative records and surveys as appropriate and feasible. The information we obtain in the second phase of our study from case studies and review of state data bases may enable us to make more specific recommendations with regard to useful measures of teacher qualifications for states to collect.

In contrast to the organization of the preceding section, here we present our recommendations for needed research first. This organization is based on the fact, as we just discussed, that there is no adequate body of knowledge from which to make definitive recommendations regarding ongoing data collection. Following the research recommendations, we offer some suggestions that we think are reasonable about the kinds of data collection that is needed.

Research

We have emphasized the role played by adjustments in quality in the operation of teacher labor markets. We know that under some circumstances, a change in market conditions, such as an increase in demand, will result in a decreased level of qualifications, but we need to know more precisely how these market adjustments work. We believe that research on this topic is vital and would offer the opportunity to obtain insightful results that will be of use for supply and demand models generally, not just those pertaining to teachers.

Recommendation 7. **Short-term adjustments between teacher supply and demand frequently occur through redefining the acceptable level of teacher qualifications. We need to know more about how these adjustments take place.**

We recommend that research be undertaken on the linkage between the qualifications of the teaching force and changing market conditions.

In addition to research on quality adjustments in teacher labor markets, we believe it is important to conduct further research linking characteristics of teachers of science and mathematics to student outcomes in those subjects. Such research is needed to provide the knowledge base that can guide the selection of indicator variables to use in models and in descriptive profiles of the characteristics of the teaching force over time.

We noted in Part I that existing research is only of limited value in supporting the selection of indicators. Indeed, it is striking that a large number of variables describing teachers and their training have been found not to be related to student test scores or test score gains. The panel is certainly not of the view that the failures of past research should be regarded as definitive. As we discussed earlier, there are major limitations to the research carried out to date on the question. One important limitation is that the measures of teacher effectiveness have typically been student scores on multiple choice tests--tests that at best measure lower-order skills such as memorization in contrast to higher-order skills such as the ability to reason well. A second major limitation of previous research is that the teacher attributes included in most studies have been restricted to the information in teacher personnel folders. Such information--for example, whether the teacher has a master's degree--probably does not capture the variation in training and skills that different teachers bring to the job.

One teacher attribute that deserves renewed attention is subject matter knowledge, particularly for teachers of science and mathematics. The panel believes that a teacher's subject matter knowledge, as measured by a score on a test designed by a group of subject matter experts, is a necessary (but not sufficient) condition for effective teaching, especially in the areas of mathematics and science. Although that proposition may seem self-evident to some, we argue that careful research is needed in this area.

First, it remains unknown whether a group of subject matter experts can design a test that is a good measure of the subject matter knowledge that teachers ought to have. It is possible that members of such a panel of experts would

disagree on what constitutes core knowledge, or would agree only if the test were of prohibitive length. The process of obtaining agreement on the composition of a test of acceptable length might involve compromises that would make the test only a poor measure of a teacher's knowledge.

Second, the relationship between teachers' scores on a test of subject matter knowledge and their effectiveness is not necessarily simple or straightforward. While it seems plausible that effective teaching requires a threshold level of knowledge, particularly in mathematics and science, the relationship between scores that are above the threshold and teaching effectiveness may not be linear. Moreover, it is plausible that there is a negative relationship between subject matter knowledge and other attributes, such as interpersonal and pedagogical skills, that contribute to effective teaching. The issue of substantive teacher knowledge is important and needs to be carefully examined.

Research on student outcomes that properly addresses the rich complex of relevant factors, including characteristics of individual students, their schools, teachers, parents, and peers, requires correspondingly rich data bases. In the past 15 years the Center for Education Statistics has sponsored several nationally representative longitudinal surveys of students, including the National Longitudinal Survey of the High School Class of 1972 (NLS 72) and High School and Beyond (HS&B). These surveys have a broad focus on life course outcomes of students, such as the decision to go to college and occupational choices, in addition to outcomes measured in terms of subject knowledge acquired in school. (The National Assessment of Educational Progress and the International Educational Assessments are other sources of data that are specifically focused on knowledge outcomes.) The Center for Education Statistics is currently sponsoring a new panel, the National Education Longitudinal Study of 1988, that will have several advantages over its predecessors for research on outcomes in science and mathematics. NELS:88 will follow a sample of students from the 8th grade, whereas NLS 72 initially sampled high school seniors and HS&B high school sophomores and seniors. NELS:88 will also focus specifically on the 8th graders' teachers in four subjects--science, mathematics, English, and social studies.

We strongly support the basic goals and design of NELS:88 and urge that the survey obtain a rich set of information on the students' teachers together with appropriate measures of student outcomes. With regard to science and mathematics teachers in particular, measures should be obtained that pertain to their academic preservice preparation in science and mathematics subjects, their general intellectual ability, their continued in-service training and commitment, and teaching

styles and attitudes that previous research has indicated may be important for outcomes. (We discuss some specific measures for inclusion in ongoing data collection in the next section.) It is also important that NELS:88 obtain detailed information on the students' schools and school districts, as previous research suggests that the school environment is a vitally important mediating factor in outcomes.

With regard to the method of data collection, the panel strongly urges that NELS:88 (and other surveys directed to educational outcomes) obtain data on teachers from transcripts and other administrative records whenever appropriate, instead of from survey questions. Transcript records are a source of hard information on a number of measures of academic preservice preparation, continuing education, and general intellectual ability. Relevant information that can be abstracted from transcript records includes:

- Postsecondary degrees obtained, dates, and institutions;
- Major(s) for each degree;
- Undergraduate grade point averages, overall and by field;
- Courses taken--credit hours, subject, whether in the liberal arts or education schools, level (introductory, advanced, undergraduate, graduate), etc.;
- SAT or ACT scores; and
- Information on high school background.

In some school systems, we understand that transcript information is retained in personnel files and hence is relatively accessible. In other systems, it will be necessary to obtain transcripts from higher education institutions. Some proportion of teachers will deny the request; however, we suspect that nonresponse will pose less of a problem than the combination of nonresponse and misresponse to questionnaire items on educational background. These items are subject to recall bias, particularly for teachers many years out of college, as well as to a bias toward reporting more extensive training, for example, more mathematics courses taken, than actually occurred (Fetters, Stowe, and Owings, 1984).

Other administrative records could also provide useful information on teacher qualifications. For example, a common and growing administrative practice is for school principals to evaluate teachers. Several studies have found that these evaluations correlate highly with estimates of teacher

effectiveness (see Hanushek, 1986:1165). We note that the use of administrative records has been growing in federal statistical agency programs as a means of reducing respondent burden and obtaining better quality data, and the Center for Education Statistics has had previous experience in working with transcript records.

Recommendation 8. Further research on the relationship of measurable characteristics of teachers of mathematics and science to educational outcomes is needed to identify teacher characteristics that should be regularly collected in surveys in order to monitor the qualifications of the teaching force.

We recommend that further research be conducted on the relationship of measurable characteristics of teachers of mathematics and science to educational outcomes of students in these fields. In order to permit comprehensive and methodologically appropriate research on this issue, the National Education Longitudinal Study of 1988 should include appropriate measures of student outcomes together with a rich set of teacher characteristics and characteristics of schools and districts. Teacher characteristics should include measures of academic training, in-service training, general intellectual ability, and teaching styles and attitudes. To the extent possible, measures should be obtained through administrative records, such as transcripts, rather than through survey questions.

We noted previously the importance of research linking measures of subject matter knowledge of teachers of mathematics and science to their effectiveness in helping students learn. However, it is unlikely that such research would provide a basis for indicators of teacher quality that could be used in supply and demand models or descriptive profiles. The reason is that scores on tests of subject matter knowledge would not be readily available for all teachers, given the costs involved--both monetary and political--in large-scale testing. Hence, the panel has considered a strategy that could identify proxy measures.

The strategy would be to design research that directly tests the subject knowledge of samples of teachers and then links the test results to other teacher characteristics that are more readily obtained, such as mathematics and science courses taken. The analysis would provide regression coefficients that could be used as weights to indicate the strength of association between each characteristic and the test results. To the extent that the research shows strong relationships, the results would provide a guide to identifying readily measurable teacher characteristics that should be col-

lected on a regular basis for monitoring the qualifications of the science and mathematics teaching force. The applicant pool could possibly serve as the source for samples to support research linking direct measures of subject knowledge to other characteristics. Applicants could reasonably be asked to take tests and to provide transcripts on their educational background.

However, there are a number of concerns that have been raised about the merits of proceeding with the approach outlined above. First, while there is no question that teachers' subject matter knowledge is important, there is a serious question about the ability of a panel of experts to devise a test of reasonable length that accurately measures this knowledge. If the test does not measure subject matter knowledge well, variables that predict teachers' scores on this test will not be reliable indicators of teacher quality. Such variables may nonetheless find their way into hiring guidelines and certification requirements. Such use is appropriate only if a teacher's score on a test does in fact predict the teacher's effectiveness.

Second, the relationship between teachers' scores on a test of subject matter knowledge and their teaching effectiveness may not be linear. It is quite likely that there is a threshold relationship. Teachers with scores below a certain level may be significantly less effective than teachers with scores above that level; there may be no difference in the effectiveness of teachers with different scores above the threshold level. If this is the case, then analysis of the relationships between subject matter knowledge and other measures of qualifications should be formulated to explore the dimensions of teacher training that influence which teachers have scores above and which teachers have scores below the threshold. This cannot be done unless the research proposed by the panel in recommendation (8) verifies that there is a threshold score and determines what that score is. In the absence of such research, it is highly likely that efforts to link teachers' scores on a test of subject matter knowledge and variables describing their training will search for linear relationships. Some variables that are linearly related to teachers' test scores may not be reliable predictors of which teachers score above the threshold and which do not. Such variables should not be used as indicators of teacher quality in supply and demand models, in hiring qualifications, or in certification requirements. Said differently, there is a concern that, unless research is carried out first that verifies that teachers' scores on a test of subject matter knowledge are related to teaching effectiveness and documents the nature of this relationship, the strategy suggested to relate subject matter knowledge to other meas-

ures of qualifications will not be useful and could be extremely misleading.

The panel is in agreement that subject matter competence of teachers of mathematics and science is important and that it would be useful to develop proxy measures of subject knowledge that could be collected regularly in nationally representative data series. The panel has not reached agreement on the merits of the arguments for and against an immediate start on research to identify such proxy measures. We intend to give fuller consideration to the issues on both sides of this important question in the second phase of the project.

Ongoing Data Collection

As discussed throughout our report, there is a great need for nationally representative time series on teacher supply. With regard specifically to measures of qualifications, the panel believes that relevant data should be collected on a regular basis for the major components of teacher supply, including continuing teachers and the major categories of new entrants, as we have defined them. We previously noted the inability of extant research to support choice of qualifications measures and indicated that, given the need to initiate time series, we had identified a list of possibly useful measures using our collective judgment. The research outlined in the previous section is urgently needed to permit refinement and modification of the measures that we suggest as appropriate.

Measures of Academic Preparation and Ability

The panel suggests that measures of academic preservice preparation and of general intellectual ability be obtained on a regular basis to permit monitoring the characteristics of the teaching force in mathematics and science. These measures are important to collect in any case, because they provide information on factors that are susceptible to policy initiatives by state and federal education agencies.

By measures of academic preservice preparation we mean such measures as college major and number of courses in the subject field. By measures of general intellectual ability, we mean such measures as grade point averages and SAT or American College Test (ACT) scores. Over 80 percent of college graduates have taken either the SAT or ACT. While recognizing problems in interpretation of scores on these tests, the panel believes that they provide a useful indicator

of overall ability, specifically of verbal ability, which has been shown to relate to student outcomes (see Part I). Measures based on SAT or ACT scores should be expressed in terms of percentage above a reasonable cutoff or possibly in terms of distributions rather than in terms of average scores, which tend to be unstable.

We strongly urge that the Center for Education Statistics surveys of teachers obtain data on academic preparation and ability through transcript records rather than questionnaire items. The same reasoning that we offered for NELS:88 applies here. Should the Center determine that it is feasible to obtain information on applicants, transcripts should be obtained for this group as well. Indeed, it is particularly important to obtain transcript information on academic preparation and ability regularly for applicants and new hires to track changes in new teacher supply. The information can be obtained on a less frequent basis for experienced teachers, given the relatively low turnover in the current teaching force.

With regard to specific measures of qualifications for teachers of mathematics and science that can be abstracted from transcripts, we suggest the following as candidates:

- For middle and secondary school levels:

  (1) Whether majored in subject field in college (i.e., the subject being taught);

  (2) Undergraduate grade point average in last two years of college;

  (3) Undergraduate grade point average in subject field;

  (4) SAT/ACT score;

  (5) Number of courses in subject field; and

  (6) Field-specific indicators of advanced training; for example, college courses in mathematics that had calculus as a prerequisite; chemistry courses that had physical chemistry as a prerequisite; physics courses that had sophomore-level engineering physics as a prerequisite; biology courses that had junior-level biochemistry as a prerequisite. (The specific courses cited can be viewed as "gateway" courses in their field.)

- For the elementary school level:

  (1) Undergraduate grade point average in last two years;

  (2) SAT/ACT score;

  (3) Number of laboratory science courses;

  (4) Number of science methods courses;

  (5) Science courses in all major areas (i.e., life, physical, earth);

  (6) Number of mathematics methods courses; and

  (7) Number of mathematics courses overall and number designed specifically for teachers.

A problem for measurement of teacher qualifications for high school and, in some states, middle school grades is that teachers may handle more than one subject. In this regard, we strongly support the recommendation of the Committee on Indicators of Precollege Science and Mathematics Education that measures of qualifications of teachers should be reported, not as percentages of teachers per se, but as percentages of students being taught by teachers with specific characteristics. Using student-weighted measures adjusts for differences in pupil-teacher ratios and staffing patterns and permits categorization by important dimensions such as the students' ethnicity. For example, a student-weighted measure would be that x percent of high school biology students have teachers who, on average, had y college courses in biology. Comparisons could also be made of the percentages for minority and other students and of the percentages for women and men students.

Recommendation 9. We recommend that the Center for Education Statistics surveys of teachers regularly include measures of general intellectual ability and of academic preparation to teach mathematics and science fields, particularly for new entrants, in order to provide time series for monitoring and analysis. These measures should be obtained to the extent possible from transcript records rather than through survey questions.

Measures of In-service Training and Commitment

For experienced teachers, the panel believes that it is important to have measures that indicate continued learning and commitment to mathematics and science fields. For a teacher with 15 or 20 years of experience, academic preservice preparation is likely to be much less indicative of current teaching competence. We suggest that a useful set of measures would include:

(1) Hours of in-service training in mathematics, science, and math and science pedagogy in last 12 months categorized by the purpose of the training (for example, to improve knowledge, to prepare to teach a new field, to implement a new curriculum);

(2) College credits obtained in the last 12 months in mathematics, science, and math and science pedagogy categorized by purpose;

(3) Membership and participation in professional mathematics and science associations; and

(4) Years of teaching mathematics and science (to distinguish teachers with many years of teaching experience but few years of experience in math or science from those with many years teaching these subjects).

We stress that research is needed to identify the best set of measures of in-service training and commitment; however, the panel believes that the above measures represent a good starting point. We note again the usefulness of reporting these measures on a student-weighted basis.

Recommendation 10. We recommend that the Center for Education Statistics surveys of teachers regularly include, for experienced teachers, measures of recent in-service preparation and participation in professional activities in mathematics and science fields. These surveys should also obtain measures of years of teaching mathematics and science distinct from total teaching experience.

Measures of Certification

Although using certification as a measure of teacher qualifications is problematic, given the great variations in requirements and certification practices among the states, the panel believes that it is important to monitor certification levels

and policies. The latter data are needed to permit careful assessment of the comparability of certification measures across states. This is particularly important, given that states that develop teacher supply and demand projections invariably rely on certification as a quality measure.

Ongoing surveys of teachers need to obtain information regularly on both the field of certification, e.g., general science, mathematics, chemistry, etc., and the type of certification, that is, emergency, provisional, permanent, etc. With regard to state policies on certification, which have been subject to frequent revision in recent years, we understand that the Education Commission of the States has been monitoring state certification practices on an annual basis since 1980 (see, e.g., Education Commission of the States, 1985; Flakus-Mosqueda, 1983). It is important that this information be disseminated widely to analysts and researchers who are studying the qualifications of the teaching force.

Finally, we note that recent reports directed to professionalizing the teaching force and teaching careers have recommended rigorous nationwide certification programs and standards (see Carnegie Forum, 1986; Holmes Group, 1986). The National Science Teachers Association (NSTA) has developed standards for certification in science subjects at the elementary, middle, and secondary school levels (NSTA, 1984, 1983) and is working to encourage teachers to obtain certification in these subjects through NSTA. To the extent that the recommendations of these organizations are implemented, certification will become a much better measure of teacher qualifications for which it should be much easier to obtain data.

Recommendation 11. We recommend that the Center for Education Statistics surveys of teachers regularly include measures of certification (type and subject fields) and that the Center obtain and disseminate available information on state certification policies and practices.

Other Measures of Teacher Qualifications

The literature suggests and our judgment supports that there are many other important characteristics of effective teachers of science and mathematics at the elementary and secondary school levels. These characteristics relate to teaching styles, including pedagogical techniques and skills, and to attitudes toward teaching, subject matter, and students. However, we believe that there is simply too little known to recommend a specific set of measures for regular data collection. We urge that the research agenda outlined previously be pursued vig-

orously to identify useful measures. In support of such research, we urge that the Center for Education Statistics make room in NELS:88 and other surveys on student outcomes for a rich set of teacher and school characteristics that will permit innovative investigation of this important topic.

Part III
How Selected State and National Models Work

The Panel on Statistics on Supply and Demand for Precollege Science and Mathematics Teachers engaged three consultants to carry out in-depth reviews of relevant data and analyses in selected states. Each review covers data and models on teacher supply and demand in two states. All three reviews also cover the national model maintained by the Center for Education Statistics. Part III consists of excerpts from the consultants' reports that describe the models and projections of teacher supply and demand included in their reviews. The text has been edited for greater consistency of format and terminology. The first section discusses the model of the Center for Education Statistics, while the second covers the models and projections developed in the six states. The latter section also provides the basis for selection of the particular state models for review.

Listed below are the authors, titles, and states reviewed in the consultant reports; the full reports are available from the authors.

Stephen M. Barro, "The State of the Art in Projecting Teacher Supply and Demand." August 1986. SMB Economic Research, Inc., Washington, D.C. (California and Colorado)

Edward S. Cavin, "A Review of Teacher Supply and Demand Projections by the U.S. Department of Education, Illinois, and New York." August 1986. Mathematica Policy Research, Inc., Princeton, N.J. (Illinois and New York)

Joel Popkin and B. K. Atrostic, "Evaluation of Models of the Supply and Demand for Teachers." August, 1986. Joel Popkin and Company, Washington, D.C. (Florida and South Carolina)

THE CENTER FOR EDUCATION STATISTICS MODEL

The Center for Education Statistics in the Office of Educational Research and Improvement of the U.S. Department of Education* regularly prepares national projections of components of the supply and demand for precollege school teachers. The Center, which is charged with the responsibility for collecting and disseminating data on education in the United States, uses data from a variety of sources in developing teacher supply and demand projections:

- Annual censuses conducted by the Center of state education agencies (SEAs) on public school enrollment by grade and total teaching staff;
- Annual censuses conducted by the Center of institutions of higher education on postsecondary enrollments and graduations;
- Periodic surveys conducted by the Center of nonpublic schools;
- Population projections developed annually by the Census Bureau;
- Annual surveys conducted by the Census Bureau of school enrollment (the October supplement to the Current Population Survey); and
- Periodic surveys by the National Education Association (NEA) of teacher training institutions and teachers.

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*The Center for Education Statistics was formerly the National Center for Education Statistics (NCES). This section draws heavily from the paper prepared for the panel by Cavin (1986:Section II) and also uses material from the paper prepared for the panel by Popkin and Atrostic (1986:Section III).

Structure of the Model

The Center for Education Statistics projects enrollments, total teacher demand, the demand for additional teacher hires (i.e., demand not filled by teachers continuing from the previous year), and the supply of new graduates from bachelor's level teacher training programs. The total teacher demand projections are published separately for public and private schools by elementary and secondary school levels, the additional teacher demand projections are published separately for public and private schools, and the new teacher supply projections represent grand totals. The supply and demand projections are not disaggregated by either subject field or geographic area. Also, the Center makes no attempt to estimate what fraction of new teacher hires will be from the reserve pool of qualified teachers who currently are not teaching or from sources other than new teacher graduates. Thus, the Center's comparisons of teacher supply and demand are best interpreted as the fraction of total new teacher hires that potentially could be made from the stock of newly trained teachers.

Figure 1 presents a diagram of the Center for Education Statistics model. Teacher demand is projected by the following sequence of steps:

(1) Enrollments by grade level are projected using a combination of birth cohort survival rates and grade retention rates;

(2) Staffing ratios (teacher-pupil ratios) are projected on the basis of historical trends; and

(3) Projected teacher demand is computed in three components: additional teachers needed because of enrollment changes, additional teachers needed because of changes in staffing ratios, and additional teachers needed to replace teachers who leave.

New teacher supply is projected using the following steps:

(1) College enrollment rates are projected using Current Population Survey data for age-specific subgroups of the population by sex;

(2) These college enrollment rates are multiplied by age-specific population projections to generate college enrollment projections;

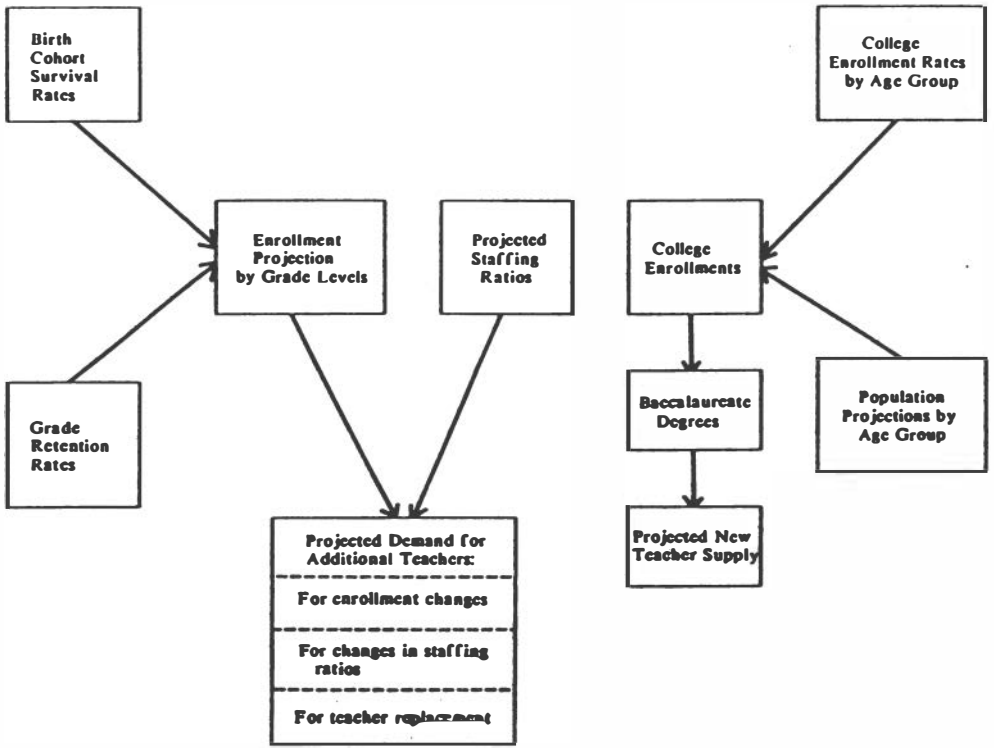

Figure 1 Structure of the Center for Education Statistics Teacher Supply and Demand Model.

(3) The number of baccalaureate degrees is projected using a regression relationship between degrees and college enrollments; and

(4) The projected supply of new graduates of teacher training programs is computed as a fraction of projected baccalaureate degrees based on data from the NEA and from the Center's surveys of recent college graduates.

The Center for Education Statistics methodology for projecting teacher supply and demand can be characterized as mechanical, involving the use of trend extrapolations based on historical time series. No behavioral components are included in the model. A characteristic feature of the projections is the use of alternative projection assumptions for key data series, to check the sensitivity of projections to particular assumptions and to permit more judgmental interpretation of the projections. The variables for which high, intermediate, and low alternative assumptions are employed are:

- Total precollege enrollment;
- Staffing ratios in public elementary and secondary schools;
- Staffing ratios in private schools;
- Teacher separation (attrition or turnover) rates;
- College enrollment rates; and
- The fraction of new baccalaureates graduating from teacher training programs.

Teacher Demand Projections

The Center for Education Statistics model requires teacher demand data on precollege enrollments, staffing ratios, and teacher separations (i.e., turnover). These data are used to estimate separately teacher demand for each component of total teacher demand changes. This section describes in detail the sources and uses of these data for the Center's teacher demand projections.

Enrollments

The Center for Education Statistics projects precollege enrollments by using a combination of age and sex-specific enrollment rates and population projections, enrollment rates in special school programs, and grade-to-grade retention rates. The first phase of the projection methodology involves application of Current Population Survey age and sex-specific enrollment rates to Census Bureau age and sex-specific population projections to generate enrollment projections by age and sex. These figures are adjusted to historical control totals for enrollment based on data collected by the Center from state education agencies; projected enrollments are adjusted using the historical adjustment rates. These enrollment projections, which are computed using low, intermediate, and high alternative population projections, form the basis of the second and third phases of the enrollment projection methodology.

The second phase involves using grade-to-grade retention rates to project grades 2 through 12 from the first-phase enrollment projections for the first grade. The Center calculates retention rates from grade-specific enrollment data obtained annually from state education agencies.

The third phase of enrollment projections involves applying age-specific enrollment rates in special school programs to the first-phase age-specific enrollment projections for all grades to compute the primary and secondary school enrollments in special programs. The total projected school enrollments for secondary schools are taken to be the sum of the regular secondary enrollments computed at the second stage and the secondary special program enrollment. The total projected enrollments for primary schools are defined similarly, except that the projected nursery and kindergarten level enrollments from the first phase are also included.

The above description of methods and data sources for enrollment projections applies to public schools. The Center also projects enrollments for nonpublic schools using the same basic methodology. The Current Population Survey data used to compute the first-phase enrollment projections separately identify public and nonpublic schools. The Center uses private school grade-specific enrollment data to calculate grade retention rates. The private school data are problematic in a number of respects, principally in that the directory of private schools that forms the sampling frame has serious omissions and biases. The surveys are also conducted every two or three years rather than annually (National Center for Education Statistics, 1984:184-185).

Staffing Ratios

Another important component of new teacher demand is that attributable to changes in staffing ratios. The Center for Education Statistics computes as its staffing ratio the number of teachers per 1,000 pupils, instead of the simple teacher-pupil ratio.

The product of enrollments and teacher-pupil ratios yields estimates of staffing requirements that can be dichotomized into the change in requirements because of enrollment and the change due to staffing ratios. Three projections of staffing ratios are made to match the low, intermediate, and high enrollment assumptions. For the low enrollment assumption, the teacher-pupil ratio is assumed to be constant. For the high assumption, projected increases in the ratio are based on the averaging of past ratios through the use of exponential smoothing equations, in which historical time-series data are weighted according to an exponentially decreasing function, so that more recent observations receive greater weight. The ratio for the intermediate assumption is an average of the two. The pairing of enrollment and teacher-pupil ratio scenarios--rising staffing ratios with the most rapidly rising enrollments and constant ratios with the slowest rising enrollments--seems motivated more by a desire to form the widest bounds than to relate enrollment causally to staffing ratios. In fact, rapidly rising enrollments are more likely to be associated with falling staffing ratios in the short run, particularly if the enrollment increases were greater than expected.

Turnover

The third main component of the demand for additional teachers in the Center for Education Statistics model is replacement of teachers who leave their jobs due to retirement, illness, maternity, or other reasons. It should be noted that teacher attrition is largely a supply phenomenon, reflecting the decisions of individual teachers. The discussion of turnover in the description of the model is retained under the heading of teacher demand because of the concept employed by the Center of decomposing the demand for additional teachers.

The Center currently uses a constant separation (or turnover) rate. The rate used in the intermediate series of projections is 6 percent (National Center for Education Statistics, 1985b:Table 25), which is based on assessment of job market conditions in the 1970s and 1980s. Unfortunately, the Center has not collected data on teacher replacement rates

since 1969; therefore, it is difficult to evaluate the realism of this assumption. The Center uses a teacher turnover rate of 8 percent in the high series of projections, which represents the historic level according to the Center, and a rate of 4.8 percent in the low projections series, which according to the Center represents a theoretical floor.

Again, the pairing of enrollment projections and turnover rates is done to establish the widest bounds. The range of turnover rates assumed can cause additional teacher demand due to attrition to vary by 25 percent. In the most recent projections, replacement demand is by far the major source of additional teacher demand, accounting for 78 to 86 percent of additional demand over the period 1988-1992. In contrast, changes in enrollment account for 7 to 14 percent of additional demand over this period and changes in staffing ratios for 0 to 13 percent (National Center for Education Statistics, 1985b:Table B-22).

Various research studies have estimated alternative teacher quit rates (see Eberts and Stone, 1984), although there are problems in comparability of study results (for example, quits from the perspective of a school district include transfers to other districts that are not quits from the perspective of a national model). Tables 4 and 5 in Part III, based on state data from Illinois and New York, indicate that quit rates vary by age of teacher--a finding supported in analyses of teacher data in other states (e.g., see Prowda and Grissmer, 1986). While these studies do not offer any clear evidence on what single separation rate might be appropriate, they do suggest that teacher separation rates vary over time in response to both the demographic composition of the teaching force and market forces, and that using a constant rate is likely to increase the error of teacher demand projections.

Teacher Supply Projections

Major components of teacher supply for a national model (ignoring migration of teachers among schools, districts, and states) include: continuing teachers who taught last year, persons newly certified to teach, teachers reentering from the reserve pool who did not teach last year but had prior teaching experience, and persons teaching out-of-field or on an emergency certificate. As noted earlier, the Center's teacher supply and demand model includes only continuing teachers (on the demand rather than supply side of the model--see previous discussion) and new graduates of teacher training institutions. The model does not project the reentering teacher or uncertified teacher components of supply.

New Graduates of Teacher Training Programs

The Center's model estimates the number of persons who will graduate from bachelor's level teacher training institutions. Therefore, in one respect, this model overestimates the number of new teachers who are available, because not all new teacher graduates obtain teaching certificates from state certification authorities (usually state education agencies) or apply for teaching jobs. However, many states permit the certification of college graduates who were not enrolled in undergraduate teacher training programs. On balance, it probably is difficult to determine whether the supply of newly certified teachers is greater or smaller than the number of new teacher graduates, without collecting detailed data from states and school districts on certificate issuance and applications.

In any case, the Center for Education Statistics projects the supply of new teacher graduates by projecting postsecondary enrollments, college graduations, and the fraction of total baccalaureates who are graduates of teacher training programs. In the first step of this process, postsecondary enrollments are forecast using essentially the same procedure as that employed for the first-phase projections of primary and secondary school enrollments. Age and sex-specific enrollment rates from the Current Population Survey are applied to age and sex-specific population projections to obtain postsecondary enrollments. In the second stage of this process, a regression model incorporating two explanatory variables--a trend variable and a categorical variable for the change in the direction of the trend--is used to project baccalaureate degrees from fourth-year college enrollments. Finally, historical data from the NEA on the fraction of total college graduates who graduated from teacher training programs are used to estimate projected new teacher supply from the forecast of total college graduates. The NEA data are available through 1982 when the series was discontinued; to develop its next series of projections, the Center for Education Statistics is using data from its 1985 survey of recent college graduates.

Alternative estimates of the fraction of graduates who obtained teacher training are applied. The first alternative percentage, associated with the low projection of college graduates, is obtained from an exponential smoothing equation that produces a negative time trend. The time trend in this case is negative because new teacher graduates as a percentage of bachelor's degrees awarded have fallen from 37.4 percent in 1971 to 15 percent in 1982. The second alternative percentage incorporates a positive time trend assumption about the fraction with teacher training and is paired with

the high graduate scenario. A constant 15 percent ratio, equal to the actual 1982 ratio, is paired with the intermediate graduate scenario. Again, the objective of the pairings is to bound the supply estimate. This is done by picking a worst-case scenario based on the falling proportion of new teacher graduates that has obtained since the early 1970s. The other bound is selected so as to reverse the downward trend. But variables accounting for the observed decline are not in the model, so there is no basis on which to evaluate whether the trend will continue, be reversed, or not move in either direction, as posited in the intermediate scenario.

Comparison of New Teacher Supply With Additional Teacher Demand

The Center for Education Statistics then provides comparisons of the supply and demand estimates produced by its model, again with a view toward bounding the outcomes. Thus, the highest new demand outcome is compared with the lowest new supply outcome, and vice versa. By 1992 the projected demand, both public and private, from the low to high scenario varies from 157,000 to 231,000 additional teachers. The projected supply varies from 99,000 to 188,000 new teacher graduates. The conclusion of the forecast published by NCES (1985b:Table B-23) is that by 1992 supply could exceed demand by as much as 19.7 percent (188,000/157,000) or demand could exceed supply by as much as 133.3 percent (231,000/99,000). Again, the only source of supply projected in the Center's model is that provided by new teacher graduates, although data from a number of states suggest that other sources of supply, such as reentering teachers, are typically a much larger fraction of new hires than are new teacher graduates (see the discussion in the section on state models). Hence, it is likely that the Center's estimates of excess demand are substantially biased upward.

Model Performance

The U.S. Department of Education has been generating consistent projections of enrollments and staffing since 1964. Thus, there is a substantial accumulated body of modeling experience on which to base assessments of model performance. At least three such significant investigations of the performance of the Center's model have been undertaken:

this section will discuss the results of the most recent such evaluation (Frankel and Gerald, 1984).*

The Center has used the mean absolute percentage error (MAPE) of its projections as a measure of model performance. MAPE is defined as:

$$\text{MAPE} = \Sigma [(1/n) \mid \hat{X}_t - X_t \mid / X_t] \, 100$$

where X_t is the actual value of the variable of interest in time period t, $\hat{X}_t$ is the projected value, and n is the number of time periods over which the MAPE is measured. Table 1 presents MAPEs for key variables in the Center's model, by lead time of the forecast. Public school enrollments evidently are forecast quite accurately by this model, as might be expected from the dependence of these enrollments on relatively short-term demographic data. Indeed, with a 10-year forecast horizon, most of the persons who will enroll in all but the lowest grades already have been born and can be forecast on the basis of historical data. College enrollment rates in the short term also tend to be accurately forecast, for the same reason that these persons can be counted accurately. Total demand for public school classroom teachers has very small MAPEs, which suggests that the staffing ratios used to forecast teacher demand on the basis of enrollment projections are very stable.

Much less accurate are the model's projections of baccalaureate degrees and the supply of new teacher graduates. Baccalaureate degrees are forecast from a regression equation based on college enrollments; these data suggest that the relationship between enrollments and degrees is not very stable for more than four future years. Projections of new teacher supply are so inaccurate as to be, practically speaking, useless even in the short run.

The Center's projections for nonpublic schools tend to be less accurate than those for the public schools, which probably reflects data limitations and the sensitivity of nonpublic school enrollment decisions to the educational policy environment. A comparison of projected enrollment and total teacher demand in nonpublic schools suggests that staffing ratios in nonpublic schools probably are quite stable, since the MAPEs of enrollments and teacher demand are of similar magnitude.

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*The first was performed under contract by Research Triangle Institute in 1974, while the second and third were performed by NCES in 1978 and 1984 (see Frankel and Gerald, 1984).

TABLE 1 Mean Absolute Percentage Errors for Key Variables in the Center for Education Statistics Model (for Projections Prepared in 1966-1982)

	Lead Time (Years)									
	1	2	3	4	5	6	7	8	9	10
Precollege Enrollment in Public Schools:										
K-12	0.2	0.4	0.6	0.7	0.8	1.1	1.8	3.0	4.9	7.2
K-8	0.3	0.6	0.8	0.9	0.9	1.2	2.1	3.4	5.8	8.8
9-12	0.6	0.8	1.0	1.3	2.0	2.5	2.9	3.8	4.6	5.3
Precollege Enrollment in Nonpublic Schools:										
K-12	3.6	6.5	nr	nr	15.0	nr	nr	nr	nr	14.3
College Enrollment	0.4	2.3	3.0	5.0	nr	nr	nr	nr	nr	nr
Baccalaureate Degrees	2.4	2.4	3.9	5.5	8.6	9.9	11.9	14.5	15.1	18.2
Demand for Classroom Teachers:										
Public Schools	0.9	1.5	2.2	3.0	3.7	4.0	4.4	4.5	4.4	4.7
Nonpublic Schools	0.5	6.5	9.9	16.0	16.2	23.7	21.1	19.9	16.9	11.6
Supply of New Teacher Graduates	14.2	24.6	31.8	nr	nr	nr	nr	nr	nr	nr

nr = not reported.

SOURCES: NCES (1985b: Tables 30, 31) for precollege enrollment in public schools, college enrollment, and baccalaureate degrees; Frankel and Gerald (1984) for precollege enrollment in nonpublic schools and demand for classroom teachers.

Users of the Center for Education Statistics Model

The Center's model generates projections of teacher demand and the supply of new teacher graduates that are intended to inform educational policy debate and planning. Probably the main consumers of the Center's projections are federal educational policy makers and legislators.* Because the projections are not disaggregated by geographical area, they are of limited interest to state education agencies and of no practical consequence to school districts. Moreover, staff of state education agencies may tend to discount national projections of new teacher graduates because they are based on data that may not be representative of their state and which may be difficult to interpret because of different state certification requirements. The usefulness of the model projections probably could be increased primarily by improving the performance of the model itself, and secondarily by disaggregating the projections.

MODELS OF SELECTED STATES

This section provides descriptions of the teacher supply and demand models and projections developed in six states: California and Colorado in the West, Illinois and New York in the Northeast and Midwest, and Florida and South Carolina in the South. First, we discuss the basis for selecting these six states.

Selection of States for Review

With regard to selection of states, we concluded that it was important to have a sample representative of the following dimensions:

- Geographic region of the country;

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*The Center's projections are known on occasion to have had an important impact on policy. One example occurred in 1966 when the U.S. Office of Education had before the Congress a bill for a heavily funded teacher training program. The Center's model projected declines in enrollments and consequently decreasing need for additional teachers. In response to this information, the bill was modified to direct funding to areas of special need, such as special education.

- Trends in elementary school enrollment over the past decade (as a measure of demand generated from population growth);
- Level of current elementary school enrollment (as a measure of size); and
- Percentage private school of total enrollment (modeling teacher supply and demand is more difficult for private schools).

With resources to review only six states, it was obviously not possible to specify a sample representing all aspects of these dimensions. Moreover, an overriding consideration was to review states that had actually completed reasonably detailed analyses of teacher supply and demand.

The six states that were chosen include four that rank in the top third on current level of elementary school enrollment and two that rank in the middle third. The four large states each fall into different categories of enrollment trends over the past decade. This set also provides a distribution from high to low percentages of private school enrollment (see Tables 2 and 3).

The panel and consultants also reviewed less intensively studies of teacher supply and demand in several other states, including Connecticut (Prowda and Grissmer, 1986), Delaware (Delaware State Department of Public Instruction, 1985b) and Oregon (Oregon Teacher Standards and Practices Commission, no date). The bibliography provides references to the studies on this topic known to the panel.

The California PACE Model*

The most fully developed analysis of teacher supply and demand in California is that produced by Policy Analysis for California Education (PACE), a research center at the University of California, Berkeley. This work, which projects teacher supply and demand through 1994-1995, is presented in a report entitled "Teacher Supply and Demand in California: Is the Reserve Pool a Realistic Source of Supply?" (Cagampang, Garms, Greenspan, and Guthrie, 1985). The following description and assessment is based on that document, on a series of discussions with Helen Cagampang, and on information provided by James Fulton of the Planning, Eval-

*The description of the California model is drawn from Barro (1986:Appendix).

Table 2 Percentage Private Enrollment of Total Elementary and Secondary School Enrollment in 1980

State	Percentage Private of Total Enrollment	State	Percentage Private of Total Enrollment
Delaware	19.0	North Dakota	8.4
Hawaii	18.4	South Dakota	7.8
District of Columbia	17.5	Tennessee	7.7
Pennsylvania	17.4	Alabama	7.6
Louisiana	17.0	Kansas	7.5
New York	16.8	South Carolina	7.4
Rhode Island	16.8	Arizona	7.3
Wisconsin	16.4	Maine	7.3
New Jersey	15.6	Vermont	7.3
Illinois	15.0	Georgia	7.2
Connecticut	14.3	Virginia	6.9
Missouri	13.0	Washington	6.9
Maryland	12.4	New Mexico	6.2
Nebraska	12.1	Colorado	6.1
Ohio	12.1	Oregon	5.7
Florida	12.0	North Carolina	4.9
Massachusetts	11.9	Texas	4.9
California	11.1	Montana	4.7
New Hampshire	11.0	Alaska	4.2
U.S. Average	10.8	Nevada	4.2
Minnesota	10.5	Arkansas	4.0
Michigan	10.2	West Virginia	3.2
Mississippi	9.5	Wyoming	3.0
Iowa	9.4	Idaho	2.8
Kentucky	9.4	Oklahoma	2.7
Indiana	8.7	Utah	1.6

SOURCE: Feistritzer (1983:Table 1).

uation, and Research Division of the State Education Department.

Teacher Demand

The demand for California teachers is estimated by dividing projected enrollments by pupil-teacher ratios. The calculation is done separately for the elementary (K-8) and secondary (9-12) grades. The enrollment projections are provided by the California Department of Finance. Numbers of teachers (full-time-equivalents or FTEs) are determined from a detailed statewide data file on individual teachers contained within the California Basic Education Data System (CBEDS). The pupil-teacher ratios used for making projections, 23.89 pupils per FTE elementary teacher and 28.08 pupils per FTE

TABLE 3 Percentage Change in Grades 1-8 Public School Enrollment, Fall 1970 to Fall 1982, and Level of Enrollment in Fall 1982

Change in Enrollment 1970-1982 (%)	Grades 1-8 Public School Enrollment Fall 1982		
	Large (States Ranking 1-17)	Moderate (States Ranking 18-34)	Small (States Ranking 35-51)
Increase or Small Decline (-9.9 to +24.0%)	Texas (-1.8, 2) Florida (-3.1, 8)	Arizona (+6.6, 27.5) Colorado (-4.0, 26) Oklahoma (-7.4, 25) Oregon (-9.2, 31)	Utah (+24.0, 35) Wyoming (+18.2, 47) Idaho (+11.2, 39) Nevada (+4.9, 43) Alaska (0.0, 49.5) New Hampshire (-5.5, 40)
Moderate Decline (-16.9 to -10.0%)	California (-14.1, 1) Georgia (-14.8, 11) Louisiana (-15.8, 16) Tennessee (-16.2, 15) North Carolina (-16.5, 10)	Arkansas (-12.2, 32) Washington (-13.3, 19) West Virginia (-14.6, 34) South Carolina (-14.8, 24)	New Mexico (-13.3, 36) Hawaii (-15.7, 41) Vermont (-15.7, 48) Alabama (-16.7, 18)
Large Decline (-26.9 to -17.0%)	Virginia (-18.0, 12) Illinois (-24.7, 4) Indiana (-25.3, 13) New Jersey (-25.6, 9) Ohio (-26.4, 5) Michigan (-26.7, 7)	Mississippi (-17.3, 27.5) Kentucky (-18.9, 22) Kansas (-21.9, 33) Wisconsin (-26.3, 20) Minnesota (-26.5, 21)	Maine (-17.0, 38) Montana (-18.6, 42) Nebraska (-20.9, 37) North Dakota (-25.8, 46)

Very Large Decline (-44.0 to -27.0%)	New York (-27.5, 3)	Iowa (-28.0, 30)	South Dakota (-27.6, 45)
	Missouri (-27.6, 17)	Connecticut (-30.3, 29)	Rhode Island (-33.0, 44)
	Pennsylvania (-29.6, 6)	Maryland (-31.7, 23)	Delaware (-37.2, 51)
	Massachusetts (-30.0, 14)		D.C. (-44.0, 49.5)

NOTE: Total U.S. public school enrollment in grades 1-8 in fall 1982 was 24,304,000. The average percentage change from fall 1970 was -19.0. Figures in parentheses are, respectively, the percentage change in enrollment in fall 1982 from fall 1970 and the ranking of the state from 1 (largest) to 51 (smallest) on level of enrollment in fall 1982. Enrollment figures for grades 1-8 were derived by subtracting kindergarten and prekindergarten enrollment from the total for grades prekindergarten through 8. Figures for prekindergarten and kindergarten in fall 1970 were estimated for Arkansas and Idaho.

SOURCE: NCES (1985a: Tables 1.2 and 1.8).

secondary teacher, are actual values for the most recent year for which data are available, 1984-1985.

PACE has some concerns about the reliability and year-to-year consistency of the enrollment projections. According to Fulton, there are some problems in predicting the migration of school-age children into Southern California and some difficulties in predicting dropout or continuation rates in high school. The latter have been complicated by recently introduced financial incentives for pupil performance, which have induced some districts to manipulate the grade-level classifications of certain high school students. It is not clear whether these phenomena have any significant effects on the demand projections.

The pupil-teacher ratios used to project demand appear to have been unusually carefully constructed. Numbers of elementary and secondary FTE teachers were specially estimated by PACE from the CBEDS data on individual teachers, taking into account the amount of teaching time reported for individuals. Teachers in nonteaching assignments were not counted. One area of concern is that certain teachers have been excluded in computing the ratios because the corresponding pupils are excluded from the enrollment projections. The excluded categories are described as pupils enrolled in special education, adult education programs, and Regional Occupation Centers. It appears that the special education pupils referred to are only those not mainstreamed into regular graded classes--i.e., only a small fraction of pupils receiving special education services. It is not clear whether the exclusions of special education teachers and pupils have been handled consistently. In any event, the lack of demand projections for at least some special education teachers is itself a limitation of the model.

There are major interregional variations in the outlook for teacher supply and demand in California, and consequently considerable interest attaches to geographical differences within the state. In response to this interest, the PACE analysts have broken down their projections by county. A data base containing elementary and secondary enrollments and pupil-teacher ratios by county has been assembled, and all the calculations required to make statewide estimates have been replicated for each of the 58 counties of the state.

The choice of the county as the unit for geographical disaggregation is unfortunate, although perhaps politically necessary. California counties are extremely disparate in size, population, and distribution throughout the state. It makes little sense, for example, to compare Los Angeles county, which embraces much of the Los Angeles metropolitan area, with each of the 8 or 10 individual counties that constitute the San Francisco-San Jose metropolitan area. It

seems even less sensible to give equal attention to the tiny, sparsely populated mountain counties. Disaggregation by county is especially unhelpful with respect to supply. It is almost meaningless to ask how many teachers are in a particular county's supply (and, in fact, no attempt is made to produce geographically disaggregated supply projections). The analytically appropriate units of disaggregation, if any, would be something corresponding to labor market areas.

The PACE model does not provide disaggregated estimates by subject area, type of pupil, or any dimension of teacher assignment other than elementary-secondary. (However, some ancillary, small-scale studies of demand for science, mathematics, and bilingual teachers are summarized in the PACE report, and the PACE group is now undertaking a study of supply and demand in these categories.) The CBEDS data base has abundant data on teacher assignment, down to the level of the individual course, and it would be a simple matter to produce the same type of teacher composition data as contained in the Colorado model. However, as explained in the next section discussing that model, such data alone provide no basis for projection, except the unsatisfactory assumption that the composition of the teaching force will be the same in the future as it is now. Thus far, data on pupil enrollment by subject area have not been available in CBEDS. Such data will be available in late 1986, however, which will make it feasible to produce meaningful demand projections by field.

The Supply of Continuing Teachers

The number of continuing California teachers in each future year is estimated in the PACE model by applying an attrition rate to the number of teachers employed in the preceding year. Two estimation methods are used, yielding two different projections of the supply of retainees. One approach assumes that the average of the statewide attrition rates for the last 7 years, estimated as 7.67 percent, will also be the attrition rate in the future; the other uses a trend-extrapolation of the attrition rate, based on a regression equation fitted to data for the last 10 years. Since the trend in the attrition rate has been downward, the latter yields lower projected attrition and hence a larger projected supply of retainees.

Attrition rates have been computed by the PACE staff from a data base maintained by the California State Teachers' Retirement System (STRS). That data file, unfortunately, identifies teachers neither by level (elementary or secondary) nor by county; consequently, only a single statewide average

attrition rate can be computed. Moreover, it is not possible to differentiate in the STRS file between data on K-12 teachers and data on junior college teachers, librarians, and certain administrators, meaning that the estimated attrition rates pertain, strictly speaking, to a broader personnel category than elementary-secondary teachers. In these respects, the STRS data are far from optimal for supporting a supply-demand analysis.

There are several reasons why it was necessary to use STRS data rather than to estimate attrition by merging and comparing CBEDS teacher data for successive years. The reasons given are nontechnical--namely, that merging CBEDS information for two or more years is a major data processing task, for which resources are not available in the State Education Department, while confidentiality restrictions preclude releasing the data for processing by an outside group. It would seem, however, that the latter objection could be overcome by scrambling the individual record identifiers, while processing the data on a sample basis is a possible strategy for reducing costs. Using the CBEDS data, it would be possible to estimate detailed attrition rates, disaggregated by level, subject area, and county. It would also be possible to estimate age-specific attrition rates, as in Connecticut and New York, and to project such rates into the future. There is great untapped potential for improving this component of the model.

The Supply of New Teachers and the Supply-Demand Balance

The PACE analysis of the supply of new entrants focuses on the numbers of teachers likely to be forthcoming from various sources or categories. Four such categories have been recognized, and attempts have been made, using fragmentary information, to develop projections (often little more than guesses) for each. The four are:

(1) New or recent graduates of California credential programs;

(2) Credential holders from out-of-state;

(3) Teachers entering from the reserve pool of nonteaching credential holders; and

(4) College graduates who pass the California Basic Educational Skills Test and obtain emergency credentials.

Projecting the number of graduates of in-state teacher preparation programs is extremely difficult because of the nature of teacher preparation and certification requirements in California. The state does not operate traditional undergraduate teacher training programs. Instead, persons preparing to teach in California are generally expected to earn a bachelor's degree in a liberal arts field and then to complete a one-year (or longer) teacher training program. The significance of this arrangement for supply projections is that there is no "pipeline" of trainees from which a flow of prospective graduates can be projected--no identifiable category of college students from which new teachers will come. In effect, almost anyone with a bachelor's degree (not only in California but anywhere in the country) can prepare to be a California teacher one year hence. In addition, the relationship between credentials earned and enrollment in post-B.A. California teacher training programs has recently been disrupted. The number of credentials issued has actually declined, while enrollments have risen sharply. The introduction of a test requirement for new credential applicants in 1983 (the California Basic Educational Skills Test, or CBEST) may explain this anomaly. In any event, the instability adds to the difficulty of predicting the number of newly credentialed teachers. Ultimately, the PACE analysts chose to base their estimate on a simple assumption: that the number of new credential earners in future years would equal the average number during the last three years, and that the same fraction of recent credential earners as in the last three years (49.7 percent) would actually enter teaching.

Even cruder procedures were used to project numbers of entrants from the other categories. In the case of newly credentialed teachers from out-of-state, data are available only on the number of such persons who obtain California credentials and not on the number who actually enter teaching. Lacking any better information, the PACE analysts assumed that the future number of such credential earners would be the same as the average of the last three years and that the same fraction as that of in-state credential earners, 50 percent, would actually enter teaching.

As to the reserve pool, the PACE group made a rather heroic effort to piece together a projection of entrants, or reentrants, from this source. They first used a small sample of records from the California Commission on Teacher Credentialing (CTC) to estimate the size of the reserve pool--i.e., the number of people with valid credentials not actively teaching. They then concluded, or guessed, on the basis of a small survey of former teachers and a "focus group" exercise, that no more than 30 percent of reserve pool members could be considered in the teacher supply--i.e., likely to enter

teaching under any reasonable circumstances. Finally, they determined from STRS records the rate at which inactive members resume teaching (1.7 percent) and applied that figure to the supply estimate, thereby obtaining an estimate of the number of reentrants per year. Finally, lacking any other basis for projecting the number of new entrants under emergency certificates, they set that figure at the historical average during the last four years.

The numerical results of these exercises are of interest because of the distribution of new entrants among the categories. The breakdown of the projected annual inflow of new entrants is:

Newly credentialed teachers	2,354	(23%)
Out-of-state teachers	1,500	(15%)
Reserve pool	3,000	(32%)
Emergency credentials	3,200	(30%)
Total	10,054	(100%)

Note that in-state newly credentialed teachers make up less than one-fourth of the new entrants into the teaching force.

In the PACE model, the issue of supply-demand balance, or "shortage," is handled by comparing the bottom-line supply estimate--approximately 10,000 new entrants per year--with the difference between projected demand and the projected supply of continuing teachers. Since this difference amounts to 15,000 to 17,000 teachers, it is concluded that there will be a shortfall of 5,000 to 7,000 teachers per year. In other words, the model is used to project a shortage.

What can be said about the validity of the projections of new entrants and, hence, the finding of a prospective shortage? Somewhat reluctantly, in view of the ingenuity displayed in constructing estimates from very few data, one must conclude that the projections of new entrants do not reflect teacher supply in any economically meaningful sense of the term. Moreover, this has nothing to do with the crudity of the projection methods. Even if excellent data had been available on numbers of persons and entry rates in each category, the same conclusion would still pertain. The problem is conceptual: it is not possible to infer supply--the number of eligible persons willing to offer their services as teachers--from information on the number of people actually hired.

To see why, consider first the newly credentialed in-state teachers. Approximately 4,800 persons obtain such credentials each year, of whom about 2,400 become teachers. How many are in the supply? The answer is some unknown number between 2,400 and 4,800. We know how many were hired, but we do not know how many of the remainder were

rejected (or discouraged) members of the supply pool--persons willing to teach under current conditions but not selected for employment. The number of teachers hired reflects not only supply but also the interplay of supply and demand. Conceivably, all 4,800 were in the supply, but only half were demanded. One cannot quantify supply with the information in hand.

Next, consider the 3,200 teachers hired under emergency credentials. There is no reason to believe that this figure exhausts the supply of persons willing to take such jobs. More likely, 3,200 is the number that districts chose to hire to fill out their teaching staffs. It is conceivable that several times as many persons might have been willing to teach under the same conditions. The number hired is the smaller of the numbers supplied and demanded. In this case, it may well be much smaller than the number supplied.

Essentially the same can be said of the other two categories of entrants. There is no reason to assume that 1,500 and 3,000 new entrants, from out-of-state and the reserve pool, respectively, are upper bounds on the numbers available from those sources. The number supplied is not directly observable and cannot be inferred from these types of projections. In general, data on entrants by category are useful for analyzing the background and composition of the teaching force, but they are of little value, projected forward, for assessing the balance between demand and supply.

Potential for Further Development

California has sophisticated, large-scale data bases, which can support major improvements in supply-demand projection models. Moreover, the data bases themselves are being expanded and improved. In 1986 data on enrollment by subject area will be incorporated into the CBEDS data base, which will make it possible to disaggregate the demand projections by teacher assignment category. A project has been initiated to computerize the CTC certification files, which, when completed in three years, will allow comparisons between the files on teachers and those on certificate holders. Such comparisons, which are infeasible now, should support a full-scale analysis of movements into and out of the reserve pool. CTC is also undertaking sample surveys of nonteaching credential holders, which should provide shorter-term information on their supply behavior.

A major improvement in the model, feasible with the data already in CBEDS, would be to incorporate a Connecticut-type analysis of attrition rates into the projections of teacher supply (see Prowda and Grissmer, 1986). This would

involve computation and projection of age-specific attrition rates for disaggregated categories of teachers. In conjunction with the disaggregation of demand estimates by subject area, this would yield a much more useful and powerful model. The required information is already in CBEDS and could be made accessible by merging the CBEDS files for two or more successive years.

Interest in teacher supply and demand is growing in California, and a committee is now working to design a coordinated interagency effort to improve data bases and analyses in the area (California State Commission on Teacher Credentialing, 1986). Given the rich data bases already in place and those now being developed, such an effort could yield a very impressive analytical capacity.

The Colorado Model*

Projections of teacher supply and demand in Colorado through the years 1990, 1995, and 2000 have been prepared by the Planning and Evaluation Unit of the Colorado Department of Education (CDE) under the direction of Roger E. Neppl. The results are presented and the methods outlined in a report entitled "Teacher Supply and Demand for K-12 Public School Programs in Colorado: 1985 and Beyond" (Colorado State Department of Education, 1986). The following summary and critique of the Colorado analysis is based on this report and on a discussion with Neppl after submitting to him a set of written questions on the methodology and the data.

Teacher Demand

The demand for K-12 teachers in Colorado is estimated by applying a pupil-teacher ratio to the projected number of pupils. The demand estimates are expressed as numbers of full-time-equivalent (FTE) teachers. The pupil projection, in the Colorado case, is a projection of pupils in average daily membership (ADM) prepared by the CDE school finance unit. The pupil-teacher ratio used for the projections, 18.49 pupils in ADM per FTE teacher, is a weighted average of the actual K-12 ratios over the last five years. No distinction has been made between elementary and secondary teachers in projecting overall teacher demand, but both the enrollment data and

*The description of the Colorado model is drawn from Barro (1986: Appendix).

the pupil-teacher ratios can be broken down by level, making such a distinction feasible.

According to Neppl, Colorado enrollment projections have been very accurate for up to five years into the future, and no major difficulties have arisen in projecting either immigration or dropout rates. Discrepancies do exist, however, between the projections prepared by the school finance unit and a new set prepared by the Planning and Evaluation Unit, which suggests that some uncertainty about the appropriate enrollment projection assumptions does carry over into teacher demand estimation.

As to the pupil-teacher ratio, the principal reason for using a five-year average rather than some type of trend projection was apparently to produce a conservative demand estimate. The pupil-teacher ratio recently declined significantly in Colorado (there were 23 pupils per teacher in 1978) but has been stable for the last three years. Adherence to the five-year average seems to reflect a subjective judgment that developments in school finance in Colorado will not support further reductions in the ratio during the coming years.

The projections of teacher demand have been broken down according to teacher assignment or certification categories by the simple method of applying the actual (fall 1985) figures on the percentage composition of the teaching force to the projected future levels of aggregate teacher demand. Thus, for example, the current percentages of teachers in mathematics, physical education, etc., are applied to the projected total number of teachers in 1990 to obtain estimates of the 1990 demand for teachers in those fields. The 15 assignments represented in this breakdown include elementary education, special education, and 13 subject-area categories. This procedure obviously does not allow for changes in the composition of the teaching force that might occur in response to changes in high school curricula or graduation requirements or in the composition of the student body.

The Supply of Continuing Teachers

The number of teachers who will leave the Colorado teaching force in each future year is estimated by applying an attrition rate to the prior-year number of employed teachers. The statewide attrition rate, based on attrition data reported by individual school districts and aggregated by CDE, is stated as 10.6 percent. This is a combined rate for teachers in grades K-12. Data are apparently available, however, to calculate separate rates for elementary and secondary teachers. According to Neppl, the 10.6 percent rate has been

almost the same for 10 years; there has been no trend and there is no reason to expect the rate to change.

Because 10.6 percent is a high attrition rate, further inquiry determined that this figure, being based on data reported by individual districts, includes teachers who transferred from one Colorado district to another. The inclusion of transferees is inappropriate, since such transfers do not constitute attrition from the point of view of the state as a whole. There appears to be no basis for estimating the percentage of transferees in the 10.6 percent figure, since the district-reported data are not broken down by destination of the departees, but, to the extent that there are such people, teacher attrition and hence the demand for new teachers are overestimated.

The Colorado model, unlike most others, does not compare the demand for new teachers with the supply of new teachers; instead, it compares total demand with a variable said to represent total supply (see below). Consequently, there is no need in the Colorado analysis to compute net demand (total demand less continuing supply) and hence no need to estimate the continuing supply. Nevertheless, the continuing supply in each year is, implicitly, prior-year employment less the attrition rate estimated as described above.

The Supply of New Teachers and Supply-Demand Balance

The Colorado analysis does not deal explicitly with the supply of new teachers. That is, it attempts neither to project availability of new teachers nor to analyze the sources from which such teachers will come. Instead, it focuses on the overall supply-demand balance. The treatment of that subject is based on the notion that teacher supply can be equated with the number of persons certified to teach. It is perfunctory, in that supply (so-called) is not projected but simply assumed to remain constant. More specifically, supply is defined, in the Colorado analysis, as the number of persons certified to teach in the state, reduced by a percentage (15 percent) representing the fraction of certified persons expected not to apply for teaching positions.* The resulting "supply" figure in 1985 is estimated to have exceeded the

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*The 15 percent reduction is based on an NCES study, probably the NCES survey of recent college graduates, pertaining to a *national* data base, which found that 85 percent of those who completed the requirements for teaching actually applied for teaching positions. See further discussion in the text.

number of employed teachers by about 52 percent. Moreover, the 1985 supply, so defined, exceeds 1985 demand in all but 2 of the 15 assignment categories (the exceptions being mathematics and special education). Assuming that the number of certified persons does not change, it will continue to exceed the projected demand for teachers for the foreseeable future (by 31, 24, and 18 percent, respectively, in 1990, 1995, and 2000). Also, assuming that there are no changes in the numbers certified in each assignment category, there will still be comfortable surpluses in most categories in those years. (Constancy of supply, according to Neppl, is, if anything, a conservative assumption, since there has actually been an upward trend over the last five years in the number of certified persons.)

The problem with this approach is that there is only a tenuous connection between the number of certified persons and teacher supply. The certified pool includes, among others, people who left teaching because of dissatisfaction with the field, people engaged in nonteaching careers, people not in the labor force, and--perhaps most important--people who do not consider teaching attractive, given current salaries and working conditions. No information is available in Colorado, either from analyses of historical data or from surveys, about the number of nonteaching certified persons who might enter or reenter teaching under current or alternative conditions. The 85-percent estimate of new teacher graduates who apply to teach has no bearing on the matter, since there is no reason to believe that this national figure pertains to Colorado and since most members of the certified pool are not the new or recent graduates to whom the 85-percent figure applies. In sum, one cannot validly infer anything about future supply-demand balances or "shortages" by the method described here.

There are also some problems in measuring the size and composition of the pool of certified persons. The CDE has no data file on current certificate holders. However, Colorado certificates remain valid for five years, so the size of the pool at the beginning of 1985 was estimated by adding up the number of persons who obtained or renewed certificates during the years 1980 through 1984. This procedure fails to adjust, however, for people who have retired, died, or left Colorado since acquiring their certificates. In that respect, it overestimates the size of the pool.

In addition, the data on the composition of the certified pool (by subject area, etc.) are based on the type of certificate, or endorsement, held by each individual. Persons who hold multiple endorsements are categorized according to the endorsement they obtained most recently. This is a shortcoming, in that (a) in the case of employed teachers, the

most recent endorsement may not correspond to the individual's primary area of responsibility, (b) the procedure is likely to distort the analysis of the composition of the teaching force and perhaps to understate the number of persons qualified to teach in certain fields, and (c) it certainly neglects the added flexibility in matching supply to demand afforded by teachers with multiple certification.

There is also a computational anomaly in the comparison between total demand and total supply in the Colorado report. For some reason, the comparison offered is between the stock of certified teachers and a so-called gross demand estimate that consists of the number of teachers required in a given year to maintain the specified pupil-teacher ratio *plus* the number of teachers that would be lost through attrition in one year. That sum doublecounts the component of demand stemming from teacher attrition. If the certified stock were compared with demand, normally defined--i.e., projected enrollment divided by the projected pupil-teacher ratio--the teacher surplus would be larger than indicated in the report.

Potential for Further Development

The data bases already available in Colorado would support a number of substantial improvements in the supply-demand model. Files on both employed teachers and certified persons are maintained at the state level. It apparently would be possible, given the necessary data processing resources, to match these files with one another and to merge files from different years. This would allow the CDE analysts to (1) break down pupil-teacher ratios into elementary and secondary (or into finer grade-level categories if desired) and produce separate elementary and secondary projections; (2) estimate average attrition rates directly for each category of teacher, without having to depend on turnover rates reported by districts, or, preferably, estimate and project detailed age-specific attrition rates, as in the Connecticut model; and (3) take full account of multiple certificates in characterizing and projecting teacher composition by field. It is less certain what could be done with respect to the supply of new teachers, but it might be feasible to do some analysis of the sources of newly certified persons and/or new hires (e.g., in-state versus out-of-state, newly trained versus previously trained) and perhaps to learn something about the rates at which people move from the reserve pool of certified teachers into the active teaching force.

The existing Colorado data bases do not contain the necessary detail to develop projections of enrollment, and

hence teacher demand, by subject area. To do that would require collection of new data. Also, with respect to the supply side, there apparently have been no analyses of the projected flow of graduates from Colorado teacher training institutions. A special study would be required to fill that gap.

In sum, a number of important improvements could be made with existing data and hence at relatively low cost. Other advances would require substantial investment. Given the general lack of urgency over prospective supply-demand imbalances in Colorado (although field-specific problems in mathematics, science, and special education are seen as possibilities), it is not clear that the CDE has sufficient incentive to undertake the latter improvements.

The Illinois Model*

Illinois has experienced continuous declines in enrollments and teacher staff since 1970 (Illinois State Board of Education, 1985a). Much of the observed decline is attributable to national trends in fertility toward sharply diminished birth rates, but another important factor has been net out-state migration, which probably is related to decline in traditional Illinois industries such as steel and manufacturing. Thus, there have been systematic tendencies toward slack teacher demand in most school districts and subject areas.

Teacher supply and demand is monitored in Illinois by the Research and Statistics Section (RSS) of the Department of Research, Planning and Statistics, in the Illinois State Board of Education (see Illinois State Board of Education, 1983, 1985a, 1985b). This administrative unit, which is mandated by Illinois statute, is responsible for reporting on teacher statistics to the state superintendent, the legislature, and various legislative commissions.

RSS performs the following primary data collection activities relevant to this study:

(1) Annual updates of the Teacher Service Record file;

(2) Annual surveys of teacher training institutions related to new teacher certification, occupational follow-up of teacher trainees, and subjective scaling of teacher supply and demand; and

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*The description of the Illinois model is drawn from Cavin (1986: Section III).

(3) Annual surveys of nonpublic schools.

The Teacher Service Record (TSR) file contains detailed demographic data and data on training and assignment for all professional staff employed by Illinois public school districts. The surveys of teacher training institutions provide the basic information on teacher supply for Illinois public schools. Nonpublic schools are surveyed annually on their enrollment, affiliation, and staffing level. Sample copies of the data collection instruments appear in Cavin (1986:App. A).

Structure of the Model

Illinois currently does not generate projections of either teacher supply or teacher demand. Instead, the RSS reports on the composition of the new certification pool and new hires by grade level and subject area. In past years, gross teacher demand was projected using enrollment projections and overall (current year) staffing ratios. However, these projections were not very accurate and the process was discontinued. RSS staff attribute the inaccuracy of these past projections to the fact that enrollments during this period were beginning to recover from a long-term decline, which affected the projections adversely both because of the inherent difficulties in forecasting trends during turning points of a time series and because staffing ratios are unstable when enrollment trends change.*

Nonetheless, the current reporting of teacher supply and demand is based on a model of sorts. The basic concept behind this model is that the number of new hires of teachers by subject area, or new teacher demand, be compared with the number of newly certified teachers in each subject area to determine areas of potential shortage. The definiton of teacher supply used by RSS is slightly different, because it includes new hires of experienced teachers (reentering from the reserve pool). However, since new hires of reentering teachers are defined to be a component of both supply and demand, these experienced teachers can be subtracted out, and the relevant comparisons that actually are being made are:

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*A new state law (Public Act 84-126) requires that four-year demand projections be generated by the State Board of Education. RSS currently is considering contracting with a group at a local university to construct a teacher supply and demand model that accounts for changes in enrollment, retention, and financial resources.

- Total new teacher certifications with total new hires and
- Total hires of newly certified teachers with total new certifications.

Thus, the first comparison, which is the gross supply/demand index presented by RSS, can be interpreted as the fraction of total new hires that potentially could have been made from the stock of newly certified teachers. The second, more conventional comparison, is simply an in-state employment rate for new Illinois teachers. Data for the past 10 years show that Illinois has trained and certified many more new teachers across all subject areas than can be hired and, furthermore, many more new teachers than the total number of additional teachers hired. In the mathematics and science subject areas, in contrast, total new teacher hires in most recent years have exceeded new teacher certifications. Nonetheless, only a relatively small fraction of newly certified teachers succeed in finding teaching jobs in math and science. Thus, in the aggregate there appears to be a hiring preference for rentrant teachers.

Teacher Demand

The current Illinois teacher model does not make direct use of enrollment data or staffing ratios. However, the State Board of Education does generate enrollment projections that could be used for projecting teacher demand. In addition, the TSR file could be used to compute staffing ratios by subject area. Therefore, in this section we discuss the available data and indicate how it could be used to generate projections of teacher demand.

Enrollments. Illinois projects enrollments for kindergarten, primary grades, and secondary grades, using a combination of birth rate and enrollment data. First, births are projected by applying age-specific birth rates to estimates of the population of Illinois women of childbearing age. Second, historical birth-to-grade level survival rates are computed as the total number of persons enrolled in a particular grade level range divided by the total number of Illinois births the appropriate number of years preceding the projection year. Third, projected birth-to-grade level survival rates are computed as the simple average of the survival rate based on the most recent year and the average of the survival rates based on preceding years; thus, the most recent year rate is weighted equally with the average of previous year rates.

Finally, the projected births and projected survival rates are multiplied together to obtain the projected enrollment level (see Illinois State Board of Education, 1985a).

The State Board of Education does not generate enrollment projections for nonpublic schools. However, it does collect annual enrollment data through its survey of nonpublic schools. These data could be used to project nonpublic enrollments either by pure time trend projection or by applying a historical nonpublic/public enrollment ratio to projected public school enrollments.

Staffing Ratios. While RSS currently does not compute staffing ratios, it does routinely collect the enrollment and staffing data necessary to construct grade-level staffing ratios. In principle, subject area staffing ratios also could be constructed, although subject area enrollment data are problematical, because figures are obtained from public school districts only every five years, in a periodic Census of Course Offerings. Staffing levels by subject area, of course, are readily obtainable from the TSR file.

Teacher Supply

Continuing Teachers. By far the largest component of teacher supply in Illinois is teachers continuing from the previous year. New hires in recent years consistently have accounted for less than 6-8 percent of the total teaching force in either primary or secondary schools. To some extent these data reflect the consequences of gradual declines in enrollments and staff contractions through the 1970s, but new hires are unlikely to become a large share of the teaching force even in periods of modest enrollment increases.

Because continuing teachers all have records in the TSR file, much more is known about their characteristics than other components of teacher supply. The TSR file permits the State Board of Education to construct very detailed information on turnover by subject area, by comparing consecutive years of the file. Table 4 presents historical turnover rates for primary and secondary school teachers and for mathematics and science teachers. Subject area turnover rates could be used to estimate what fraction of projected total teacher demand in each year would be accommodated by retention of previous-year teaching staff and how many new hires would be required. In addition, date-of-birth data on the TSR file could be used to construct age-specific attrition rates.

TABLE 4 Retention Rates for Illinois Public School Teachers 1977-1984 (Percentage Retained in Consecutive Years)

Year	Primary Grades	Secondary Grades		
		Mathematics	Science	All Subjects
1977-1978	90.5	91.7	92.1	90.8
1978-1979	90.4	91.7	92.3	90.2
1979-1980	91.6	92.3	90.5	91.9
1980-1981	91.8	92.5	92.5	92.1
1981-1982	92.6	93.0	93.8	93.3
1982-1983	92.5	94.6	94.5	93.0
1983-1984	93.5	n.a.	n.a.	93.4

NOTE: Data are for downstate schools only (i.e., all school districts except the Chicago Public Schools). This table shows retention rates of teachers for comparability to Table 5. However, the source publication shows attrition rates of teachers, i.e., 100 - the retention rate.

SOURCE: Illinois State Board of Education (1985b: Table 8; 1983: Tables 2,3).

One interesting observation from Table 4 is that these turnover rates do not provide support for the notion that math and science teachers are more likely to leave teaching for alternative occupations because of better opportunities. Turnover among math and science teachers consistently is *lower* than that of all secondary school teachers.

Newly Certified Teachers. As noted above, the supply of newly certified teachers is a main focus of the Illinois model. Recently, newly certified teachers have represented about 40 percent of new hires of science and mathematics teachers in Illinois. RSS collects two kinds of survey data that are related directly to new certifications. The first is an annual survey of Illinois teacher training institutions that requests detailed information on students who are completing preparation for a teaching certificate. Counts of such persons eligible to become public school teachers are disaggregated by

sex and by detailed subject area.* Historically, these surveys have been the only accessible source of information on teacher certification, because the Illinois teacher certification files were not automated. With the recent implementation of an automated master certification file, these surveys may decline in importance.

The second source of new teacher supply data is an annual survey of college and university placement directors, asking them to rate, on a 10-point scale, their assessment of teacher shortage or surplus in a number of subject areas. Since placement directors generally are aware only of the availability of teaching positions for their most recent graduates, these ratings represent the subjective assessment of placement directors of which subject areas suffer shortages or surpluses. Mean scores are reported for each subject area. These ratings may not be very accurate and must be interpreted cautiously, but they are broadly consistent with the trends noted in the gross supply/demand index to the extent that relatively fewer new math and science teachers are being prepared in relation to available positions than new teachers in other subject areas.

Obviously, a substantial fraction of newly certified teachers fail to obtain teaching positions in the Illinois public schools. The automated master certification file in principle could be matched against the Teacher Service Record file to identify the characteristics of this component of the reserve pool of available teachers. However, this match cannot be performed by subject area endorsement, both because the TSR file does not indicate subject area endorsement and because the certification file is not updated to reflect new subject area endorsements. Instead, RSS surveys college and university placement directors on the occupational choices of recent teacher graduates. Respondents are requested to provide counts of prior-year teacher graduates who are teaching in Illinois, teaching in another state, or in some other occupation. Unfortunately, not all placement directors respond to the survey, and the answers of those who do respond may be subject to unknown biases. Therefore, there is no reliable information available on the characteristics of newly certified teachers who fail to obtain positions in the Illinois public schools.

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*RSS staff believe that approximately 90 percent of the persons counted by the survey respondents actually receive Illinois certification. It currently is not known whether there is any variation in this rate among subject areas, but these comparisons could be made fairly easily.

Another component of the stock of newly certified teachers is teachers who migrate to Illinois from out-of-state. In some cases, these new certificate holders may be new teacher graduates from out-of-state teacher training institutions who expect to work in Illinois. However, many new certificate holders probably are experienced teachers from the school systems of other states. In either case, estimating the number of immigrant new teachers is likely to be very difficult for Illinois, because of the limitations of its certification file.*

Returning Teachers (Reentrants). Reentering teachers are another component of the reserve pool of available teachers. Considerably more information is available for these teachers than for newly certified teachers, because each reentrant teacher has previous Illinois teaching experience and, therefore, a record in the TSR file. In addition, the termination data from the TSR file could give important insights into the composition of the reserve pool. For example, by comparing the TSR file records for each returning teacher with the record for his or her most recent Illinois teaching appointment, one could identify the following groups:

- Those who have taken maternity leave;
- Those who have taken educational leave; and
- Those who have taken leave for medical reasons.

Moreover, one could estimate average spells of nonteaching activity and construct return ratios of the number within each termination category who ultimately return to teaching. However, as noted earlier, the TSR file does not contain subject area endorsements, and therefore it is not possible to identify groups in the reserve pool by subject area for estimating available supply.**

Noncertified Teachers. Illinois state law prohibits public school teachers from teaching within a subject area without

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*It is possible, by using the TSR file, to compute the numbers of new teacher hires who are from out-of-state, but not the total supply of available teachers from out-of-state.

**The TSR file does indicate subject area assignment, but while Illinois teachers must have current subject area endorsements to teach within that subject area, they need not be assigned to their primary endorsement area.

a current subject area endorsement. However, because the TSR file historically has not contained data on subject area endorsements and could not be matched against the certification file by subject area, there has been no convenient way for RSS to monitor compliance with this requirement. Therefore, it is not known how many noncertified teachers are employed by subject area, although the total number is believed to be quite small. However, computer records for newly certified teachers have begun to include data on subject area endorsements.

Model Performance

Since Illinois currently does not generate projections of either teacher supply or teacher demand, the issue of model performance is not really meaningful. The review of data sources bearing on teacher demand and supply undertaken by this study suggests that it might be possible to project teacher demand fairly reliably using enrollment projections and historical staffing ratios. But without detailed enrollment data for subject areas, neither enrollments nor staffing ratios can be projected for subject areas. With regard to teacher supply, it may be possible to use TSR file data to estimate some components of the reserve pool, specifically the number of teachers who have taught in Illinois public schools, have left, and are likely to return to teaching.

Users of Model and Potential for Disaggregation

Teacher supply status reports prepared by RSS routinely are distributed to the Illinois state legislature, the Illinois Teacher Certification Board, the state superintendent of education, deans of teacher training institutions, and college placement officers. The various state agencies review these reports as part of their respective policy review and policy-making functions. College deans and placement officers can use these reports to develop a better source of the needs of Illinois public schools for their graduates. However, teacher training institutions probably tend to have a pro-shortage bias,* which suggests that the teacher supply reports are discounted to some extent by this group of consumers.

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*The ratings of teacher shortage consistently suggest shortages in subject areas for which new certifications are marginally adequate to cover hiring needs (Illinois State Board of Education, 1985b: Tables 15 and 17).

Because the notion of teacher supply used by Illinois concerns the adequacy of teacher training programs to supply the instructional needs of the state's public schools, it makes little sense to think of disaggregating these supply figures for geographical subareas of the state. The teacher supply data, however, are disaggregated by subject area.

Enrollment projections currently are not disaggregated either by geographical area or by subject area. Since Illinois vital statistics do distinguish geographical units within the state, it should be possible to combine grade-level enrollment data with subarea population projections to generate enrollment projections for these subareas. However, these projections could be unreliable because of large variations among subareas in migration rates. It may be more difficult to forecast enrollments by subject area, because historical data on subject area enrollments are obtained only at five-year intervals. Therefore, if the subject area distribution of enrollment changes very rapidly, projections based on historical subject area enrollment distributions will be unreliable.

The New York Model*

New York, like Illinois, has experienced greater-than-average rates of decline in public school enrollments and teacher staffing over the past 15 years. Enrollments declined by about 25 percent during this period, while the number of classroom teachers declined by about 10 percent. By 1981, there was an average of about 13 applications received by districts for each open position (New York State Education Department, 1982). Thus, the aggregate market for school teachers in New York has been characterized by slack demand conditions in virtually all subject areas.

Projections of public school teacher supply and demand are made in New York State by the Information Center on Education (ICE), which is responsible for maintaining all education data bases and coordinating all data collection activities for the New York State Education Department (see New York State Education Department, 1983b, 1985a, 1985b, 1986a). ICE maintains the following major data bases of interest for this study:

- The Basic Educational Data System (BEDS), which contains both district and school level

*The description of the New York model is drawn from Cavin (1986: Section IV).

institutional data and professional staff data, for all public primary and secondary schools;

- The Higher Education Data System (HEDS), which contains data on postsecondary institutions; and

- The Nonpublic School Reporting System, which contains enrollment and other data on some 2,000 nonpublic schools in New York.

These data bases contain continuous annual (i.e., school year) series of major data elements from 1967 to the present.

The BEDS data base serves as the basis for most of the teacher supply and demand analysis performed by ICE. It has two main components: the Institution Master File (IMF), which contains detailed enrollment and staffing data for all public primary and secondary schools; and the Personnel Master File (PMF), which contains detailed demographic, educational, and job assignment data for every person employed as permanent professional staff by a public school in New York.* The PMF is especially important, because its longitudinal aspects can be (and are) exploited to distinguish new teacher hires from reentering teachers, to check whether teachers currently are teaching out-of-field, and to compute age-specific retention rates by subject area. Also, the reporting system for nonpublic schools functionally is very similar to the IMF component of BEDS and is mandated by the state. Copies of the data collection forms for BEDS are contained in Cavin (1986:App. B).

Structure of the Model

The New York teacher supply and demand model is, for forecasting purposes, really just a model for total and additional teacher demand. Teacher supply, in terms of new certifications and previously certified teachers who currently are not employed as teachers (i.e., the "reserve pool"), is not modeled explicitly. Recent experience suggests that many more teacher candidates are certified each year than are hired, so

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*To assess the reliability of these data, in 1980 ICE undertook a detailed validation study for all BEDS data forms. According to this study, error rates in BEDS data reporting ranged from about 1 percent for enrollment and staffing figures to 5-6 percent for some data elements in the PMF (see New York State Education Department, 1981).

that overall, teacher supply tends not to be a matter of concern. However, ICE does attempt to estimate the size of the reserve pool and monitors the characteristics of teachers hired from the pool.

Teacher demand is calculated by the following sequence of steps:

(1) Enrollment by grade level is projected using a combination of birth cohort survival rates and grade retention rates;

(2) Total teacher demand is estimated by applying projected staffing rates to the enrollment projections;

(3) Preliminary subject area teacher demand is estimated by applying subject area staffing ratios to subject area enrollments;

(4) These preliminary figures for subject area teacher demand are adjusted to the control totals computed in step 2;

(5) Projections of continuing teachers are made by applying historical subject area teacher retention rate distributions to the base year teacher age distribution;

(6) Projected new teacher hires, by subject area, are taken to be the difference between total teacher demand (from step 4) and teacher retention (from step 5); and

(7) New teacher hires are distributed between newly certified teachers and returning teachers by using historical data on hires.

Projections are prepared year-by-year for a 10-year period from the base year.

Teacher Demand

The New York teacher demand model requires data for enrollments and staffing ratios. Because of the richness of the BEDS data base, data for these variables are available by grade level and subject area.

Enrollments. Enrollments by grade level are projected using two basic sources of information. Initially, second

grade enrollments are estimated by applying historical birth cohort survival rates to birth projection data generated by the New York State Department of Commerce.* The second grade was chosen because birth cohort enrollment rates were considered more stable for grade 2 than for kindergarten or grade 1. Kindergarten and first grade enrollments are estimated using these second grade enrollment projections and the historical grade-to-grade retention ratios from kindergarten and first grade to second grade. Enrollment projections for grades 2-11 are generated by applying, successively, grade-to-grade retention ratios to enrollment data for the base year** or from the projected second grade enrollment figure, as necessary.

Enrollments by subject areas are projected using projected total enrollments and historical data on the distribution of total enrollment among subject areas. These enrollment figures are not, however, computed explicitly; instead, they are used as an intermediate result in the calculation of subject area distributions of future teaching staff needs. The source of data for subject area distributions of enrollment is the PMF component of BEDS.

ICE also generates enrollment projections by grade level for the nonpublic schools, by a process similar to that for public school enrollments described above. Second grade enrollments cannot be based directly on birth cohorts, however; instead, second grade enrollments are projected directly from historical data, with grade-to-grade retention ratios being used to construct other grade level enrollments. These grade level projections then are adjusted to a control total formed by projecting total enrollments by nonpublic school affiliation.

Staffing Ratios. Staffing ratios are constructed from BEDS data on teaching staff and enrollments. Overall staffing ratios are based on the Institution Master File, which provides control totals for constructing subject area staffing ratios that are based on PMF records. These ratios are projected using linear trends when possible, and using either the most recent year ratio or a weighted average of previous year ratios otherwise. The actual figure in each case is selected judgmentally.

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*This cohort survival rate is based on a weighted average of the historical birth cohort survival rates for the preceding 10 years, with the most recent years receiving greater weights.

**Grade-to-grade retention ratios are computed on the basis of the most recent two years.

In principle, staffing ratios could be constructed for nonpublic schools as well as public schools, but since nonpublic school teachers are not included in the PMF, there is no way to compute subject area staffing levels. Therefore, ICE typically does not construct staffing ratios for nonpublic schools.

Teacher Supply

Recently, continuing teachers have accounted for about 93 percent, newly certified teachers for about 2 percent, and reentering teachers for about 5 percent of mathematics and science teachers in New York. New York state law prohibits the use of noncertified teachers in public instruction, except in cases of emergency, which must be reviewed and approved by the State Education Department. Tabulations of PMF data reveal that fewer than 2 percent of the total state public school teaching staff taught in the 1984-1985 school year without certification.

Continuing Teachers. The PMF contains very detailed data on the teachers who continue teaching in New York public schools from the previous year. Since this group is by far the largest component of teacher supply, its characteristics tend to dominate any description of effective teacher supply.

Teacher turnover rates are used to construct projected stocks of continuing teachers in a given year. The difference between this stock and projected total demand constitutes the number of new teacher hires required.

The Personnel Master File component of BEDS permits ICE to construct very detailed distributions of teacher turnover by age and subject area, simply by comparing consecutive years of the file. Table 5 presents age-specific retention rates for mathematics and science teachers in New York public schools. These figures suggest that mathematics and science teachers leave teaching at essentially the same rate as all other secondary school teachers. There is no evidence from Table 5 that younger mathematics and science teachers are lured away from teaching to more attractive career opportunities at a greater rate than are teachers in other subject areas.

ICE computes the projected stock of continuing teachers as follows. They first construct the base year age distribution of teachers. The base year teaching staff is distributed into age intervals for each subject area and used as the entering group for a cohort survival projection. The contin-

TABLE 5 Age-Specific Retention Rates of New York Public School Teachers in 1984 (Percentage Retained from 1983)

Age	Mathematics	Science	All Secondary Subjects
Under 35	90.6	89.9	89.2
35-39	94.1	95.6	94.4
40-44	94.9	95.6	94.8
45-49	95.8	95.8	95.2
50-54	91.9	93.0	92.0
55-59	84.2	84.0	83.5
60 and over	73.2	69.1	70.2
Total all ages	92.4	92.7	91.6

SOURCE: New York State Education Department (1985a).

uing teachers for each projected year are "aged" through the projection period. The probability of retention to the projected year is taken to be the appropriate age-specific retention probability. Thus, the stock of continuing teachers is the number of teachers in each age group multiplied by the age-specific retention rate for that group. New hires, which are added each projection year to account for the balance of projected demand, are presumed to have the same age distribution as the continuing teachers. Thus, the age distribution of teachers changes over the projection period at a rate determined by the stock of continuing teachers, continuing an overall aging trend observed since 1967. Qualitative changes in the age distribution for teachers can be caused by the age distribution of new hires. However, the fraction of new hires in the total teaching force (currently about 10 percent) is not sufficient to offset the overall aging trend in the total teaching staff, which is expected to continue through 1990.

Newly Certified Teachers. ICE collects data through the Higher Education Data System (HEDS) on enrollment in teacher training programs in New York colleges and universities. However, these data are of limited relevance to the supply of new teachers, for two reasons. First, many teacher program enrollees may fail to obtain provisional teaching

certificates as a result of alternative occupational choices or for other reasons. Second, teachers trained in other states or other college programs can seek new certification in New York. For example, of the 681 persons who in 1984 received certificates to teach secondary school mathematics in New York, only about 30 percent were persons recommended by New York teacher training institutions. Therefore, the most relevant data are those bearing on certification.*

The Education Department recently has begun to maintain a cumulative file on persons certified to teach in New York. This file is based on certification transactions generated by certification applications by teachers.** It has been used to investigate how many newly certified teachers succeed in being hired as teachers by districts in New York, by matching the certification file against the PMF. Many persons newly certified to teach in New York do not in fact obtain teaching jobs in the New York public schools. The majority of these persons either accept teaching jobs in other states, jobs in other occupations, or try to work their way into New York schools by becoming substitute teachers. Some unknown fraction of this group remains for some unknown period in the reserve pool of available, but not currently working, teachers.

Teachers who migrate to New York from other states also can be considered part of the stock of newly certified teachers, although in many cases such immigrants already have teaching experience. For such teachers who actually are hired by New York public schools, of course, there are records in the PMF. The fields in the PMF that specify "occupation last year" and "location" of that occupation could be especially useful in estimating how many new college graduates and experienced teachers are hired from out-of-state. However, there appears to be no obvious means of estimating the potential suppply of teachers from out-of-state.

Returning Teachers (Reentrants). Many of the same data limitations discussed above for new teachers apply to reentering teachers as a component of the reserve pool. (Currently, experienced teachers account for 80 percent of all new hires, while newly certified first-year teachers account for 20 percent.) However, because reentering teachers have

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*New York State grants only provisional teaching certificates to new baccalaureates. Permanent certification requires a master's degree, which must be obtained within five years.

**It does not, therefore, necessarily contain current data on persons who are not actively teaching.

taught previously in the New York State public school system, they do have records in the Personnel Master File that will be as recent as their most recent teaching assignment. In principle, one could examine the PMF for spells of nonteaching activity and, characterizing these spells by duration, location of assignment, and age and sex of teacher, identify at least some components of the reserve pool. It may be possible, for example, to estimate the approximate size of the following constituent groups by subject area:

- Teachers on maternity leave (assuming that young female teachers who leave active teaching for relatively short periods are likely to have done so for maternity);
- Teachers who have left the teaching force entirely (assuming some arbitrary duration based on PMF data for completed spells of nonteaching activity); and
- Teachers who have taken extended educational leave to complete advanced degrees for permanent certification.

One data element in the PMF that could be especially helpful in this regard is "major occupation last year" and whether that occupation was performed in New York State.

Noncertified Teachers. As remarked previously, New York prohibits the use of noncertified instructors in the public schools, except under restricted circumstances. Moreover, New York law requires that courses be taught by a teacher having a current subject area certification in that field. The PMF contains relatively rich data on certification and assignment that permit the State Education Department to monitor compliance with this law. Tabulations of these data for a recent school year show that about 98 percent of the mathematics teachers and about 97 percent of the science teachers had the appropriate subject area certifications.

Model Performance

ICE does not routinely monitor the performance of its teacher demand model. However, one study made by ICE examined the accuracy of the subject area teacher demand projections for a two-year period. Not surprisingly, the projections were better uniformly for the first forecast year than for the second. But interestingly, the projections for mathematics and science teachers were considerably more

TABLE 6 Accuracy of 1982 Teacher Projections for New York (Forecast Error as Percentage of Actual)

Subject	1982-1983	1983-1984
Primary Grades:		
Kindergarten	+1.3	-21.6
Common branch	+0.9	-1.5
Other	+8.7	+6.1
Total	+2.1	-1.9
Secondary Grades:		
English	+0.2	-0.4
Foreign languages	-2.4	-8.4
Mathematics	-0.7	-3.9
Science	-0.4	-3.3
Social studies	-0.2	-2.1
Occupational education	+0.7	+2.1
Other	-4.3	-6.9
Total	-1.3	-3.4
Combined Grades:		
Special education	-26.2	-35.6
Physical education	-4.1	-6.1
Library	-0.7	-6.3
Reading	+3.8	+3.4
Total	-12.2	-18.0
All Subject Areas	-2.1	-5.7

SOURCE: New York State Education Department (1984).

accurate than those for all subject areas combined (see Table 6).

The overall stability of secondary school course enrollments explains much of the projection accuracy observed. For the most part, grade-level enrollments in secondary schools can be projected very accurately over short periods with knowledge of actual primary grade enrollments and historical grade-to-grade retention rates. The most unstable projections tend to be at the kindergarten and special educa-

tion levels, which are especially sensitive to educational policy.*

Users of the Model and Potential for Disaggregation

While the enrollment projections generated by ICE, especially those related to high school graduates, are widely used by New York school districts and postsecondary institutions, the projections of teacher demand per se are not. Currently, the main consumer of the teacher demand projections is the state commissioner of education, who uses the projections to respond to public concerns regarding imminent teacher shortages. One other obvious group of potential consumers for the teacher demand projections is the New York teacher training institutions. From the standpoint of a rational expectations model of teacher training, anticipated levels of teacher demand should be a major factor in determining teacher supply. However, according to ICE staff, teacher training institutions do not actively solicit these projections from the State Education Department. These institutions are not necessarily behaving irrationally, however. They may perceive that even a modest chance of teacher shortage outweighs the greater likelihood of teacher oversupply, or that teacher quality can be protected only by training a sufficient number of teachers for district administrators to have a number of applicants for each available position.

Enrollment projections in New York currently are disaggregated by grade level and geographical area. Enrollment-based teacher demand projections currently are disaggregated by subject area and primary-secondary levels. There appears to be little interest in further ICE disaggregation of enrollment projections by subject area or of teacher demand projections by geographical area, because school districts are likely to have access to a wealth of institutional experience that is difficult to quantify yet provides more reliable information than state level projections.

Because it has not needed to be particularly concerned about an adequate supply of teachers in recent years, New York does not forecast teacher supply, except to monitor teacher training program enrollments and teacher certificates issued. However, this situation may not persist. Therefore, New York could consider the following activities for estimat-

*For example, both the kindergarten and special education projections were affected in 1984-1985 by major policy changes in New York City.

ing the size and composition of the reserve pool of available teachers:

(1) Using the PMF, estimate the the number of teachers who are on maternity leave or educational leave or have left the teaching force permanently;

(2) Using the PMF, characterize the new teachers who are immigrants from other states; and

(3) Using the certification file and PMF in combination with unemployment insurance wage report records, characterize persons who are not currently teaching by their occupation and whether they are still in New York.*

The Florida Model**

For the last four years, the Strategy Planning and Management Information System division of the Florida State Department of Education has prepared a report on teacher supply and demand in Florida. Prior to that were several years of exploratory work with state university reseachers. The scope and detail of the report have increased as the report has evolved and grown. The most recent report (Florida State Department of Education, 1985) examines measures of actual teacher shortages (defined as vacancies or teachers out-of-field) by subject area and school district for 1984-1985, compares projected demand and supply by subject area for 1986-1987, and projects demand by subject area through 2000. (The demand projections cover single years through 1990-1991 and then the years 1995-1996 and 2000-2001.) The report also examines underlying population trends and the relative sizes of school-age and teacher-age cohorts to draw inferences about the supply of teachers and the supply-demand balance through the end of the century.

The estimates of supply and demand draw together and place on a common basis data from a series of sources. The

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*A less desirable, but potentially workable, alternative would be to match teacher records to social security records on employment. This could be more difficult for states because of lags in social security file availability and confidentiality rules regarding release of social security records.

**The description of the Florida model is drawn from Popkin and Atrostic (1986:Section IV).

common basis is subject fields such as "general mathematics," "English/language arts," and "social science/social studies." Reconciliation is required because subject fields generally differ from the categories in which the data are recorded to serve their original functions, such as specific classroom courses (for counting vacancies) and certification fields (for estimating the supply of new graduates and the number of current teachers teaching out-of-field).

Teacher Demand

Current-Year Estimates. Teacher demand estimates for the current school year are prepared each fall. Teacher demand in the current period is defined as the number of currently employed teachers plus the number needed to fill vacancies and to replace teachers teaching out-of-field, all defined in terms of full-time equivalences and established pupil-teacher ratios. The estimates are based on three data sources: a vacancy survey by subject field and district, conducted in the fall of the preceding year; teacher terminations in the preceding year, with interdistrict transfers separately identified; and teachers teaching out-of-field in the fall of the preceding school year.

School districts prepare the fall vacancy survey on the basis of vacancies between July 1 and October 1. Fall vacancies account for about 90 percent of vacancies for the full year. Vacancy data are combined with course code data on enrollment, teachers, and full-time-equivalent teachers. Reporting of course data is by course code, such as Algebra I or French II, and must be aggregated into subject fields for the annual report.

The vacancy survey, which began in 1982, is an evolving data series that expanded in the fall of 1983 to include information on the number of teachers in each course who were teaching out-of-field. Teaching out-of-field is defined as teaching courses for which the teacher does not hold the appropriate certification. In examining the out-of-field data for 1983 and 1984, Dade County appeared to contribute disproportionately to Florida's total out-of-field teachers. For example, about half of Florida's out-of-field secondary teachers were in Dade County, although only 14 percent of the teaching force is in that county. The report, therefore, reports three sets of out-of-field totals and rates--for the entire state, for Dade county alone, and for the state excluding Dade County--and examines trends in those statistics between 1983 and 1984.

The vacancy survey also collects information on the number of interdistrict transfers. This information is used to

refine the state aggregate for teacher demand to reflect net hires and vacancies. Interdistrict transfers account for a significant proportion of total newly hired teachers--one-fourth in 1983 and one-third in 1984.

Teacher termination data, by cause of termination, have been collected for a longer period. As much as half of all terminations in recent years are interdistrict transfers. The termination rate is used in computing projected teacher demand. No information is available on terminations by subject field, so the most recent distribution of vacancies by subject field is used in the projections to distribute total terminations across fields.

Projections. Teacher demand projections are made for the next school year and through the year 2000. The projections are based on estimates of enrollment, teacher-pupil ratios by course, and teacher termination rates in the aggregate and by course. The projections begin with the number of teachers in the base year and adjust that total for terminations and for changes in enrollment.

Enrollment projections are crucial components of teacher demand projections. Florida arrives at its enrollment projections through a complex process of refinement. Official population projections by county are developed for the state. These population projections have embedded in them economic growth and migration assumptions. Enrollments are based on age-group population projections refined by a combination of cohort-survival techniques and grade-retention ratios.

From these components, projections are prepared of the number of new teachers required by subject field and by source of teacher demand: enrollment growth, teacher resignations, program growth, and replacing teachers teaching out-of-field. Program growth refers to the impact of new state graduation requirements, but not the possible impact of giving districts the option to lengthen the school day to seven periods. For the 1986-1987 school year, Florida projected that 931 additional teachers of mathematics and 1,130 teachers of science would be needed (Florida State Department of Education, 1985:Table 23). Of the new mathematics and science teachers, 50 percent would be needed to replace resigning teachers, 42 percent to replace out-of-field teachers, and 8 percent to accommodate program growth. Enrollment change would have a negligible impact on demand for additional teachers in these fields.

Teacher Supply

Current Estimates. Estimates for the current period of additions to teacher supply derive from three sources: the number of candidates passing the most recent teacher certification examination, the number of newly certified teachers, and graduates of Florida teacher education programs. Existing data do not permit constructing estimates of reentrants from the reserve pool of nonteaching certificate holders.

The total number of applicants who take and pass Florida's written teacher certification examination provides information on potential new additions to Florida's supply of newly certified teachers. The number of successful candidates is an upper bound because not all candidates who pass the examination will obtain Florida teacher certificates. There were 7,426 successful candidates in 1983-1984, and 8,081 in 1984-1985 (Florida State Department of Education, 1985:Table 13). An alternative source, the Active Certificate File, discussed below, shows only 5,608 newly certified teachers in 1984-1985. The discrepancy arises because education students may take the examination before graduation and thus before they are actually eligible to receive a certificate, because potential teachers may fail to fulfill the other certification requirements, and because liberal arts students who take the examination may later decide not to enter teaching. Another limit to the usefulness of these data is that the certification areas of the teachers passing the certification test are not available. Information is available on whether the applicants for certification were graduates of Florida or out-of-state colleges and universities. In both 1983-1984 and 1984-1985, approximately 55 percent of the candidates passing the examination were graduates of out-of-state institutions.

The Active Certificate File, which records certification areas, does not track Florida certificate holders. Until the mid-1970s, Florida had lifetime teacher certification and therefore did not require current information. As a consequence, addresses and teachers' employment status are not current, so that whether a certificate holder is teaching, is employed otherwise in Florida, has left the state, or has died, is not recorded. It is possible to retrieve data by year of certification, and this information is used to provide an estimate of one facet of potential teacher supply by certification field. Comparisons by subject field between the number of newly certified teachers and the number of teachers new to the Florida school system are suggestive of shortages and potential oversupply. In some fields, such as elementary education, the number of new certificates outstrips the number of new teachers hired (1,978 versus 1,417 in 1984-1985),

while in other fields, such as mathematics, new hires exceed new certificates (399 to 274 in 1984-1985).

The Active Certificate File contains information on whether the teacher candidate graduated from a Florida or an out-of-state institution, but the quality of that data element is highly variable and was not used in the most recent report. The only source of such information is the file of successful certification candidates, which lacks certification field data.

A final source of data about Florida's pool of potential new teachers comes from a survey of the state teacher education programs conducted by the Florida Association of Colleges for Teacher Education. The association reports graduates and anticipated graduates by certification area. The State Department of Education aggregates these 138 certification areas into the 45 subject fields used in its annual report. Even with a two-year projection period, estimates of total Florida teacher education graduates and projections by field have had only mixed success. Estimates of this component of the flow of new teachers are therefore incorporated into the Florida model but are not regarded as firm estimates.

Out-of-state teacher graduates account for a sizable proportion of Florida's teacher supply: about 55 percent of those passing the certification examination, about 65 percent of those applying for new teaching certificates, and about 35 percent of newly hired teachers in recent years (see Florida State Department of Education, 1985:13, 20; Florida State Education Standards Commission, 1986:22). Information from teacher education programs in those states accounting for large shares of Florida's out-of-state new hires generally is unavailable. As the Florida report notes, assuming constancy in the percentages of out-of-state teachers is risky, especially for detailed teaching fields. Hard data on teacher migration are difficult to acquire for trend forecasting. Behavioral models, basing in-state and out-of-state mix estimates on relative rates of economic growth and teacher salaries, together with the population projections for teacher cohorts already used in Florida's analysis, could provide guidance on a more relevant definition of supply.

Projections. Because of the difficulties in generating even short-term, one- to two-year projections of teacher supply, longer-term teacher supply forecasts to pair with detailed teacher demand forecasts are not made. Instead, general discussions of relative trends in cohort sizes of K-12-age and teacher-age populations are made. Projected population growth for these cohorts in Florida shows that the population of typical new-teacher ages, 22 to 29, will grow only

modestly or will decline by about 5 percent, over five-year intervals between 1985 and 2000. At the same time, school enrollment projections show growth rates of at least 7 percent in each period. Similar trends are expected nationally, with a consequently bleak picture for the Florida supply-demand balance expected.

Designating Critical Fields

Florida statutes require the State Department of Education to identify annually areas of critical teacher shortage. The critical areas are used in implementing teacher loan and scholarship program funds and district quality incentive programs. Some fields (mathematics and science) are defined to be critical areas. Other critical areas are determined annually. The rules for determining which are the other critical areas require the detailed tabulations and projections of the report on teacher supply and demand, such as vacancies and teaching out-of-field by subject field and projected supply of Florida education graduates. The annual report forms the basis of the annual determinations of critical areas.

New Data System

The Florida Department of Education is putting in place automated student and staff information data bases. Each data base will contain extensive demographic data and appropriate data elements recording experience and achievement in the Florida education system. Despite the wealth of data that this system will make available, one crucial component of Florida's model will not be provided automatically: generating estimates of unfilled vacancies by subject field and district will require the report preparers to organize materials from the student and teacher data bases to produce estimates similar to those now provided directly by the school districts themselves.

The data base's major contribution to Florida's model is likely to be on the teacher supply side. Data on causes of teacher termination, date of certification, and whether the teacher was trained in Florida will be part of the automated data system. These data could provide the trend information needed to serve as a basis for projecting teacher supply over a longer horizon than two years and for estimating the role that migration will play in teacher supply. Specific salary information for each teacher will also be part of the record, permitting analysis of the effect of pay on teacher retention.

The South Carolina Model*

The South Carolina Department of Education prepared its first teacher supply and demand analysis in December 1985. The work was conducted on short notice from data collected for other purposes in response to a legislative request. Results of the analysis have been used to help designate critical teaching fields which in turn direct student loan programs. The report, prepared by the Management Information Section of the Office of Research, presents a one-year demand-supply comparison, a four-year comparison, and four-year projections, all reflecting state-wide demand or supply of about 35 detailed teaching fields (South Carolina State Department of Education, 1985a; see also 1985b). All three comparisons use similar definitions of supply and demand.

The one-year model spans 1984-1985, the year the report was prepared. Four-year comparisons also were made because 1984-1985 was believed to reflect unusual circumstances. South Carolina's Education Improvement Act of 1984 mandated increased staffing and course requirements, causing a one-time leap in the number of teachers hired. Four-year comparisons, for the years 1980-1981 to 1984-1985, lessen the impact of that one-time leap. For detailed teaching fields, new hires net of transfers for 1981-1985 are compared to the number of new certificates issued. Finally, projections to 1989-1990 are provided in the South Carolina report.

Teacher Demand

Analysis of Employment Patterns. South Carolina analyzed changes in employment of teachers by detailed teaching field, as a means of determining total teacher demand. A matrix cross-classifies detailed subject areas such as Algebra I into broader activity areas, such as mathematics. The change in total teacher demand, or more precisely employment, between 1984 and 1985, is broken down by category of teacher. That is, the demand for teachers in 1985 is determined by the taking the 1984 teacher total, subtracting teachers leaving (net of transfers between subject areas), and adding new hires of newly trained and reentering teachers. The estimates were prepared separately for three instructional levels: prekindergarten through eighth grades, secondary seventh and eighth grade courses, and ninth through twelfth grades. (Librarians and guidance counselors are included in the esti-

*The description of the South Carolina model is drawn from Popkin and Atrostic (1986:Section V).

mates as separate activity areas at the appropriate levels. They are included in the estimates to accommodate staffing requirements stemming from South Carolina's 1984 Education Improvement Act.)

Demand throughout the South Carolina report includes continuing teachers and new hires but excludes vacancies and counts of teaching out-of-field. Data on teacher vacancies by course, teaching field, or district, are not readily available from South Carolina's extensive data base. Separate reporting of teachers or full-time-equivalent teachers teaching out-of-field also are not readily available.

On a year-to-year basis, continuing teachers account for most--over 90 percent--of the second year's teaching force (92 percent for science and mathematics fields), and teachers with prior experience account for nearly two-thirds of the newly hired teachers in South Carolina (71 percent for science fields and 66 percent for mathematics--see South Carolina State Department of Education, 1985a:Tables 12 and 13). As a best first effort at estimating additional teacher demand by subject area, net internal transfers were combined with new hires in the South Carolina report.

A second approach to analyzing teacher demand examined a longer period, 1981 to 1985, which smooths out the effects of the Education Improvement Act on 1984-1985 teacher demand somewhat. Data from the teacher certification file were matched by social security number for 1980-1981 and 1984-1985, giving the number of continuing employed teachers. Newly employed teachers consist of teachers with no prior teaching experience and those with prior teaching experience. Demand over the 1981-1985 period is defined as total net transfers among areas plus the newly employed.

Examining data over the longer period sheds light on teacher attrition. As noted above, on one-year comparisons, continuing teachers constitute over 90 percent of the next year's teaching staff. In the four-year comparison, continuing teachers--teachers who taught in the South Carolina public school system in both 1980-1981 and 1984-1985--accounted for only 71 percent of 1984-1985 teachers. This is about what would be expected if the 8.3 percent attrition rate held steady over the period.

Teachers with experience accounted for only 45 percent of newly hired teachers over the longer period, compared with two-thirds on a one-year comparison. Newly certified teachers accounted for 55 percent of new hires. Newly hired in this instance means employed in the South Carolina public schools in 1984-1985 but not in 1980-1981. Careful analysis and additional calculations showed that most teachers hired between 1982 and 1984 were still in the system in 1985. Movement in and out of teaching during this period took

place primarily among teachers hired before 1981 and not employed in 1980-1981. These teachers are counted as experienced new teachers when they are rehired in a one-year comparison.

The result is that attrition is less over a longer period. Annual attrition on a one-year basis is 8.3 percent. The total attrition rate over the four-year period is 24.8 percent (teachers not in the system in 1985 as a percentage of total teachers in the 1980-1981 base period), corresponding to an annual attrition rate of 6.9 percent. The difference between the two rates is approximately 500 teachers per year, or about 19 percent of the annual total of teachers hired during this period.

Projections. South Carolina bases total teacher demand projections on enrollment changes. Enrollment is forecast five years ahead, using the cohort-survival method. The survival ratio is obtained by dividing enrollment in a given grade in a given school district by enrollment in the previous grade the year before in the same school district. Historical survival ratios are calculated and averaged over the previous five years. These average ratios are used to project enrollment for grades 2 through 12. First grade enrollment is projected as a function of the birth rate six years earlier. South Carolina acknowledges that its method does not explicitly take account of migration into and out of the state, although migration enters through survival ratios and annual updates to student projections. For total enrollment, South Carolina reports a forecast error of 0.3 percent for the 1984-1985 school year. District forecasts display larger percentage errors, the largest of which tend to be for small school districts.

Enrollment projections by grade were used to determine total teacher demand in 1989-1990. The projections do not include geographic detail. Projections of teacher demand by subject area for 1989-1990 were also provided in the South Carolina report. The projections assumed no program changes that would require additional staff, no reallocation of teachers across subject areas, and a continuation of the 6.9 percent annual attrition rate. A correction for the one-time hiring increase from the Education Improvement Act was incorporated.

Teacher Supply and Supply-Demand Comparisons

The primary measure of teacher supply in the South Carolina analysis is the number of new certificates issued in a period, including reactivated lapsed certificates. A total of 19 per-

cent of new certificate holders hold multi-area certifications. For these persons, fractional entries were made across their certification areas.

Current education graduates from South Carolina colleges were not counted as a supply source for several reasons. College degree titles did not match teacher certification areas about 20 percent of the time. The graduates may not seek certification in South Carolina. Finally, the number of new certificates issued over the last nine years consistently exceeded the total number of education graduates from South Carolina colleges by at least 47 percent, and usually by more than 60 percent.

Comparisons of additions to teacher supply (new and reissued certificates) are compared with additional demand (transfers among subject areas and newly employed) in 1985 by subject area. Geographic detail is not available. Comparisons for science fields show that holders of new and reissued certificates represented 97 percent of additional demand overall, with a 2-to-1 surplus of holders of new and reissued general science certificates and a 50 percent shortfall in most other science fields. For mathematics, holders of new and reissued certificates represented 60 percent of additional demand.

Similar supply-demand comparisons are presented for the 1981-1985 interval. Two differences in the four-year comparisons are (1) that supply over the four-year period includes only new certificates issued because data on reissued certificates were unavailable for all four years, and (2) that teachers are categorized by current certification areas rather than initial certification areas.

In both the one- and four-year comparisons, demand is a count of actual teachers, either newly employed or transferred among subject areas. Supply as measured is not as closely linked to the number of teachers available in 1984-1985. Not all newly certified teachers will choose a teaching career (or be hired). And experienced teachers, a major component of newly hired teachers, are not part of the supply measure.

Projections of teacher supply by field assume the average annual number of certificates issued will be the same in 1985-1990 as in 1981-1985. Other reserve pool sources of supply--individuals holding certificates but not teaching, persons holding lapsed certificates, in-migrants who do not apply for certificates--are not incorporated. Projections assume that the 1981-1985 new certificate rate remains stable.

A supply/attrition index is computed for each field, defined as average annual supply divided by average annual attrition. Index values range from 0.20 (driver education) to 6.99 (early childhood), and average 1.33. The average index

for science fields is 1.48. Within sciences, the range is equally diverse, from 0.44 for chemistry to 2.53 for general science. The index for mathematics is 0.95, within the range of science indexes. The supply/attrition index highlights relative oversupply and shortfalls, but precludes more precise evaluations. South Carolina's report notes, first, that the projections do not incorporate projected changes in enrollment (expected to be small during this period), and second, there is no clear critical value for the supply/attrition ratio. Beyond that, the assumption that attrition and new certification rates will remain stable is unlikely to be valid over this forecast period because of the 1984 Education Improvement Act. Changes stemming from that legislation affect many facets of teacher supply and demand, including teacher salary increases.

Critical Fields

South Carolina's 92 school districts were surveyed in November 1985 about their perceptions of critical teacher fields for 1985-1986. Critical fields had insufficient applicant pools or actual teacher vacancies in 1985-1986. Only 79 percent of the districts responded at all, and, among those, responses often were partial. The report presents results in detail for the responding districts and observes that statewide generalizations need to be viewed with caution. Mathematics and chemistry were among six most critical teaching fields reported, with mathematics deemed critical by 51 percent of responding districts and chemistry by 26 percent. These designations are consistent with results of the supply-demand analysis for the period 1981-1985.

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