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ABSTRACT

This study used exploratory modeling, a methodology that combines traditional quantitative forecasting techniques with the insights from scenario-planning, to analyze the conditions under which California can preserve access to its system of public higher education. The study identified two trends currently dominating the issue of future access--future state funding and feasible improvements in productivity. Three major conclusions were drawn: (1) if the fraction of state funds allocated to higher education remains at current levels or increases and if productivity increases at faster than historic rates, California will avoid serious access deficits; (2) if the fraction of state funds allocated remains at the current level, California can maintain access only by achieving productivity increases that are very large relative to historical rates of improvement; and (3) the above conclusions are largely insensitive to any plausible decisions about changes in student fees or trends in future demand for higher education. Four appendices provide additional detail and documentation on modeling enrollment and degrees, admission criteria, revenues, and productivity. (Contains 20 references.) (DB)

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The Class of 2014: Preserving Access to California Higher Education

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Preface

California's ability to preserve current levels of access to its system of public higher education is threatened by increasing enrollments, pressures on the state budget, and the increasing costs of higher education. This study addresses the conditions under which California can preserve access over the next two decades. The study uses a new approach to decision making under uncertainty, called exploratory modeling, that combines traditional quantiative forecasting techniques with the insights from scenario-planning.

This effort is one element of a larger program performed by RAND's Institute for Education and Training (IET) to study issues of direct relevance to California's higher education system. As such, this work should be of interest to California policymakers dealing with higher education within the state, as well as to policymakers in other states who may be facing issues similar to those confronting California.

This program has been supported by the California Higher Education Roundtable, which includes leaders from the California Community Colleges, California State University, University of California, and California private universities. This work has benefitted greatly from the direction and data obtained from these representatives, as well as from the California Postsecondary Education Commission.

Summary

For over thirty years, California's system of public higher education has led the nation in providing a college education to all citizens who could benefit from it. This policy has helped California generate great wealth and social mobility. In the emerging information economy, widespread higher education is more important than ever.

Several trends, however, suggest that California's ability to maintain, much less increase, high levels of college-education may be at risk. First, with the state's growing population, many more students will seek access to higher education. This "Tidal Wave II" could be as large as a million additional students. Second, the fraction of state resources devoted to higher education has been dropping in recent years because of growing demands on the state budget that compete with education, such as corrections, health, and welfare. Without a significant change in priorities, it is likely that funding for higher education will continue to be limited. Third, the costs of higher education have been rising faster than inflation over the last thirty years. While other sectors of the economy have also seen such rising costs, the higher education sector has not shown a significant offsetting increase in productivity.

The challenge for policymakers is to assure access to California higher education in the face of these trends. The problem is complicated by the fact that each of these trends is uncertain. No one knows precisely how many students will seek access to higher education, nor what funds will be available from the state, nor which productivity improvements are possible or desirable in higher education. A number of studies have assessed these trends and recommended actions state policymakers should take. These studies take the traditional approach of basing their recommendations on a single best estimate of each of these trends, essentially ignoring much of the uncertainty about the future.

When uncertainties are large, however, projections of the future are often wrong. Policies based on best estimates can fail if the future turns out differently than expected. In addition, decision makers can spend too much time debating the most likely future rather than developing flexible, robust strategies that can take advantage of fortuitous opportunities and avoid unexpected difficulties.

This study uses a new approach to make a quantitative assessment of the various trends facing California higher education and to suggest the implications they have for current policy choices. Our approach combines two previously distinct strands of strategic planning methodology. The traditional forecasting techniques employed in most studies of California higher education use sophisticated models and available data to project likely trends. These approaches provide much rigor but have difficulty coping with the uncertainty inherent in most decisions. Recently, many public and private sector organizations have begun to use scenario-planning techniques that help decision makers bring uncertainty into their planning and help different stakeholders agree on a framework for discussion. However, scenario-planning as currently practiced cannot make use of available quantitative information.

Our new approach, called exploratory modeling, exploits new computer capabilities to embed quantitative forecasting into scenario-planning. Using this approach, we examine how the interrelationship of key trends—growing demand for higher education, increasing competition for state revenues, and potential productivity improvements—may affect the future of California higher education. We use computer simulation models and data similar to those used by other studies. Rather than projecting the most likely trends, however, we examine a large number of plausible scenarios for the future. We make visual representations of these scenarios and use these "landscapes of plausible futures" to clarify key uncertainties facing decision makers, to provide a framework that can be used by the different stakeholders to debate differing views of the future, and to compare the effects of different policy choices.

While it may seem that abandoning a best estimate for a large set of plausible futures complicates the decision-making problem, it actually provides real and very useful information. Perhaps surprisingly, when we trade the question "What is most likely to happen in the future?" for "Which policy choice deals best with the uncertainty we face?" the complexity posed by an unpredictable future often falls away and reveals a small set of clear choices.

In this study, we show that two trends dominate the question of future access to California higher education: future state funding and feasible improvements in productivity. We find that

- If the fraction of the state general fund allocated to higher education remains at current levels or increases (breaking a twenty-year downward trend) and if productivity increases at faster than historic rates, California will avoid serious access deficits. If either of these fails to occur, however, California could face large access deficits.
- If the fraction of the state general fund allocated to higher education remains at the current level, California can maintain access only by achieving productivity increases that are very large relative to historical rates of improvement. At present, it is not known whether such productivity improvements are possible and, if they are, how to achieve them.
- The above conclusions are largely insensitive to any plausible decisions about changes in student fees or any plausible trends in future demand for higher education.

The uncertainties related to the future of California higher education are real and are a fundamental part of the challenge facing policymakers. Large uncertainties are not, however, a barrier to effective decision making. This study suggests that a flexible, robust strategy for ensuring future access to California higher education must pay close attention to two critical questions: Can the state readjust its financial commitments in order to maintain current funding levels for higher education? and Can the higher education system improve its productivity significantly faster than it has over the last thirty years?

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1. Introduction

Over the last forty years the state of California has built an impressive program of higher education. Anchored by its three-tiered public system, higher education has made immense contributions to the state's economy and the widespread opportunity (however imperfect) that has characterized California society. The state's commitment to higher education was codified in the 1960 Master Plan, which guaranteed that all individuals who could benefit from a college education would receive one. But whatever higher education has contributed to California in the past, it is likely to be even more important over the next twenty years. In our evolving information economy, a college degree is one of the key determinants of economic success. California's economy may be significantly poorer if the workforce does not become increasingly college educated. In addition, the state's social cohesion may suffer if restricted access to higher education widens income disparities among different groups in the state's population.

Trends Affecting Higher Education

Several trends over the last twenty years suggest that California's ability to maintain, much less increase, high levels of college education may be in danger:

- Demand for higher education, which has grown sevenfold in California since World War II, is expected to continue growing over the next two decades as the current bulge of students in the elementary schools works its way through the system. This so-called Tidal Wave II could be smaller or larger depending on whether the children of groups with traditionally low levels of education, particularly recent Hispanic immigrants, attend college at rates approaching those of whites and Asians.
- The percentage of the state budget that supports higher education has declined over the last twenty years as state spending on health, welfare, and corrections has increased dramatically. Public

resistance to increased taxes has largely capped total state spending. Thus, state resources per student in higher education have declined over the last decade and, without a significant change in state spending priorities, may continue to do so into the future. Concurrently, federal funding for student loans and financial aid has grown slowly over recent years and may continue to do so under pressures to balance the federal budget.

- The costs of higher education have risen consistently faster than inflation over the last thirty years. For instance, the Higher Education Price Index (HEPI), which measures the real increase in the prices of the goods and services used by higher education institutions, has outpaced the Consumer Price Index (CPI) by an annual average of one full percentage point. In other sectors of the economy, such sustained imbalances in the cost of inputs has led to either large changes in productivity, often with large organizational changes, or decline.

There is wide agreement about these basic trends, but there is a broad spectrum of opinion as to how deleterious they will be for the future of California higher education. For instance, the Research and Planning Department at the University of California predicts that state funding for higher education will show healthy growth over the next two decades, as the state economy grows and the fraction of state funding that goes to higher education remains constant (Copperud and Geiser, 1996). Conversely, Shires (1996) of the California Public Policy Institute of California predicts state support for higher education will drop precipitously as increased state spending on corrections cuts the fraction of the state general fund allocated to higher education in half. Similarly, there are many different projections of the precise number of students who will seek access to higher education.

Traditional Analytic Approach

In the traditional approach, a policy study would assess each of these conflicting predictions and decide which are the most likely future trends. Based on this best estimate of the future, the study would recommend the policies most likely to succeed. This traditional approach sometimes works very well, but policies based on one "best estimate" can fail if another future comes to pass. Unfortunately, decision makers and policy analysts, like most people, have a strong tendency to underestimate their uncertainty about the future.[1] They focus on some single best estimate often the one they think most likely or most supportive of the case they wish to make.

The dangers for California higher education are clear. Policies predicated on high levels of state funding that never materialize or on overambitious estimates of productivity improvements could deny large numbers of potential students a higher education. However, policies predicated on overly pessimistic assumptions could waste resources and disrupt lives, overfixing institutions that are not broken. In addition, decision makers can spend too much time debating the most likely future rather than developing flexible, robust strategies that can take advantage of fortuitous opportunities and avoid unexpected difficulties.

We believe that the differing predictions of the trends facing California higher education represent real uncertainty about the future that is difficult if not impossible to resolve. In some cases—such as the sensitivity of student demand to changes in tuition—there currently is not enough information to predict well. In other cases—such as the budget priorities of future legislatures and the impact of information technology on the classroom—the phenomena involved are inherently unpredictable. Thus, the different predictions for the future of California higher education do not reflect faulty analysis by one party or another so much as the fact that factors such as future funding or demand for education result from an inherently unpredictable set of future political and individual decisions.

New Analytic Approach

This study uses a new approach to make a quantitative assessment of the various trends facing California higher education and to suggest the implications they have for current policy choices. Rather than projecting the most likely trends, we examine a large number of plausible scenarios for the future. We make visual representations of these scenarios and use these "landscapes of plausible futures" to clarify the key uncertainties facing

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[1]See, for instance, Chapter 6 "Human Judgment about and with Uncertainty" in Morgan and Henrion, 1990.

decision makers, to provide a framework that different stakeholders can use to debate differing views of the future, and to compare the effects of different policy choices.

Our approach combines two previously distinct strands of strategic planning methodology. Traditional forecasting employs sophisticated models and available quantitative data to project likely trends. These approaches provide much rigor but have difficulty coping with the uncertainty inherent in most decisions. Recently, many public and private sector organizations have begun to use scenario-planning techniques, such as those developed by Royal Dutch Shell and the Global Business Network.[2] These approaches help decision makers bring uncertainty into their planning and help different stakeholders agree on a framework for discussion. However, scenario-planning as currently practiced cannot make use of available quantitative information.

Our new approach, called exploratory modeling (Bankes, 1994, 1993), embeds quantitative forecasts into scenario-planning. We exploit the new capabilities provided by wedding information technology (primarily networked computer workstations and powerful desktop graphics) to new concepts of decision making under extreme uncertainty.[3] In this study, we use computer models to describe future enrollments in the three public California systems of higher education—University of California (UC), California State University (CSU), and the Community Colleges (CCs); the revenues available for undergraduate education; the effects of potential productivity improvements; and the impact of potential fee increases. The quantitative data and mathematical representations we use in our analysis are similar and in many instances identical to those used by other analysts. But rather than use these models to make best-estimate projections, we use

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[2]Schwartz (1991) provides one of the classic descriptions of scenario-planning methodologies. His Global Business Network can be found at www.gbn.org. Wack (1985) provides a description of Royal Dutch Shells' developments in scenario-planning. Dewar (1993) describe assumption-based planning, the RAND-developed version of these methods.

[3]The field of decision analysis largely deals with situations where uncertainty about the future can be characterized by well-known probability distributions. Exploratory modeling can address cases of extreme uncertainty where we do not know the probability distributions. Some concepts similar to exploratory modeling can be found in the policy region analysis of Watson and Bruede, 1987.

them as constraints on the range of plausible futures for California higher education.

This approach is useful because there is often a great deal of information about a problem that is insufficient for making accurate predictions but is nonetheless useful for making decisions. For instance, simple accounting relationships among the flows of students and money through the higher education system impose important constraints on the future. While it may seem that abandoning a best estimate for a large set of plausible futures complicates the decision-making problem, the large set of plausible scenarios represents real and very useful information. Perhaps surprisingly, when we trade the question "What is most likely to happen in the future?" for "Which policy choice deals best with the uncertainty we face?" the complexity posed by an unpredictable future often falls away and reveals a small set of clear choices.[4]

This report focuses on the first step in an exploratory modeling analysis, creating a landscape of plausible futures for California higher education and using this landscape to identify those uncertainties and trends most salient to the decision-makers' choices. In the future, we hope to address the second step, comparing the performance of a large number of potential policy choices against this landscape to help policymakers choose the best policy consistent with their risk profile and their own expectations about the future.

Organization of This Report

The next section of this report summarizes the data and models we use to describe the California higher education system. Section 3 presents our landscapes of plausible futures for California higher education, and Section 4 presents our conclusions. A series of appendices describe the details of our calculations and provide additional results to support the arguments laid out in the main body of this report.

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[4]See for instance, Lempert, Schlesinger, and Bankes, 1996, which uses exploratory modeling to show that an adaptive strategy dominates the other policy options currently proposed to address the problem of global climate change.

2. Analytic Framework

This section describes the models and data used in our analysis. We organize this discussion around four general factors affecting the future of California higher education. As shown in Figure 1, **exogenous trends** are those factors affecting the future of higher education over which policymakers, in this case the members of the California Roundtable, have little or no control. **Policy levers** are those factors affecting the future that are controlled by the policymaker. **Measures** are ways in which to assess whether the performance of the higher education system is good or bad. **Relationships** are the ways in which the measures are related to changes in the levers and exogenous factors.

Our study focuses on three of the key trends facing California higher education: (1) increasing demand for higher education due to a growing population and increases in participation rates among traditionally under-represented demographic groups, (2) potentially constrained state funding for higher education, and (3) the degree to which productivity improvements can feasibly offset rising costs for higher education and decreasing revenues. These factors are shown as hexagons on the left side on Figure 1.

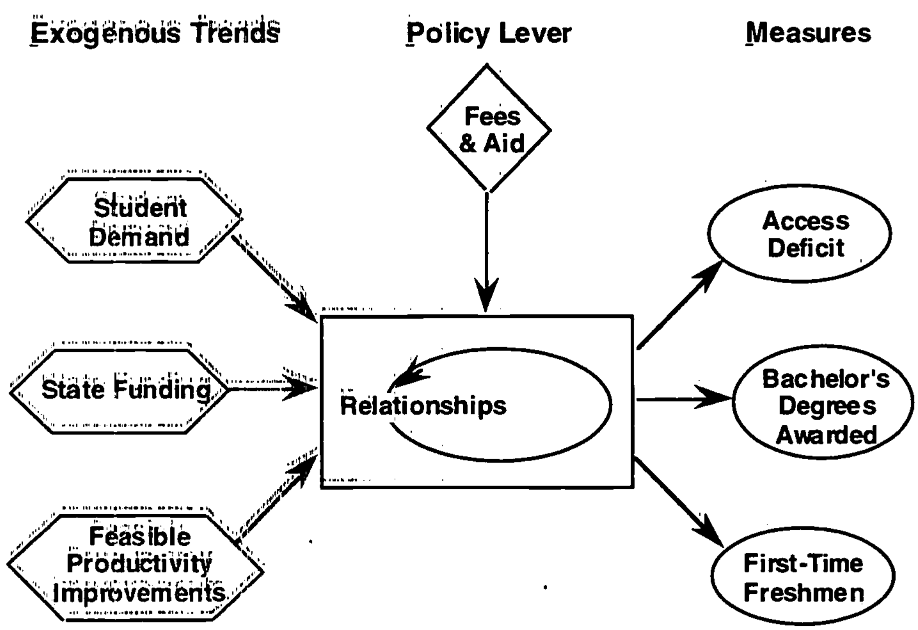

Figure 1—Key Factors Considered in Our Analysis

We consider three simple measures of the performance of the higher education system. Shown as ovals on the right side of Figure 1, these are

- **Access deficit**: the number of individuals who wish to enroll but cannot be accommodated. It is a clear and widely used measure that refers directly to one of the goals of the Master Plan.
- **Bachelor's degrees awarded**: a rough measure of an output of the higher education system that has some importance for society, recognizing that California higher education also provides training, performs research, and contributes to society in a variety of other ways. Degrees awarded is also a measure in which California is currently weak. California ranks 16th among the states in total college enrollment per capita but 46th in degrees awarded per capita.
- **Number of first-time freshmen**: a useful measure when time to graduation varies, since lingering upperclassmen can increase enrollments while reducing an institution's ability to admit new students.

We concentrate on one policy lever, student fees, which have been a focus of significant debate in recent years. The division between exogenous factors and levers is to some extent a choice of the decision-maker. For instance, the Roundtable has some influence over the proportion of state funds allocated to higher education. It could choose to take actions that might expand this influence. Similarly, the Roundtable could take actions to affect the feasible levels of productivity improvement in the higher education system. The choice of levers and exogenous factors in this study is meant as an initial examination of the range of policy options. In future work, we hope to expand our consideration to different policy levers, particularly those associated with improving productivity.

We consider a variety of relationships that determine how the exogenous trends and policy levers affect the measures. We focus on the flow of students and money through each of California's three public systems of higher education—UC, CSU, and the CCs. In brief, students wish to attend a public college or university. This demand is influenced by the level of fees. Each system determines how many students it will admit, based in part on its capacity as measured by the revenues available per student and by how efficiency improvements affect the revenues required per student. Each system gains revenues from state funds (CCs also get local funds) and from fees paid by enrolled students. Graduation and advancement rates affect the number of degrees awarded and the size of the student population. The student population, in turn, affects the revenues each system gains from fees, the total revenues per student, and the access deficit. In our analysis, we consider coupled flows among all three public California systems.

There are, of course, relationships that are not considered here. For instance, we do not consider the effect increased fees may have on speeding the rate at which students advance through the system. Nonetheless, the relationships we consider provide a solid basis for understanding the impacts of and interactions among the trends affecting California higher education.

The remainder of this section provides an overview of our analytic framework. The interested reader can find full mathematical details in the appendices.

Trends in Student Demand

The first key trend facing California higher education is an increasing number of potential students. Most observers expect that the demand for access to California higher education over the next twenty years will surge, though there is disagreement over how many individuals actually will and should seek to be accommodated. In this analysis, we consider four alternative estimates of the demand for higher education in California; together they span the plausible range of assumptions about the size of what is often called Tidal Wave II.

We make our estimates of future demand based on projections of California's population and using the "participation rate" methodology of Shires (1996). Following Shires, we assume that the demand for higher education is what the enrollment would be in the absence of financial constraints. We estimate these unconstrained enrollments in two steps, as more fully described in Appendix I. First, we use data on past higher education enrollments and California demographics to calculate the average rate at which individuals from different ethnic, age, and gender cohorts participate in the UC, CSU, and CC systems. Second, we multiply demographic projections for the future size of each cohort by these participation rates to estimate enrollments through 2014. As in Shires' work, we track the number of students in each class (freshmen, sophomore, junior, and senior) and the transfers between the systems. We augment Shires' model to include advancement and graduation rates, which we use to estimate the number of seniors awarded bachelor's degrees each year by UC and CSU.

Our four alternative enrollment estimates are shown in Figure 2. For each estimate, we calculate the number of students enrolled in the UC, CSU, and CC systems each year from 1996 through 2014. Each estimate uses a different set of assumptions about participation rates, but they all use common projections of California's future demographics. The line labeled "base" in each frame of Figure 2 shows our enrollment estimates for each system using the participation rates derived from enrollment data provided by the California Postsecondary Education Commission (CPEC) and the State Demographic Units' data for 1993 through 1995. For the high and low demand estimates, we use participation rates 20% higher and 20% lower, respectively, than those used for our base estimates. For the highest demand estimate, we start with participation rates 20% higher than the base values for each cohort and then further increase the participation rates for the Hispanic cohort by 4% annually. Currently, Hispanics represent the state's fastest growing population group and have college participation rates significantly lower than other groups. The highest demand estimate represents a case in which Hispanics are attending college with a participation rate increasing annually by 4%, chosen so that the participation rate for Hispanics in UC at the end of twenty years is nearly equal to that of non-Hispanic whites.[1]

Figure 2 also compares our four alternative enrollment estimates to projections made by CPEC, the State Department of Finance, and the University of California.[2] While the methodologies to generate these other

[1] For each alternative enrollment estimate, we report the number of students in each system, since the data used to calculate the coefficients for equations (4) and (5) are reported as "headcounts." To translate our enrollment estimates into aggregated full-year Full-Time Equivalents (FTEs), multiply the reported values by 0.96 for the UC system, 0.75 for CSU, and 0.64 for CC. Unless noted otherwise, we report enrollments in headcount numbers throughout this study.

[2] See CPEC, 1995b. UC estimates come from the Planning Group of the University of California Office of the President.

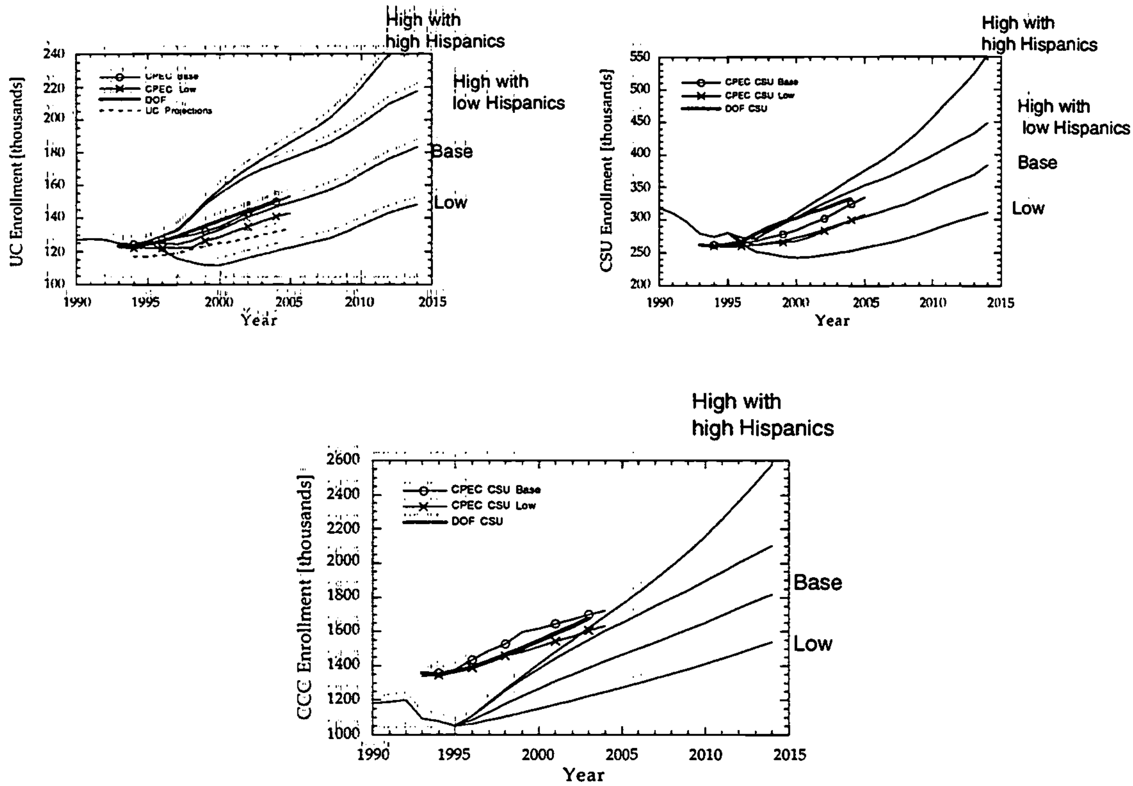

Figure 2—Alternative Enrollment Estimates Compared to Other Projections from Other Studies

projections differ from our model in the way they handle factors such as student flow, admissions assumptions, and definitions of student status, they are all based on state demographics, either in terms of total population of cohorts or in terms of high school graduates of cohorts, which is proportional to first order. The differences between the lines in the CC (lower) plot arise from differences in the way students are counted; in fact, our numbers agree closely with CPEC's Student Profiles reported data for the CCs from 1989 to 1994.[3] Within the period 1995 to 2005, for which enrollment projections are available from all the sources shown here, our baseline enrollment estimate is in general agreement with the other projections.

Other studies have made different choices—for instance, estimating participation rates using 1989 enrollment and demographics data.[4] These

[3] See "Student Profiles, 1995," CPEC, October 1995, p. 1–11.

[4] See, for instance, Shires, 1996.

differing estimates partly reflect real uncertainty about the demand for higher education among the next generation of Californians. Our alternative enrollment estimates span the breadth of plausible demand projections generally put forth for the future of California higher education.

Trends in State Funding

Besides demographic trends, a second key issue facing California higher education is the financial support that will be available from the state government. UC, CSU, and the CCs draw their income from a variety of sources, but revenues from the state general fund constitute a substantial fraction of each system's funds for undergraduate education. (CCs are additionally supported by local property taxes.) From 1970 to 1996, the fraction of the general fund allocated to higher education has dropped from 17% to 12% as state spending on other priorities—particularly corrections, health, and welfare—has increased. There is much disagreement as to whether this decline in state higher education funding will continue into the future. In our analysis, we consider five alternative estimates of the allocation of state general funds to higher education as a way to span the plausible range of assumptions about the funds available.

We make our estimates of future revenues based on data describing the current sources of revenues. It is not a straightforward task to determine the funds allocated to undergraduate education in each system: each system receives funds from a variety of sources, and many types of spending benefit several missions within a system. For instance, UC building maintenance benefits both undergraduate and graduate education. We thus make the simplifying assumption that the funds available for undergraduate education in each system come from three sources—the state general fund, student fees, and, for the CCs, property taxes. We estimate the current total general fund and property tax allocations to undergraduate higher education by multiplying CPEC data on 1995 spending per undergraduate in each system—$6,809 for UC; $4,734 for CSU; and $3,050 for the CCs (about equally divided between local property taxes and the state)—by CPEC's 1995 enrollment data. We estimate the current average fees per student in each system from CPEC data on total enrollment and the total revenues from fees. As described in detail in Appendix II, we then project future general fund and property tax allocations to higher education by assuming they grow at some annual rate.

We estimate future revenues from fees in each system by multiplying future fees by our estimates of the number of enrolled students. Fees can, of course, affect the number of enrolled students, as we discuss below. In this analysis, we focus only on revenues associated with the costs of current operations. We leave the important topic of capital costs for future work.

We make five alternative estimates of future allocations for the state general fund to undergraduate education. All five estimates assume that the California economy, and thus the state general fund, grows at 2.7% annually.[5] In our "optimistic" funding estimate, we assume, as does the UC Research and Planning Department, that the fraction of the general fund allocated to higher education will remain constant at its current level, and thus that the general fund revenues allocated to each of the three systems grows at 2.7% per year. In our two pessimistic estimates, we assume that a rapidly declining share of the general fund goes to higher education because of increased spending on corrections, K-12 education, and other programs (Shires, 1995; Carroll et al., 1995), so that the net general fund revenues allocated to the three systems declines by 1% annually. In one of these estimates, "pessimistic, with 98," we assume that the CC share of these declining revenues increases because of Proposition 98 mandates, so state revenues to the CCs grow at 1.5% annually while state revenues to UC and CSU decline at -3.5% annually. In the other pessimistic estimate, "pessimistic, without 98," we assume that state revenues to all three systems decline at -1% annually. We also include two intermediate estimates, "slow growth" and "flat," which have general fund allocations to each of the three systems growing, respectively, at 1.5% and 0% annually. These estimates are shown in Figure 3. Note that only four lines can be seen, because the two pessimistic plots have the same amount of total dollars allocated to higher education.

For each of our alternative estimates, we assume that property tax revenues to the CCs grow at 3% per year (Shires, 1996). Note that we do not consider potential changes in federal funding that may affect UC, nor do we consider property tax revenues that might affect the CCs. We have left these important topics to future work.

[5] This is the growth rate projected by UCLA for the California economy from 1996 to 2005. We have extended that projection to 2014.

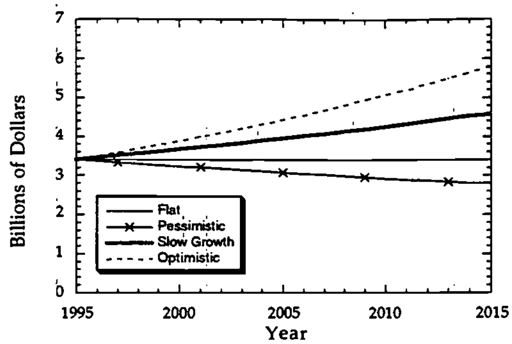

Figure 3—Alternative Estimates of the State General Funds Allocated to Higher Education

Affect of Funding on Access

The state funding available for higher education may strongly influence the number of individuals able to obtain a college education. Our earlier estimates of future demand were based on enrollment projections in the absence of financial strictures. Now we estimate enrollments under conditions of financial constraints and introduce the concept of an access deficit. We follow Shires (1996) in defining the access deficit as the difference between the projected, unconstrained demand for higher education and the number of students who could be accommodated at some projected level of future state funding.

Shires argues that prior to the recession of the early 1990s, funding for California higher education was largely demand driven—the state provided funding to serve projected enrollments. Since the recession, however, funding has been budget driven—the state allocates the funds it can afford to spend on higher education, and each of the systems does what it can with that allocation. Following Shires, we estimate enrollments in each of our scenarios using two simple rules for admissions: (1) unconstrained admissions, in which we allow students to continue to attend each system at the same rates they have in the past, and (2) constrained admissions, in which enrollment may be limited so that the level of spending per undergraduate remains constant in real terms. The unconstrained admissions rule gives demand-driven enrollment estimates, while the constrained admissions rule produces estimates of budget-driven enrollments. We thus calculate the access deficit for any particular scenario, as described in detail in Appendix III, as the difference between enrollments estimated using the unconstrained and constrained admission rules.

Figure 4 shows the access deficits for the pessimistic, with 98 and optimistic estimates of future state funding to UC (left) and CSU (right). Note that the access deficit is small to nonexistent with optimistic levels of funding, while the pessimistic funding estimate causes large access deficits in both systems.

Trends in Productivity

Potential improvements in productivity are the third key trend facing California higher education. Productivity is a difficult topic for a number for reasons. In recent years, many private sector organizations have significantly improved their performance and reduced their costs through productivity improvements. Productivity improvements should also be possible in the public sector, and, indeed, many public sector institutions have made progress in recent years. Nonetheless, productivity is often more difficult to measure and improve in the public sector compared to the private sector, since the goals of the typical public sector institution and the interests of its stakeholders are more diverse than is the case for most private sector organizations. In particular, there is the real danger that attempts to improve productivity in public institutions of higher education will degenerate into cost-cutting exercises that sacrifice the critical yet more intangible characteristics of the institution, such as the quality of its education.

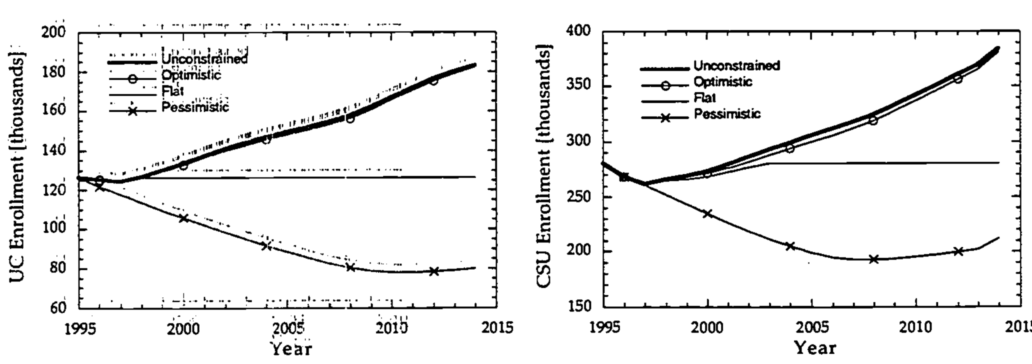

Figure 4—Effect of Alternative Estimates of General Fund ("Optimistic," "Flat," And "Pessimistic," with 98) on UC and CSU Enrollment

There are not enough available data and analyses to enable us to estimate the rate of productivity improvement possible in California higher education or to recommend steps the Roundtable should take to improve productivity. Instead, we explore a large range of assumptions about the feasible rate of productivity improvements within California higher education and examine the consequences of these various assumptions. We show that assumptions about feasible productivity improvements, along with assumptions about future state funding, are the key factors affecting the future of California higher education.

In his work on productivity in public sector institutions, Epstein (1992) describes two types of productivity improvements: efficiency and effectiveness. Efficiency refers to the level and quality of service an organization can produce from a given amount of input resources. Effectiveness refers to the extent to which an organization meets the needs of its stakeholders and customers. Epstein provides two specific ways to demonstrate productivity improvements that we use in our analysis. First, an organization can demonstrate a measurable reduction in cost while maintaining or improving key measures of effectiveness. Second, an organization can demonstrate a measurable improvement in one or more key effectiveness indicators without increasing input costs.

In our work, we take the graduate and advancement rates as our admittedly crude measures of effectiveness for UC, CSU, and the CCs. Advancement rates are directly related to average time to graduation, an important indicator used by UC and CSU to assess their performance; graduation rates are directly related to the number of bachelors degrees awarded, an important factor for both the individual students and the society at large. As described in detail in Appendix I, our model uses graduation rates to estimate the number of degrees awarded from our estimates of the number of seniors, and it uses advancement rates to estimate the number of members of one class who move on to the next. For our measure of efficiency, we take the minimum revenues required per student in each system. As described in detail in Appendices II and IV, we use this value to determine the maximum enrollment, and thus access deficits, in each system under conditions of financial constraints.

We consider five alternative assumptions about the feasible rate of efficiency improvements in California higher education: -2%, -1%, 0%, 1% and 2% annually. Figure 5 shows UC and CSU enrollments for the high, low, and middle values in this range. In each of these cases, we hold the effectiveness, as measured by graduation and advancement rates, constant. We see that a high rate of efficiency growth reduces the access deficit almost to zero, while a negative rate of growth causes very large access deficits, similar to those caused by the pessimistic estimate of revenues from the state general fund (see Figure 4).

We take our plausible range of efficiency improvements from data on the costs of inputs to higher education over the last thirty years. The Higher Education Price Index (HEPI) measures the real increase in the price of the services and goods, such as salaries and equipment, that U.S. higher education institutions use in their operations. Figure 6 shows that the price of these inputs has consistently outpaced inflation in the rest of the economy, as measured by the Consumer Price Index (CPI), by up to 3% per year. On average, prices to higher education have risen 1% faster than inflation over the last ten years. The figures shown here are nationwide averages; independent data do not exist for California institutions. Our choice of the range of annual efficiency improvements shown in Figure 5 is somewhat narrower than the range of variation in input prices shown in Figure 6. This conservative estimate should strengthen our claims that the actual, though currently unknown, level of feasible efficiency improvements will be one of the key factors determining the future of California higher education.

We also consider five estimates of the rate of improvement in effectiveness (advancement and graduation rates): -0.5%, 0%, 0.5%, 1.0%, and 1.5%. As with efficiency, few data and analyses are available for estimating what improvements are possible. Thus, we base our range of effectiveness improvement on comparisons of the number of bachelor's degrees awarded per enrolled student in different states. We choose a high estimate (1.5%) of annual effectiveness improvement as the rate necessary to achieve a four year time to degree for nearly all UC cohorts and for a majority of CSU cohorts. Figure 7 compares the enrollment and number of degrees awarded in 2014 by CSU for the case of the -0.5% decrease in effectiveness ("low") and the case of the 1.5% effectiveness improvement ("high"). In both cases, we hold

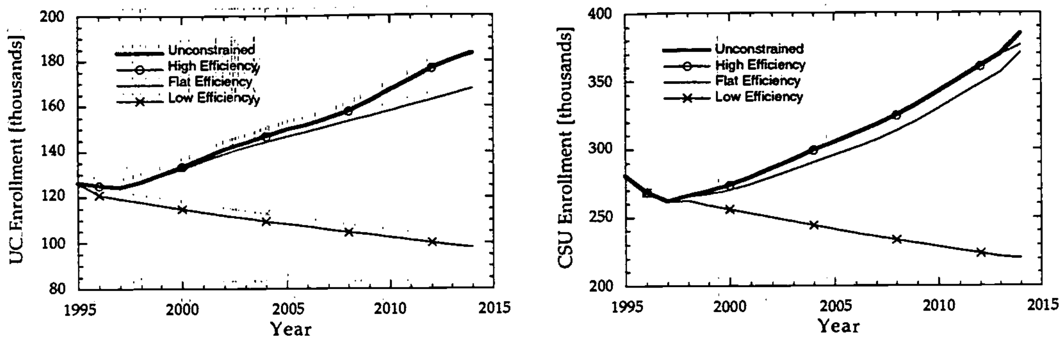

Figure 5—Effect of Alternative Assumptions about Feasible Efficiency Improvements on UC and CSU Enrollment

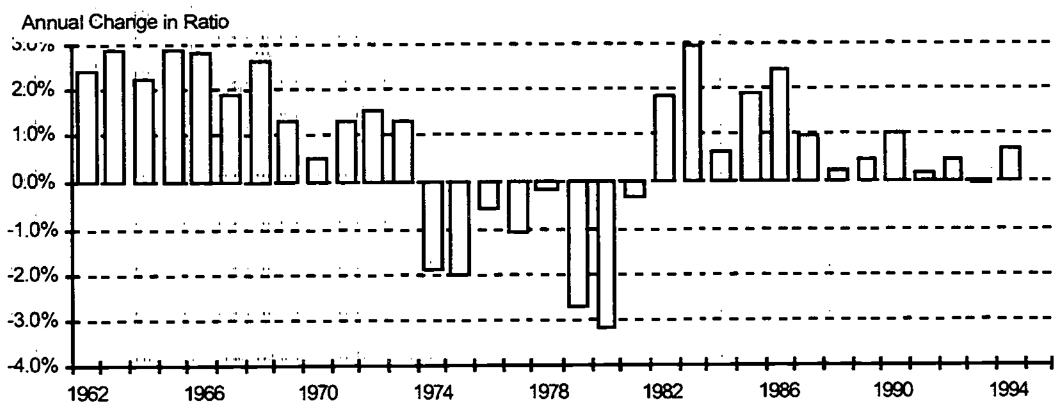

Figure 6—Cost of Inputs to Higher Education, 1962–1995

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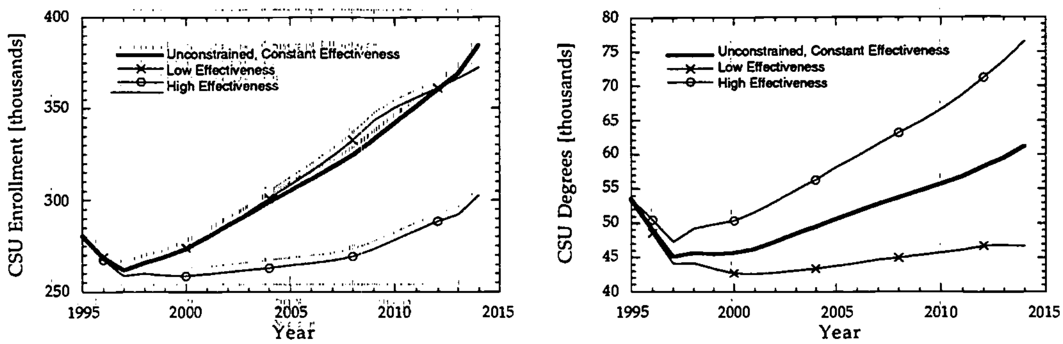

Figure 7—Effect of Alternative Assumptions about Feasible Effectiveness Improvements on CSU Enrollments and Degrees Awarded

efficiency constant. Note that high effectiveness increases the total number of degrees awarded even with reduced enrollment (since students flow through the system faster). Meanwhile, low efficiency produces fewer degrees but increases enrollment by "clogging up" the system with students repeating grades.

Student Fees and Aid

Increases in student fees can increase the revenues available for undergraduate education. Fee increases can also affect potential students' decisions on whether to seek a college education. Thus, fees represent an important decision for policymakers and have been a topic of much debate in recent years.

In our analysis, we estimate the impact of fees on enrollment by varying the participation rates based on data on the sensitivity of students to changes in the price of higher education. As discussed in detail in Appendix I, we use data compiled by Kane (1995) of the National Bureau of Economic Research. Using national data, Kane estimates the effects of tuition increases on enrollment in systems within the same state. He finds that a $1,000 tuition increase at public four-year universities decreases enrollment in four-year public institutions by 1.2%, increases enrollment at public two-year colleges by 0.5%, and increases enrollment at private colleges and universities by 0.5%. Kane also finds that a $1,000 tuition increase at public two-year colleges decreases enrollment in two-year public colleges by 4.7%, increases enrollment at public four-year universities by 1.8%, and increases enrollment at private colleges and universities by 0.4%. While Kane's data are among the best available, they are hardly definitive. Thus, we consider alternative estimates of the sensitivity of student demand to changes in tuition, ranging from no sensitivity to a sensitivity three times that measured by Kane.

In our analysis, we consider four different policy choices for fee increases over the next twenty years: 0%, 1%, 2%, and 3% per year. These values are consistent with the recommendations of a report (often called the Callan report) issued by the California Higher Education Policy Center (1996) that: (1) fee increases should not exceed 6%, 5%, and 4% per year at UC, CSU, and the CCs, respectively; and (2) the state should provide student financial aid equal to one-third of student fee increases. Our fee increases reflect the net increase seen by the student after financial aid.

Figure 8 shows the effects of a 1% ("Low Fee") and 3% ("High Fee") annual fee increase on UC enrollment for a scenario with optimistic funding from the state and low efficiency improvements. Kane's data were used for the sensitivity of enrollments to tuition. Note that while fee hikes increase the revenues per student for the systems (allowing more students), they simultaneously price out students through price elasticity (reducing enrollment). Overall, the effects of the fee changes are relatively small compared to the effects of changes in enrollment due to the different estimates of state funding for higher education.

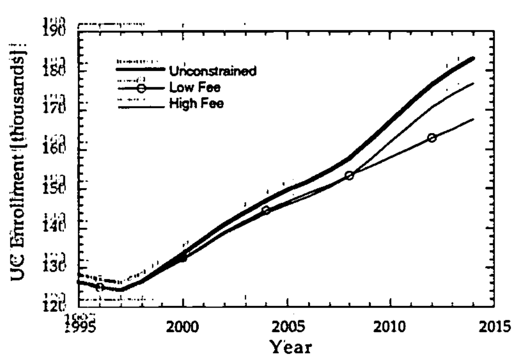

Figure 8—Effect of Student Fees on UC Enrollment

3. Landscape of Plausible Futures

Up until now, we have considered the implications of individual trends, assumptions, and levers, considered one at a time. Now we create a "landscape of plausible futures" to show how the interaction of all of these factors will affect the future of California higher education.

Funding and Productivity Trends Are Key

A key conclusion of this study is that California's ability to provide widespread access to a college education over the next fifteen years is dominated by two key questions: How much funding will the state provide for higher education? How feasible are significant improvements in productivity? We make the first part of our argument here, showing that the future UC access deficit depends strongly on what happens to allocations from the state general fund and on the feasible levels of improvements in efficiency.

Figure 9 shows the UC access deficit in 2014 for twenty-five scenarios, each with its own set of assumptions about the future levels of state funding for higher education in California and about feasible improvements in efficiency, the first of the two types of productivity improvements we consider. The figure represents each scenario with a colored box that shows the degree of access deficit in 2014 for a particular pair of assumptions about funding and efficiency improvements. This graph summarizes a large number of line graphs of the type shown in Section 2. For instance, the boxes labeled "UC" and "Shires" in Figure 9 correspond, respectively, to the optimistic and pessimistic lines in Figure 4.

It is clear from Figure 9 that UC cannot maintain current levels of access through 2014 if allocations from the state general fund decrease or if efficiency improvements do not offset cost increases for the inputs to higher education (i.e., efficiency does not improve at 0% or greater). With the "pessimistic" allocation of state funds, UC can maintain its performance only with very large increases in efficiency, and then only if the allocation of state funds is not subject to Proposition 98 constraints. With Proposition 98 constraints, UC can make up the funding shortfall in none of our scenarios. On the other hand, if efficiency improvements are insufficient for offsetting the cost increases for the inputs to higher education, even the most optimistic general fund scenarios cannot prevent an access deficit at UC.

It is useful to compare our results with projections made by others looking at the future of California higher education: (1) Shires (1996) of the California Policy Institute, (2) Cooperud and Geiser (1996) of the UC Research and Planning Department , and (3) California Higher Education Policy Center (1996). We use these comparisons to make two important points. First, the comparisons help validate our model of the California higher education system. Since we can reproduce the results of these other studies, our model must be reasonably consistent with those currently in use. Second, we show that these different projections are not primarily caused by differences in data and analytic methodology. Rather, the different projections embody fundamentally different assumptions about the future. It is not currently possible (nor may it ever be possible) to resolve these differences with available data and models. Thus, the divergent projections found in today's debate are to be expected and are not likely to be resolved anytime soon.

Shires projects a pessimistic future for California higher education. He assumes that real costs will remain constant with inflation, that state funding for higher education will drop by roughly 1% per year, and that student demand will grow by about 25% over the next ten years. As shown in Figure 9, the Shires projections correspond to our scenario with "pessimistic, with 98" funding and no change in efficiency. Shires bases his pessimistic assumptions about state funding for higher education on an analysis of future demands on the state budget. He notes that 82% of the state budget currently goes to K-14 education (K-12 plus the CCs), corrections, and health and welfare—all areas that are increasing (and in some cases are mandated by the state constitution or federal government).[1] As shown in Figure 9, our analysis agrees with that of Shires: if these trends continue, they will cause very severe access deficits at UC.

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[1] In 1996 federal welfare reform legislation replaced federally mandated welfare entitlements with block grants to the states. It is unclear how this will affect California's overall welfare spending over the next twenty years.

Copperud and Geiser have prepared enrollment estimates based on what they see as the best, worst, and most likely case allocations from the state general fund. The worst-case projections are similar to those of Shires. The most likely case assumes undergraduate enrollments based on 1995 participation rates, productivity improvements that keep up with inflation, and the state adhering to its intent (expressed in the Supplemental Report of the 1994 Budget Act) to increase annual funding to UC and CSU by the marginal cost of educating additional enrolled students. These projections correspond to our scenario with an optimistic general fund allocation and no change in efficiency. As shown in Figure 9, our analysis agrees with the analyses of the UC planning office that these trends, if they continue, will allow UC to avoid serious access deficits.

The Callan report proposes a "New Compact for Shared Responsibility" to enhance opportunity in California higher education. It advocates increasing state allocations to higher education as the number of students grows, but argues that productivity improvements can be used to keep this funding from rising as fast as the student population. The report suggests a combination of strategies that may allow UC, CSU, and the CCs to provide the same or higher levels of educational opportunity while reducing operating and capital costs to the state. The strategies aimed at operating costs reduce these costs by about 1% annually, which suggests state funding needs to increase 1.5% annually to accommodate the report's projected 2.5% annual growth in student population. Thus, the Callan report projections correspond to our scenario with slow growth in general fund allocations and 1% annual improvements in efficiency. As shown in Figure 9, our estimates agree with those of the Callan report that, in this particular scenario, UC avoids serious access deficits.

Level of Demand and Fees Are Less Important to Access

We have argued that access to California higher education in 2014 depends strongly on state funding and feasible levels of efficiency improvements. We will now show that access is relatively insensitive to two other factors often at the center of recent policy debates—the demand for higher education among students and changes in student fees. In particular, our analysis suggests that: (1) whether or not fees and the level of student demand are important depends strongly on trends in state funding and efficiency improvements, and (2) no plausible assumptions about student demand or fees can save the situation if either funding or efficiency trends are adverse.

Figure 10 shows the UC access deficit in 2014 for 100 scenarios, each with a different set of assumptions about future state funding, feasible efficiency improvements, and student demand for higher education. To examine the effect of three exogenous trends, the figure adds a third dimension to the two considered in Figure 9. As in Figure 9, the lower left-hand corner of the figure shows scenarios with low efficiency improvements and pessimistic general fund allocations. The upper right-hand corner of each panel shows scenarios with large efficiency improvements and optimistic general fund allocations. The reader can also see how the access deficit varies with the level of student demand by looking down each of the twenty-five columns running into the page. The boxes at the front of each column (those closestto the reader) show scenarios with high student demand; the boxes at the back of each column (those furthest from the reader) show scenarios with low student demand. In each column, the second box from the back is the scenario as shown in Figure 9.

Fourteen of the twenty-five columns in Figure 10 are either all red or all green. In these scenarios, the level of student demand makes little difference to the ultimate outcome.[2] Bad situations remain bad and good situations remain good, independent of assumptions about how many students seek admission to UC. However, in four of the fourteen columns, the access deficit goes from small to large as the level of student demand increases. In these cases, student demand significantly impacts the access deficit.

We find similar results for student fees. In some cases, fee increases have a large impact on access deficits, but for most combinations of future state funding and efficiency improvements, fees do not have a significant impact. Rather than plot four dimensions on a single figure, Figure 11 uses three two-dimensional plots to show access deficits at UC for forty-eight

[2]The level of student demand does change our estimates of the access deficit in these cases. However, it does not change access enough to cross the numeric thresholds represented by the colors.

scenarios with differing assumptions about increases in student fees, the level of student demand, future state funding, and feasible efficiency improvements. The top panel shows access deficit as a function of fees and student demand, assuming slow growth in state funding and an annual 1% increase in efficiency. The bottom row of this panel, with its three green and one yellow boxes, corresponds to the column labeled "A" in Figure 10. This panel demonstrates that this combination of state funding and efficiency improvement largely ensures small access deficits, largely independent of what happens to fees and student demand.

In contrast, the middle panel shows a situation in which the access deficit is strongly dependent on fees and access deficits. This panel shows access deficit as a function of fees and student demand, assuming no growth in state funding and no increase in efficiency. The bottom row of this panel, with its one yellow and three red boxes, corresponds to the column labeled "B" in Figure 10.

The third panel shows a case in which no plausible trend in student demand nor choice about student fee increases will save a bad situation. This panel shows access deficit as a function of fees and student demand, assuming pessimistic levels of state funding and an annual 1% decrease in efficiency. The bottom row of this panel corresponds to the column labeled "C" in Figure 10.

Effectiveness Trends Are Important to Maintain

We also find that access at CSU and the CCs in 2014, like access at UC, depends strongly on future state funding and feasible increases in efficiency and is relatively less sensitive to assumptions about student demand and changes in student fees. Figure 12 shows the importance of state funding and efficiency improvements for CSU. However, this figure has a different third dimension than that used in Figure 10. Rather than display the relative insensitivity of access deficits to student demand, Figure 12 shows the effects of feasible improvements in effectiveness, our second measure of productivity. The figure demonstrates that improvements in effectiveness (1) can have a significant impact on the number of CSU graduates, but (2) cannot maintain access when trends in funding and efficiency improvements are adverse.

Figure 12 has two panels. The upper panel shows the number of degrees awarded in 2014 at CSU for 125 scenarios, each with a different set of assumptions about the future allocations of state funding for higher education, feasible improvements in efficiency, and feasible improvements in effectiveness. The lower panel shows the number of first-time freshmen admitted to CSU in 2014 for the same 125 scenarios. One can read how the number of degrees awarded and the number of first-time freshmen vary with improvements in effectiveness by looking down each of the twenty-five columns running into the page in the upper and lower panels, respectively. The boxes at the front of each column show scenarios with significant improvements in effectiveness; the boxes at the back show scenarios with annual decreases in effectiveness. In each column, the second box from the back shows a scenario with no change in effectiveness, similar to the scenarios we showed in Figure 10.

Figure 12 shows that the number of degrees awarded by CSU in 2014 depends strongly on the level of feasible improvements in effectiveness, as well as on state funding allocations and improvements in efficiency. For instance, CSU cannot maintain its production of degrees, even in the most optimistic funding and efficiency improvement scenarios, if its advancement and graduation rates drop by 0.5% annually, as seen in the upper right-hand corner of Figure 12. This suggests that any increases in efficiency cannot come at the expense of the effectiveness of the institution. Conversely, CSU can maintain its production of degrees in scenarios with weak state funding and poor efficiency improvements, if it is able to increase its advancement and graduation rates by 1.5% annually, as seen in the middle of Figure 12.

Effectiveness improvements do not, however, have a significant impact on access, as measured by the number of first-time freshmen shown in Figure 13.[3] Twenty-two of the twenty-five columns in this lower panel are all red or green. In these scenarios, effectiveness improvements make little difference

[3]We use first-time freshmen rather than CSU access deficit as our measure of access in Figure 12 because improvements in efficiency actually increase the access deficit. This is because access deficit is a measure of total enrollment, and enrollment drops as students move more quickly through the system, as shown in Figure 7. On the other hand, as fewer upperclassmen linger in the system, space becomes available to admit more freshmen. This emphasizes the importance of looking at several metrics when examining the performance of a complicated system.

to the ultimate outcome. In only three columns do improvements in effectiveness change the number of freshmen admitted from red to green. Thus, Figures 12 and 13 demonstrate that effectiveness improvements can maintain the number of graduates produced by CSU even in scenarios where trends in state funding and efficiency are unfavorable, but that effectiveness improvements alone cannot maintain access when these other trends are adverse. We find similar results for UC and the CCs.

Differences Among Systems

Until now, we have emphasized the similarities among the UC, CSU, and CC systems because all three systems respond in fundamentally the same way to trends in state funding, productivity, student demand, and fees. Nonetheless, there are important differences, particularly between the CCs and the other two systems. Figure 13 shows the access deficit in 2014 at the CCs for 100 scenarios, each with a different set of assumptions about state funding, efficiency improvements, and student demand. This figure is analogous to Figure 10 for UC.

Figure 14 demonstrates that access to the CCs, like access to UC and CSU, depends strongly on the feasible improvements in efficiency. However, access to the CCs depends somewhat less strongly on state funding allocations and more strongly on student demand than is the case for UC or CSU. The CCs are more sensitive to demand because they draw from a much larger spectrum of potential students (both part and full time), many of whom technically repeat grades more frequently than their UC and CSU counterparts. Figure 14 shows this enhanced dependence on demand—in eight of the twenty-five columns (compared to four in Figure 10), increased demand changes the access deficit from green to red.

The CCs are less sensitive to state general fund allocation because nearly half of their revenue comes from local property taxes. Figure 13 shows this relative insensitivity to state funding allocation—in scenarios with no change in efficiency and baseline student demand, the CCs can maintain access deficits smaller than 25% even in the most pessimistic funding scenarios. In such scenarios, UC and CSU have access deficits greater than 25%. In addition, note that the CCs fare better with the "pessimistic, with 98" funding allocation than with the "pessimistic, no 98" allocation, while the two other systems fare significantly better with the latter. This result stems from the fact that Proposition 98 mandates a certain percentage of the state general fund to K-14 education, thus diverting funds to the CCs at the expense of UC and CSU.

4. Conclusions

These landscapes of plausible futures show how the interrelationship of key trends—growing demand for higher education, increasing competition for state revenues, and potential productivity improvements—affect the future of California higher education. We show that the last two trends dominate the question of access. The state must maintain or increase general fund allocations to higher education or make large productivity improvements in the higher education sector if it is to avoid very large access deficits. Accurate predictions of future demand and decisions about the level of student fees can be important in determining whether there will be access deficits if the system is on the cusp of serious trouble. However, if either productivity or general fund allocations fall toward one of the pessimistic scenarios, fees and participation rates will be largely irrelevant to understanding or solving the problem of access. California can maintain its current rates of awarding bachelor's degrees in the face of pessimistic funding scenarios if graduate rates increase toward levels currently found in other states. However, such improvements will not address problems of access.

This study also stresses the large uncertainties facing the future of California higher education. In our view, these uncertainties are real and a fundamental part of the problem facing the Roundtable and other decisionmakers concerned with higher education. The landscapes of plausible futures are relatively insensitive to assumptions about the participation rate because our uncertainty in the future demand for education is bounded by demographics. All the members of the class of 2014 are alive today. However, California's long-standing financial commitment to higher education is caught in the middle of long-standing, powerful, and conflicting trends. The public resists growth in total government spending at a time when spending on social services and corrections, also driven in part by demographics, continues to grow. Every funding scenario we show in our landscapes, from the most optimistic to the most pessimistic, requires that at least one long-standing trend be broken.

Similarly, over the last twenty years many institutions throughout U.S. society have prospered by significantly changing their organizations and their uses of technology so as to achieve significant improvements in their cost structures and the effectiveness with which they perform their missions. Others have not prospered, because they have not made such changes, have made the wrong changes, or have implemented changes poorly. Higher education is clearly different from the profit-making, private sector institutions that provide most of the examples of significant productivity increases. Nonetheless, the present time is fluid enough that the range of productivity increases shown in our landscapes seems a fair representation of the uncertainty as to what improvements may be possible.

Large uncertainty is not a bar to effective decision making. Managers routinely craft flexible, robust strategies that can take advantage of a wide variety of opportunities while avoiding the serious consequences of a wide variety of vicissitudes. However, the first step in crafting such a strategy is to pay sufficient attention to the key uncertainties about the future. The debate over the future of California higher education too often seems to shy away from addressing the central issues. It is not unreasonable to debate fees and projections of future demand; however, doing so makes implicit assumptions about future state funding and productivity improvements.

Overall, the future of California higher education rests on two questions: Can the state readjust its financial commitments in order to maintain current funding levels for higher education? and Can the higher education system improve its productivity significantly faster than it has over the last thirty years?

Appendix I
Modeling Enrollment and Degrees

In this appendix, we describe the details of the enrollment model used to generate the results given in Sections 2 and 3. Our model builds on the "participation rate" methodology used by Michael Shires [Shires, 1996], which is based on the demographics of California's general population. Like Shires, we draw upon this population to model the number of first time freshmen (FTF) in UC, CSU, and the Community Colleges broken down into different ethnic, age, and gender cohorts. Then, we model the flow of each cohort of admitted students between systems and classes (freshmen, sophomore, junior, and senior), as shown on Figure A.1. Unlike Shires, we also consider the effect of students who repeat classes and dropout; we also estimate the number of bachelor's degrees granted from the number of seniors in UC and CSU, including those students who had transferred from Community Colleges. Below, we will discuss these steps in more detail.

Calculation of Freshman Enrollment

We model the number of first-time freshman of a given ethnicity, gender, and age as

$$\begin{aligned} &FTF(system, ethnicity, gender, age, xt, year) \\ &\quad = Demog(ethnicity, gender, age, year) \\ &\qquad * cPRT(system, ethnicity, gender, age, xt, year) \end{aligned} \tag{A1}$$

where $Demog(ethnicity, gender, age, year)$ is the projected population in California of a given ethnicity, gender, and age cohort in a given year;[1] the participation rate $cPRT(system, ethnicity, gender, age, xt, year)$ represents the fraction of each population cohort that becomes freshmen in each (UC, CSU, or CC) system each year; and xt indexes full-time vs. part-time status. In the unconstrained admissions case, the full number of first time freshmen calculated above is

1Other groups have used projected high-school graduates as the baseline input;besides factoring an assumed coefficient for high-school graduation rate, these two methods should be equivalent.

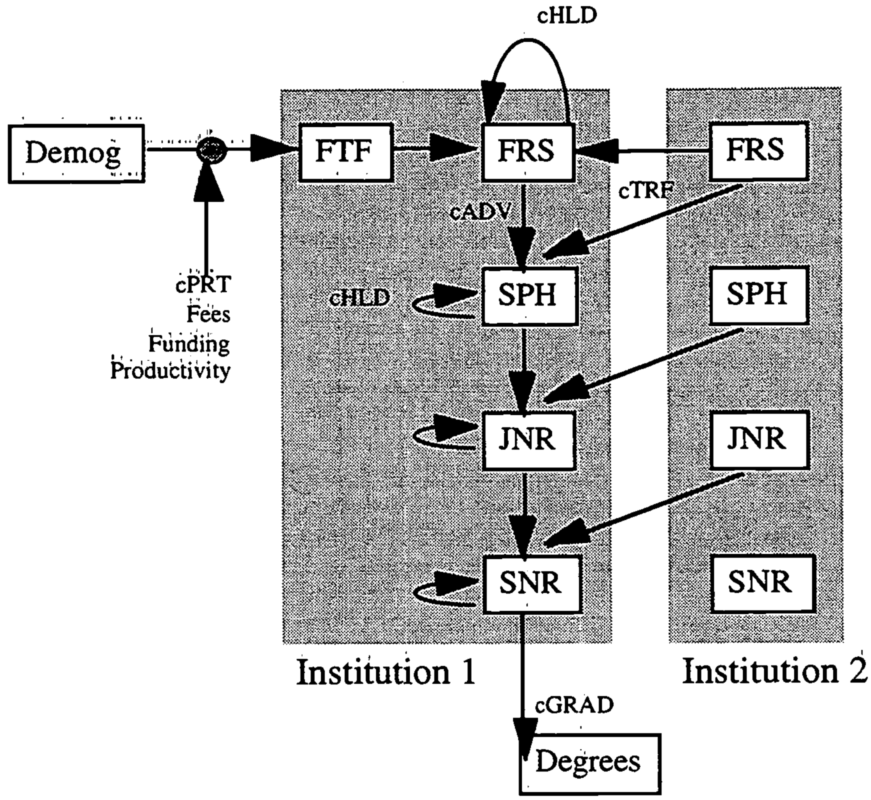

Figure A.1—Student Admissions and Flows

assumed to be admitted into the various systems. In the constrained admissions case, only a subset of this calculated number is assumed to be admitted; this process is described in detail in Appendix II.

We take *Demog(ethnicity, gender, age, year)* from population projections for each of one hundred cohorts[2] provided by the State Demographic Research Unit. We estimate participation rates from California Postsecondary Education Commission (CPEC) data on the number of first time freshmen from 1993 to 1995 in the UC, CSU and CC systems.[3] We parse this data to generate historical populations of first time freshmen broken down into the

2 In our model, the state's population is broken down into one hundred cohorts of ethnicity (Asian, Black, Hispanic, White, and Other), gender (male and female), and age group (10 categories ranging from 0 to 99+ years old).

3 Unless otherwise stated, all historical student data for the state were obtained from CPEC data files. Although CPEC has data going further back than 1993 we have averaged over only the last three years of data.

cohorts listed above.[4] We then use demographic data for each cohort from 1993 to 1995 to find the average participation rate:

$$cPRT(system, ethnicity, gender, age, xt) = \frac{1}{3} \sum_{year=1993}^{1995} \frac{FTF(system, ethnicity, gender, age, xt, year)}{Demog(ethnicity, gender, age, year)} \quad (A2)$$

Following Shires, we use the value for the first time freshmen (from equation A1) to calculate the total number of enrolled freshmen as

$$\begin{aligned} FRS(sys, year) &= FTF(sys, year) \\ &\quad + cHLD_1(sys) * FRS(sys, year-1) + TRF_1(sys) \end{aligned} \quad (A3)$$

where $cHLD_1(sys)$ is the percentage of freshman in each system who repeat their freshman year and $cTRF_1(sys)$ is the number of students from other systems who transfer in as freshmen. We assume these coefficients remain constant over time and estimate them using CPEC data (1) on the enrollment for each system by class, ethnicity, gender, full/part-time status, and year; (2) the number of transfers between systems by source system, destination system, class, ethnicity, gender, full/part-time status, and year; and (3) the number of first time freshmen by system, ethnicity, full/part-time status, and year.

Calculation of Sophomore, Junior, and Senior Enrollment

Analogously to the freshmen class, we write the number of students enrolled as sophomores, juniors, and seniors in each system as

$$\begin{aligned} SPH(sys, year) &= cADV_2(sys) * FRS(sys, year-1) \\ &\quad + cHLD_2(sys) * SPH(sys, year-1) + cTRF_2(sys) \end{aligned}$$

$$\begin{aligned} JNR(sys, year) &= cADV_3(sys) * SPH(sys, year-1) \\ &\quad + cHLD_3(sys) * JNR(sys, year-1) + cTRF_3(sys) \end{aligned} \quad (A4)$$

$$\begin{aligned} SNR(sys, year) &= cADV_4(sys) * JNR(sys, year-1) \\ &\quad + cHLD_4(sys) * SNR(sys, year-1) + cTRF_4(sys) \end{aligned}$$

4Actually, the original data has First-Time Freshmen broken into cohorts of ethnicity, gender, full/part-time status, and year. In order to assign an age distribution, we use the age distribution of the entire Freshman class (which includes transfers and holdovers from previous years, which thus slightly skews the age higher).

where the first term on the right of each equation is the number of students that advanced into that class from a lower class, the second term is the number that remained in the same class from the previous year, and the third term is the number that transferred into that class from another system. Unfortunately, we cannot calculate the advancement and holdover rate coefficients directly, because the existing data does not distinguish members of a class (e.g. sophomores) advancing from the previous class (e.g. freshman) from members of that class held over from the previous year (e.g. students who repeat their sophomore year); there is no data on "first-time" sophomores. We can, however, estimate these coefficients indirectly, as described below.

Shires writes the number of enrolled sophomores, juniors, and seniors as

$$\begin{aligned} SPH(sys,year) &= cADV_2'(sys) * FRS(sys,year-1) + cTRF_2(sys) \\ JNR(sys,year) &= cADV_3'(sys) * SPH(sys,year-1) + cTRF_3(sys) \\ SNR(sys,year) &= cADV_4'(sys) * JNR(sys,year-1) + cTRF_4(sys) \end{aligned} \quad . \quad \text{(A5)}$$

Shires estimates his effective advancement rates, $cADV'(sys)$, for the years with available data, as the ratio between two adjacent classes. Using this general method, we find, for instance,

$$cADV_2'(sys) = \frac{1}{3} \sum_{year=1993}^{1995} \frac{SPH(sys,year) - cTRF_2(sys)}{FRS(sys,year-1)}, \qquad \text{(A6)}$$

where the summation is used to average over three years. Similar ratios give $cADV_3'(sys)$ and $cADV_4'(sys)$. Historically, these ratio are relatively stable over time.

We can now combine equations (A4) and (A5) to relate cADV' to cADV and cHLD. The equations for the sophomore class give

$$\begin{aligned} & cADV_2(sys) * FRS(sys,year-1) + cHLD_2(sys) * SPH(sys,year-1) \\ & \quad = cADV_2'(sys) * FRS(sys,year-1) \end{aligned} \quad . \text{(A7)}$$

and similarly for the junior and senior classes.

We can get a second equation for $cADV_n(sys)$ and $cHLD_n(sys)$ by noting that in any given cohort of any given class, the students must either: i) remain in the same class, ii) advance to the next class, or iii) drop out or transfer to another system. Thus

$$cADV_n(sys) + cHLD_n(sys) + cDRP_n(sys) = 1 \quad , \qquad \text{(A8)}$$

where $cDRP_n(sys)$ refers to students leaving by dropping out or transferring.

We can now solve for $cADV_n(sys)$ and $cHLD_n(sys)$ using equations (A7) and (A8). We can use drop out and transfer-out data for the UC and CSU systems available in the form of life-tables which track cohorts of students on a year-by-year basis (rather than grade-by-grade). While these data are not necessarily equivalent in character with the enrollment data (which track students by grades), the fact that we are mostly focusing on those students who stay within the systems rather than those who leave makes this analysis fairly insensitive to the details of the drop out rate. Not surprisingly, the enrollment predictions obtained using this method agree fairly closely with the results obtained by Shires.

For the Community Colleges, we calculate enrollments using Shires' equations (A5), because insufficient data is available to reliably calculate the coefficients for equations (A4). Furthermore, we set the advancement and transfer rates for the junior and senior classes to zero, since these classes do not exist in the CCs. We treat transfers from the Community Colleges to the freshmen, sophomore, and junior classes at UC and CSU in the same way as we treat transfer between the four-year systems. However, we assume Community College transfers going into the UC and CSU senior class come from the CC sophomore class, rather than from a non-existent junior class. Transfers from the CCs are treated as a distinct cohort as they progress through the UC and CSU systems.

Calculation of Degrees Awarded

We calculate the number of bachelor's degrees awarded each year by the University of California and California State Universities as

$$Degrees(sys, year) = cGRAD(sys) * SNR(sys, year-1) \quad , \qquad \text{(A9)}$$

where $cGRAD(sys)$ is the graduation rate for each system, broken down into the various student cohorts enumerated above. We use 1993 to 1995 data for the ratios of the number of degrees awarded divided by the number of seniors to calculate $cGRAD(sys)$.[5] The available data also specify the number of degrees awarded to students who had transferred from the Community Colleges.[6] Because we track those transfer students separately, we can also project the number of bachelor degrees awarded to CC students who eventually transfer into UC or CSU.

5 These data may be obtained at the CPEC website.

6 From 1993 to 1995, nearly a quarter of all degrees awarded by UC went to such transfers, with nearly one half for CSU.

Appendix II
Details on Admission Criteria

Constrained Admissions

Appendix I specifies the details of the enrollment model for the case of simple unconstrained admissions, using equation (A4) for UC and CSU and using equation (A5) for the Community Colleges. For the case of constrained admissions, we assume that the constrained system limits its admissions each year such that the revenues per student remains greater than or equal to the 1995 values. Thus, we write this constraint as

$$Enrollment(sys, year) \leq Enrollment(sys, 1995) * \frac{Revenues(sys, year)}{Revenues(sys, 1995)} \quad \text{(A10)}$$

where $Revenues(sys, year)$ are the revenues for undergraduate education in each system estimated as described in the next section. We assume that a system admits the maximum number of students each year such that the total enrollment satisfies equation (A10). If revenues are sufficiently large, the system can admit all the students who wish to become first-time freshmen, as in equation (A1). If revenues are insufficient, equation (A10) becomes the binding constraint and we calculate the number of first-time freshmen admitted iteratively, since the revenues depend on the number of student enrolled through the student fees.

In any given scenario, we can set the admissions criteria, constrained or unconstrained, individually for each system. Because of transfers, the admissions criteria at one system will affect the enrollment at another. Figure A.2 compares enrollment at CSU and revenues per undergraduate in the cases of constrained and unconstrained admissions for the slow-growth scenario for the state general fund revenues to higher education. Note that unconstrained admissions results in larger enrollments than the

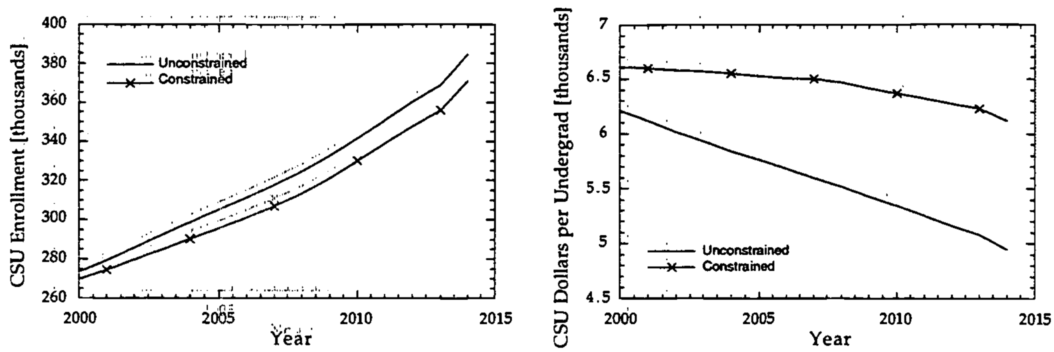

Figure A2—Effects of Constrained and UAdmissions on CSU Enrollments and Revenues Per Student.

constrained case but lower revenues available per student.[1] With unconstrained admissions, alternative assumptions about the allocation of state general funds to higher education has no effect on enrollment, as seen in comparison with Figure 4, though it can have a large impact on revenues per student. For constrained admissions, increased state funding increases enrollment by raising the number of dollars available for undergraduate education.

Effect of Student Fee Changes

In addition to financial constraints, admissions of first time freshmen can also be modified by changes in the student fee. Changes in student fees can affect potential students' decisions whether or not to enroll in the UC, CSU, and CC systems. We calculate the admission of first-time freshmen in each system as a function of the fees by re-writing Eq. (A1) as

$$\begin{aligned} &FTF(sys, ethnicity, gender, age, xt, year) = \\ &\quad Demog(ethnicity, gender, age, year) \\ &\quad\quad * cPRT(sys, ethnicity, gender, age, xt, year) * ePRC(sys, fees), \end{aligned} \tag{A11}$$

where $ePRC(sys, fees)$ is the elasticity of demand for a given system based on the fees in all systems (to allow for both self- and cross-elasticities).

1 The apparent decrease in revenues per student in the constrained case arises from the fact that the modeled revenues per student increases from 1995 to 2000; the subsequent decline merely returns this value to the 1995 level by 2014.

We estimate these elasticities from data compiled by Tom Kane of the National Bureau of Economic Research. Kane estimates the effects tuition increases on enrollment in systems within the same state (based on national data). His preliminary findings indicate that:

- The effect of a $1000 (in 1991 $) increase in public 2 year tuition is:

  A decrease in public 2 year enrollment of 4.7%

  An increase in public 4 year enrollment of 1.8%

  An increase private enrollment by 0.4%

- The effect of a $1000 (in 1991 $) increase in public 4 year tuition is:

  An increase in public 2 year enrollment of 0.5%

  A decrease in public 4 year enrollment of 1.2%

  An increase private enrollment by 0.5%

In our model, we write these relationships as

$$ePRC(sys1, UCfees, CSUfees, CCCfees) = \prod_{sys2}\left[1 + K \cdot cELS(sys1, sys2) \cdot 1000 \cdot \Delta(sys2)\right] \qquad \text{(A12)}$$

where the product is over the three types of systems, $sys2 = UC, CSU, CC$; $\Delta(sys2) = Fee(sys2, year) - Fee(sys2, year-1)$ gives the year to year change in the student fees at various systems; K is a simple constant; and $cELS(sys1, sys2)$ is the self or cross-elasticity for demand at system 1 due to fee changes at system 2 given by Kane. For instance, the effect on Community College enrollment due to a $1000 increase in Community College tuition is $cELS(CC, CC) = .047$. There is little agreement about the value of price elasticities within the education community; values ranging from -0.74 to +0.41 have been cited.[2] We thus consider three alternative values for the constant K, K = 0, 1, and 3. We also consider four alternative estimates of fee increases: 0%, 1%, 2%, and 3% per year. Some of the results of this modeling is shown in Figure 8. In general, fees had only a small effect on enrollment even with K = 3.

2Larry L. Leslie and Paul T. Brinkman, "Student Price Response in Higher Education: The Student Demand Studies," Journal of Higher Education, Vol. 58, No. 2, March/April 1987, pp. 181-204.

Appendix III
Details of Revenues to Education

In Section 2, we considered the impact of state general fund allocations as revenues into the various systems. In this appendix, we consider system revenues in more detail.

We write the revenues available for undergraduate education in each of California's public systems of higher education as the sum of funds given directly to each system from the state and local government, as well as the funds given to each system by each attending student in the form of fees. Thus,

$$\begin{aligned}\text{Revenues}(sys, year) &= State(sys, year) + Local(sys, year) \\ &+ Fee(sys, year) * Enroll(sys, year)\end{aligned} \tag{A11}$$

The state funds include contributions from the general fund, lottery revenues, and other state sources. The local revenues, only applicable for the community colleges, come from property taxes. In our study, we assume that these state and local contributions are independent of the number of students attending each system. On the other hand, the revenue each system gains from fees is proportional to the number of students enrolled. This fees term includes fees paid directly by the student as well as any financial aid which flows to the system via its enrolled students. In this analysis we focus only on revenues associated with the costs of current operations. We leave the important topic of capital costs for future work.

The state and local funding for each system each year is written as

$$\begin{aligned}State(sys, year) &= State(sys, 1995) * [1 + GrowState(sys)]^{Year-1995} \\ Local(year) &= Local(1995) * [1 + GrowLocal]^{Year-1995}\end{aligned} \tag{A12}$$

where $State(sys, 1995)$ and $Local(1995)$ are the state and local contribution in 1995 and $GrowState(sys)$ and $GrowLocal$ are the growth rates describing how the funding changes over time. All three systems get state funding; only the Community Colleges have support from local property taxes. In 1995, the University of California spent an average of $6,809 in state funds for each of the 153,571 full-time equivalent students enrolled. Thus we take $State(\mathrm{UC}, 1995) = \$1,045,665,000$. Similarly, the California State University spent an average of $4,734 in state funds to educate each of 252,000 full-time equivalent students, so that $State(\mathrm{CSU}, 1995) = \$1,192,968,000$. In 1995, the Community Colleges spent an average of $3,050 of state and local funds to educate 858,606 full-time equivalent students, with about half of these funds from property taxes, so that $State(CC, 1995) = \$1,434,681,000$ and $Local(1995) = \$1,184,067,000$. Dividing CPEC values for total revenues from fees by total FTE enrollments in each system gives values for average fee per student as $Fee(UC, 1995) = \$3,800$, $Fee(CSU, 1995) = \$1,850$, and $Fee(CC, 1995) = \$200$.

Appendix IV
Details on Productivity

In this appendix, we will consider in further detail how productivity measures are used and manipulated in our model. In one of his definitions of productivity, Epstein (1992) defines productivity improvement as a measurable reduction in cost while maintaining or improving key measures of effectiveness. To address this measure in our simulations, we take the graduation and advancement rates for each system in equations (A4) and (A9) as our key measures of effectiveness. We define an annual rate of productivity improvement p_1 as the rate at which the minimum revenues needed per student can decrease while the graduation and advancement rates remain unaffected. We thus re-write equation (A10) for the maximum enrollment for each system in the constrained admissions case as

$$Enrollment(sys, year) \le \left(\frac{1 + HEPI}{1 + HEPI + p_1} \right)^{Year-1995} * \\ Enrollment(sys, 1995) * \frac{Revenues(sys, year)}{Revenues(sys, 1995)} \quad \text{(A13)}$$

Note that we have defined the productivity p_1 relative to HEPI, so that a productivity improvement of $p_1 = 0$ means that the number of dollars necessary for each system to educate an undergraduate just keeps pace with inflation.[1]

Figure 5 in Section 2 compares UC and CSU enrollments for $p_1 = -2\%$ annually ("Low Efficiency"), $p_1 = 0\%$ ("Flat Efficiency"), and $p_1 = 2\%$ ("High Efficiency") efficiency increase in the constrained admissions case, assuming the Optimistic scenario for the state general fund revenues. For comparison, enrollments under the unconstrained admissions case is also presented. We see that a high rate of productivity growth reduces the access deficit almost to

1In fact, this method relies on average costs. A similar method can be used to perform this analysis with marginal costs, with some fixed (not proportional to student body) amount of revenues subtracted off the total.

zero while a negative rate of growth causes very large access deficits, similar to the situation of the Pessimistic estimate of revenues from the state general fund.

In a second definition, Epstein defines productivity improvement as a measurable improvement in some key measure of effectiveness while maintaining or reducing costs. To address this measure in our simulations, we use either unconstrained admissions or constrained admissions with $p_1 = 0\%$, and define an annual rate of productivity improvement p_2 as the rate at which advancement and graduation rates increase, applied to all the cohorts.[2] Thus,

$$\begin{aligned} cAVD_n(sys, year) &= cADV_n(sys) * [1 + p_2]^{Year-1995} \\ cGRD_n(sys, year) &= cGRD_n(sys) * [1 + p_2]^{Year-1995} \end{aligned} \quad \text{(A14)}$$

Figure 7 in Section 3 shows the effect of variations in the advancement and graduation rates on enrollments and degrees awarded by the CSU. Similar results were seen for UC, though the differences between low and high efficiencies were not as great (since advancement and graduation rates are higher for UC, there is less room for improvement).

2However, values for cADV and cGRD are capped with a maximum value of 1.0. These rates are applied to Community College students mainly in terms of the progress of CC transfers through the other two systems.

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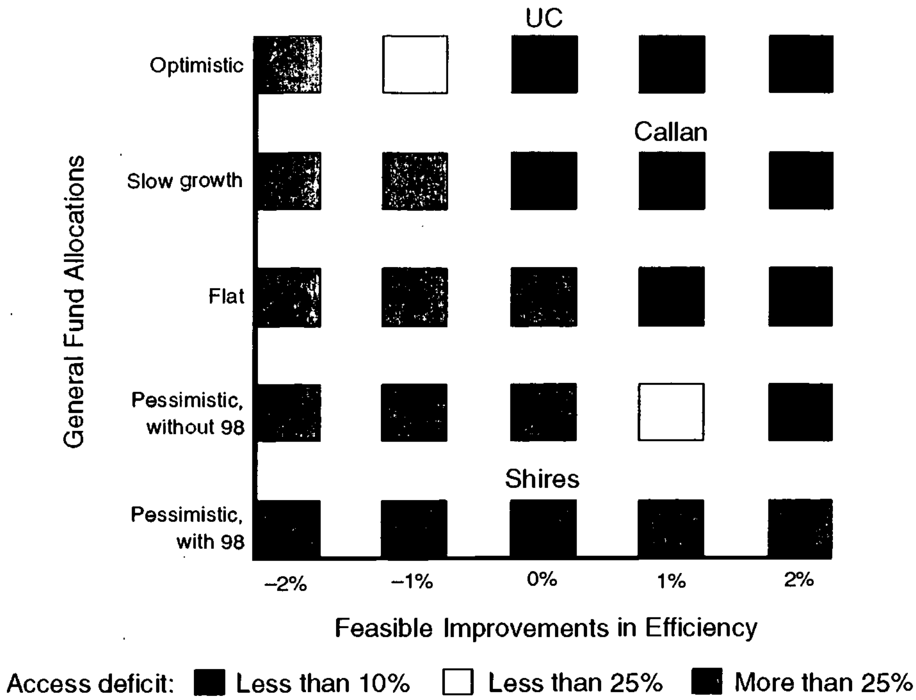

Figure 9—UC Access Deficits in 2014 for 25 Scenarios with Different Assumptions About State Funding and Feasible Efficiency Improvements

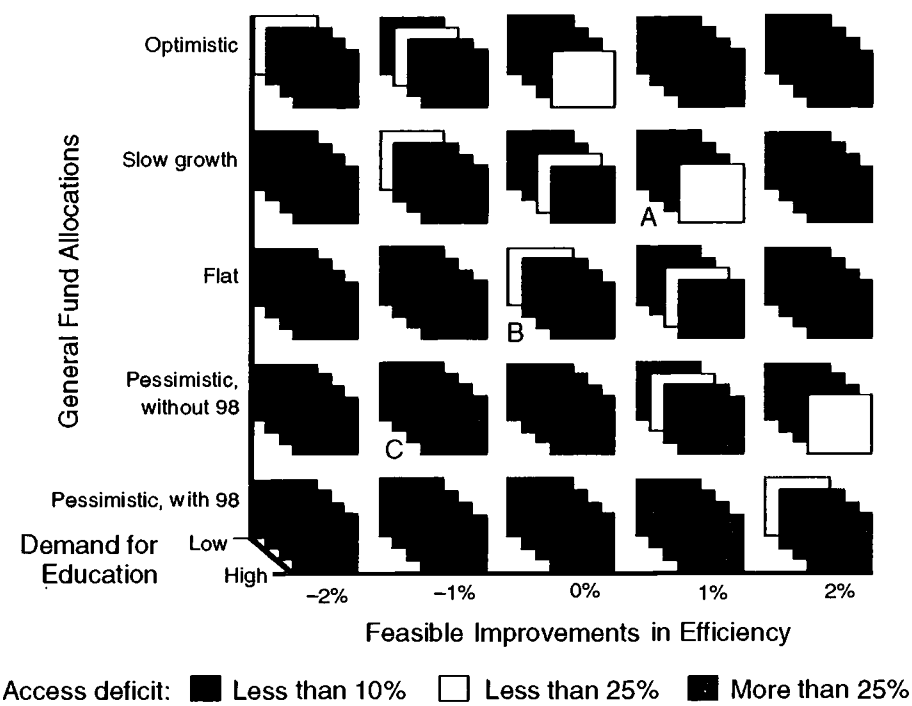

Figure 10—UC Access Deficits in 2014 for 100 Scenarios with Different Assumptions About State Funding, Feasible Efficiency Improvements, and Student Demand

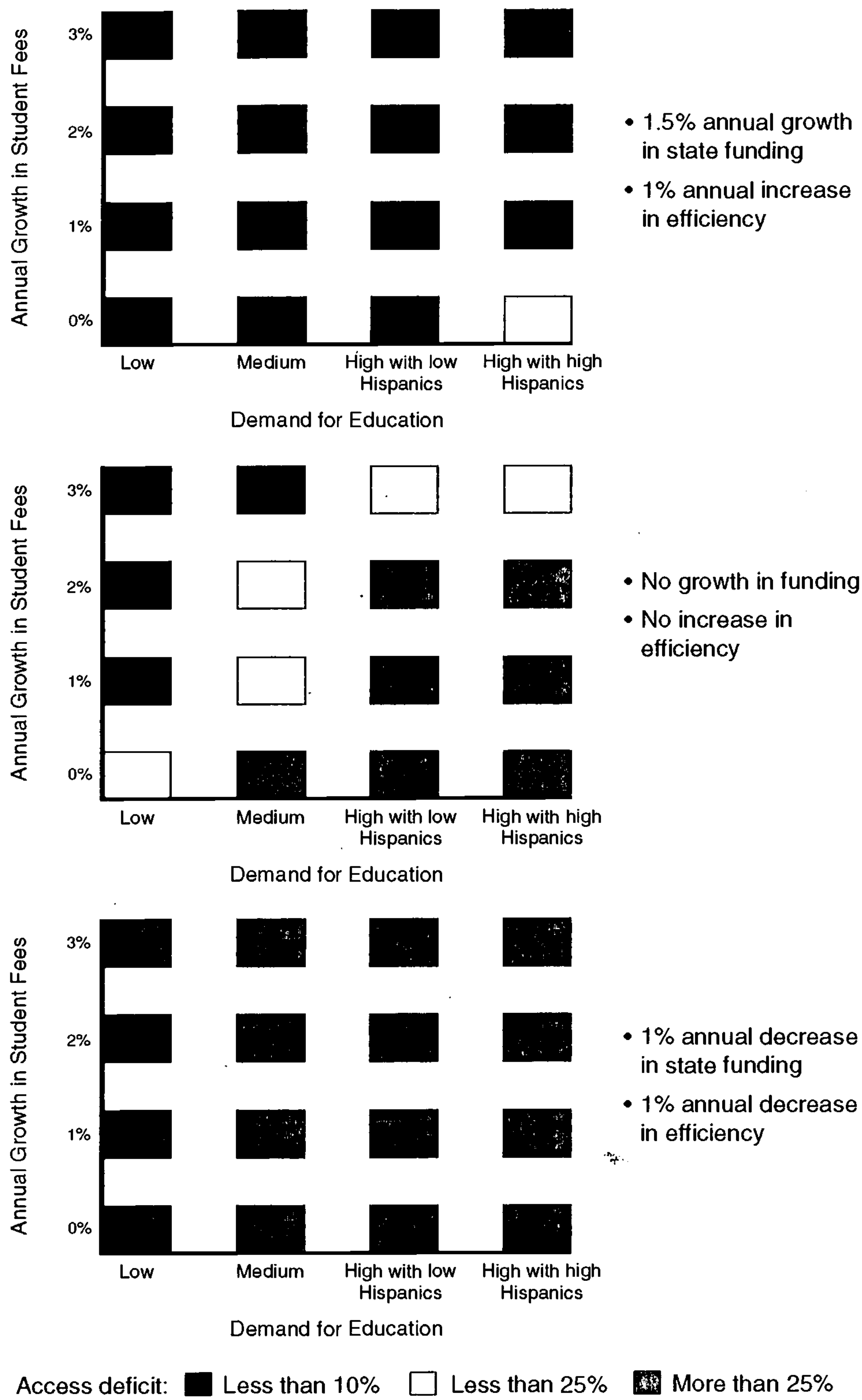

Figure 11—UC Access Deficits for 48 Scenarios with Different Assumptions About Fee Increases, Student Demand, State Funding, and Feasible Efficiency Improvements

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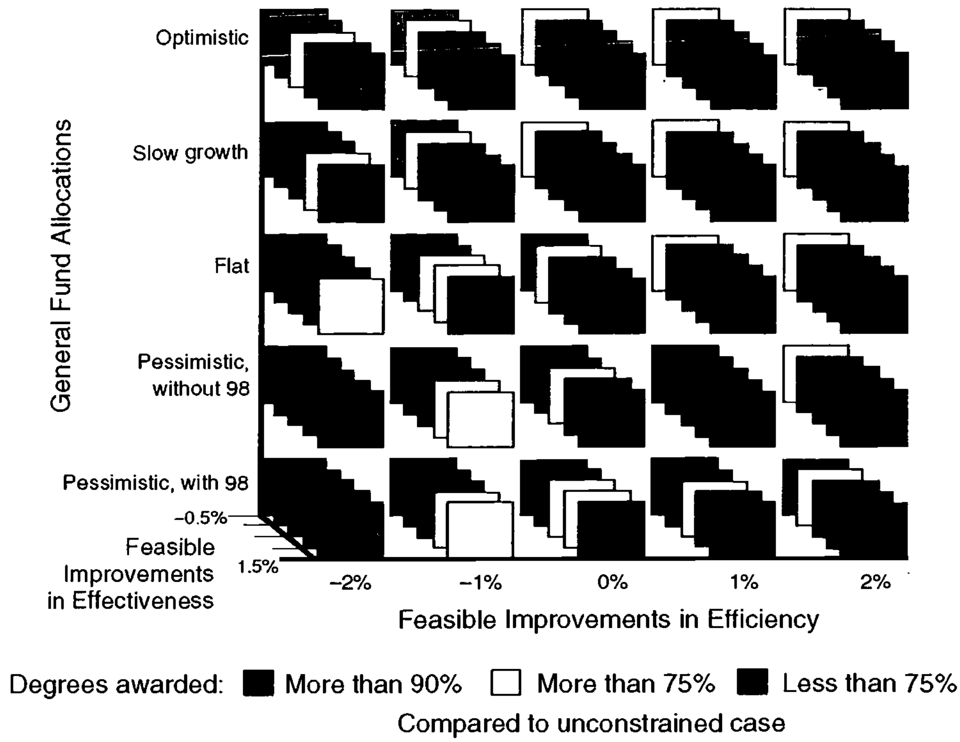

Figure 12—Bachelor's Degrees Awarded by CSU in 2014 for 125 Scenarios with Different Assumptions About State Funding, Feasible Efficiency Improvements and Feasible Effectiveness Improvements

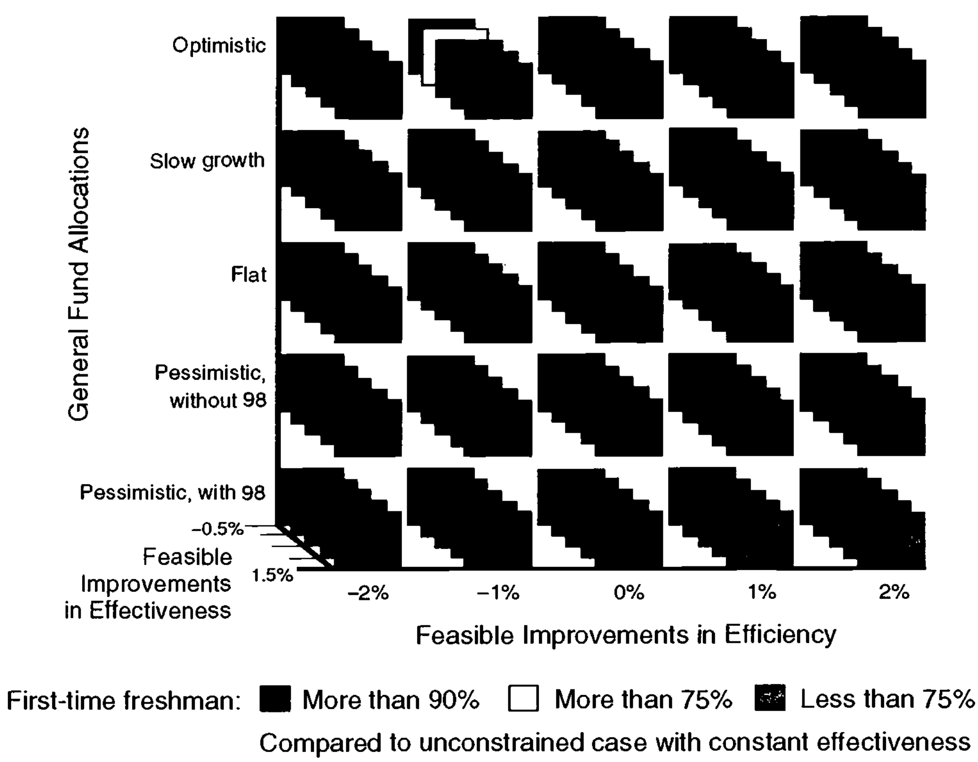

Figure 13—First-Time Freshman at CSU in 2014 for 125 Scenarios with Different Assumptions About State Funding, Feasible Efficiency Improvements and Feasible Effectiveness Improvements

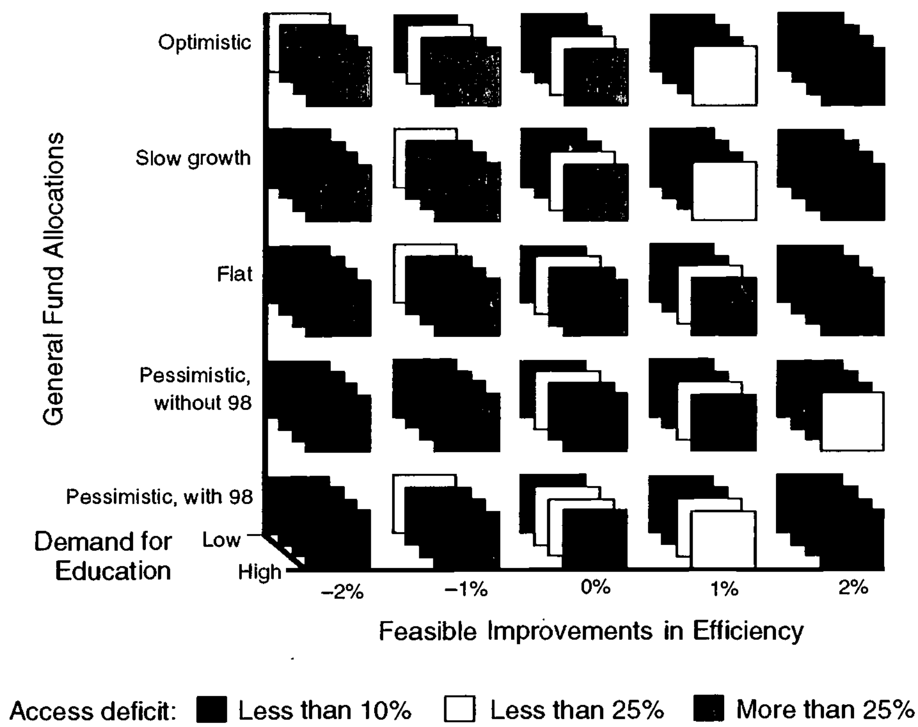

Figure 14—Community College Access Deficits in 2014 for 100 Scenarios with Different Assumptions About State Funding, Feasible Efficiency Improvements, and Student Demand

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