Objective To develop a predictive model for projecting the pediatric workforce and retrospectively test its accuracy at different points in time over the past several decades.

Methods We applied a modified version of the physician workforce trend model developed by Cooper et al. We first analyzed and tested the relationship between economic activity and the number of active pediatric medical physicians for several periods from 1963 to 2000. To project economic activity and population changes in the United States, we conducted linear trend analyses by using the available historical data through the year before the forecast period of interest.

Results There has been significant growth of the absolute numbers of the pediatrician workforce over the past several decades. There was a strong correlation ($R^2 = .98$) of gross domestic product per capita (using 1996 dollars) with the number of active pediatricians (generalists and specialists) per 100,000 children in the United States by year over a 37-year period from 1963 to 2000. Predictions of pediatrician supply using historical census and economic data to inform the trend analysis were also very highly correlated with actual supply.

Conclusions The methods used in this study to predict the pediatric workforce were very accurate and consistent over a 37-year period. (J Pediatr 2003;143:570-5)
workforce, rather than attempting to define what would be most likely to occur. In contrast, Cooper recently developed a new model of physician workforce projection, trend analysis. Previous studies of physician workforce projections have been based on detailed microanalyses of activities and related time. The model described in Cooper et al\textsuperscript{12} and Cooper\textsuperscript{13} adopts a more global, macroanalytical approach of long-term trends that underlie the supply and demand of physician services. Proponents of trend analysis posit that sustained domestic economic expansion is the dominant factor that has driven health care use and the growth of the physician workforce. Other factors playing a less significant role include population growth, work effort of physicians, and medical services provided by nonphysicians.\textsuperscript{11}

Similar to the shortcomings of previous studies of the general physician workforce, the predictions of the pediatric workforce also have not achieved accuracy to the degree necessary to be helpful in long-term workforce planning.\textsuperscript{14} To address this problem, we sought to develop a predictive model for projecting the pediatric workforce and to test its accuracy retrospectively at different points in time over the past several decades. If consistently accurate, the model could be an important aid in future planning for health care delivery to children in the United States.

**METHODS**

We applied a modified version of the physician workforce trend model developed by Cooper.\textsuperscript{13} One feature of the trend model is based on the relationship between long-term economic forces and the demand for physician services. Cooper et al\textsuperscript{12} illustrate the close, long-term trend in developed countries between the level of economic activity, as measured by a country’s real (inflation-adjusted) gross domestic product (GDP), and health care expenditures. Cooper\textsuperscript{13} further proposes that because health care labor force is the principal component of health care expenditures, there exists a consistent and strong relationship between economic expansion in developed countries and growth in the health care labor supply.

By using a modified version of the trend model by Cooper,\textsuperscript{13} we first analyzed and tested the relationship between economic activity and the number of active pediatric medical (nonsurgical) physicians. The test phase of this work took early historical data points and projected over a period that already had occurred. For example, by using pediatric supply data from 1963 to 1980, the model was applied to forecast workforce supply trends for 1981 to 1990. These retrospective analyses provide an indication of how closely the modified trend model matches actual data. Based on this successful test phase, future projections were estimated for the relation between economic activity and the supply of pediatric medical physicians through the year 2020.

There are five primary data components used in this modified trend analysis: (1) real US GDP in the years 1929 to 2000, (2) total population figures for the years 1929 to 2000, (3) population of children age 0 to 14 years for the years 1960 to 2000, (4) number and characteristics (generalist vs subspecialist) of active pediatric medical physicians for the years 1963 to 2000, and (5) number of general pediatricians annually entering and exiting the workforce for the years 1968 to 2000.

Data for historical, real GDP were obtained from the US Bureau of Economic Analysis. Annualized population counts and the number of children were obtained from the US Census Bureau. Subspecialty designation for pediatric medical physicians was not actively tracked until the early 1960s. Data on the number and characteristics of active pediatric medical physicians were obtained from the American Medical Association (AMA) Physician Characteristics reference guides (1962-2002).

The estimated numbers of pediatricians entering and exiting the workforce originate from separate data sources. The American Board of Pediatrics provided the number of physicians taking the general pediatrics certifying examination for the first time between 1968 and 2001. These data served as a proxy for the number of physicians entering general pediatric practice (a physician does not have to pass the examination to practice medicine). To approximate the number of pediatricians exiting the workforce, we obtained historic data from the AMA Masterfile by physician age for pediatric
generalists and subspecialists between 1980 and 2000; physicians self-declare their specialty in the Masterfile. When the pediatrician turned 69 years old, it was assumed that the pediatrician exited the active workforce supply. This approach to estimating rates of workforce entry and exit is more detailed than that used by Cooper in his trend analysis.

One advantage to the macroanalytical approach to workforce analysis is the ease with which the model can be tested by using historical data to create retrospective trend forecasts. Starting in 1981 and repeating the process for every 5-year increment through 2001, we applied the modified workforce model to forecast the relationship between real GDP and pediatrician physician supply. Because the pediatric supply data from the AMA dated back only to 1963, we forecasted out only 10 years for the two analyses that began in 1981 and 1986, respectively. Because more data were available for the trend analyses that began in the years 1991, 1996, and 2001, we forecasted the trend out 20 years.

Forecasting Real Gross Domestic Product per Capita

To project economic activity and population changes in the United States, we conducted linear trend analyses by using the available historical data through the year before the forecast period of interest. For example, to project real GDP per capita for the 1981 to 1990 forecast, real GDP and total population data were analyzed from 1929 to 1980. By using average GDP change from 1929 to 1980, forecasts were made for 1981 to 1990. A similar method was applied to the population forecasts.

Forecasting Number of Active Pediatric Medical Physicians per Child

The forecasted ratio of number of active pediatric medical physicians per child required projecting both the number of children and the number of active pediatricians per year. Similar to projecting change in the population as a whole, to forecast the number of children per year, we analyzed historical rates of change from 1960 through the year before the forecast period of interest.

As mentioned, to project the number of pediatricians per year, we applied a multistep process that considered the current supply as well as specific rates of increase (entering) and decrease (exiting) of the active medical pediatrician supply. For a given forecast period, we began with the supply of pediatricians for the previous year. For example, the AMA Masterfile contained 29,462 active medical (generalists and subspecialists) pediatricians working in the United States in the year ending 1980. That initial value of 29,462 active pediatricians in 1980 served as the baseline that was then adjusted to forecast the number of active medical pediatric physicians for each year in the forecast period 1981 to 1990. This baseline number of pediatricians was adjusted to reflect the estimated number of pediatricians entering and exiting the workforce for each year in the projection. As noted, to estimate the number entering the field, we analyzed the number of physicians taking the general pediatrics certifying examination for the first time between 1968 and year before the projection. The forecasted number of physicians entering the field during each year of the projection is a linear estimate based on historical trends since 1968. For each forecast period, a unique linear estimate projected the number of physicians entering the field each year.

The number exiting the field each year of the forecast period was based on the number of physicians estimated to turn 69 years old for each year of the forecast. For example, when completing a 10-year projection, this information was ascertained by analyzing the number of active pediatricians who were 59 years to 68 years during the year before the forecast. Therefore, those active pediatricians who were 68 years old in 1980 would have exited in projection year 1981. Similarly, pediatricians who were 59 years old in 1980 would have exited in projection year 1990. These exit projections by age were completed by using the AMA Masterfile for each year before the forecast period. Forecasting the number of pediatricians entering and exiting the supply provided a net flow of pediatricians for each forecasted year. The baseline number of active medical pediatricians for the year before the forecast was then adjusted for each subsequent year in the
forecast period by the projected net flow of pediatrician supply. The forecasted number of active pediatricians was then divided by the forecasted number of children to obtain the number of pediatricians per child ratio.

RESULTS

There has been significant growth of the absolute numbers of the pediatrician workforce over the past several decades. Growth not only occurred in absolute terms but also resulted in a doubling of the per capita (based on the population of children age 0–14 years) distribution of pediatricians over the years 1978 to 2000 (Fig 1). Correlation ($R^2 = .98$) of GDP per capita (using 1996 dollars) with the number of active pediatricians (generalists and specialists) per 100,000 children in the United States by year over a 37-year period from 1963 to 2000 (Fig 2). The points along the trend line are quite uniform in their proximity to the curve. AMA and American Board of Pediatrics data from 1963 through 1980 were used to project the pediatrician workforce for 1981 to 1990 (Fig 3). Population and GDP trends were forecast by using census and economic data from 1929 to 1980. As the figure shows, the trend model projections closely approximated the actual figures along the trend line ($R^2 = .99$). Trend method prediction of the pediatric workforce for the years 1986 to 1995 using data from the 22-year period 1963 to 1985 (Fig 4). Compared with the actual trend line, the projections closely approximated the actual figures ($R^2 = .99$). A 20-year period of projection (1991–2010) is attempted by using the actual data from the 26-year period 1963 to 1989. For the first 10 years of this period (1991–2000), the projection correlates very closely to the actual trend line. However, for the period 2005 to 2010, the projection varies increasingly from the historical trend line. Specifically, the projected number of pediatricians required based on the model is higher than the number expected, based on historical trends. Data from the 32-year period 1963 to 1995 project the 20-year period from 1996 to 2015. Again, regarding the period for which we have existing data to check the accuracy of the projection (1996–2000), there is almost perfect correlation. For the period of overlap with the data presented in Figure 5 in future projections (2000–2010), this projection has the benefit of 5 years of additional data and is closer to the historical linear pattern. However, the projected number of pediatricians based on the model remains higher than the number expected, although the gap has narrowed. Entire future projection for the years 2001 to 2020 based on data from the 37-year period 1963 to 2000. This trend analysis projection has the benefit of incorporating data from an additional 5 years (1996–2001) not included in the trend line produced in Figure 6. The addition of these data in the model results in a projection that is more closely correlated with the dominant trend line, especially for the first 10 years (2001–2011) of the projection, reflecting a further narrowing of the gap between the model projection and the trend line.

DISCUSSION

Trend analysis has been used in published reports to examine the general physician workforce. We sought to use this method specific to pediatrics. The methods used in this study to predict the pediatric workforce were very accurate and consistent over a 37-year period. Accuracy was greatest when predicting 10 or fewer years into the future, less so for longer periods.

A key aspect of our predictive model was the relation-ship of the GDP per capita to the number of pediatric physicians per child younger than 14 years. Despite variations in the relative strength of the US economy over the period studied, the relationship remained highly correlated and predictive of the pediatric workforce.

In contrast with many previous predictions that forecast a physician surplus by the year 2000, an important finding of our projections to 2020 is a potential shortage of pediatricians relative to the expectations along our trend line (Fig 7). Our findings suggest that the current net inflow of pediatricians will not be sufficient to meet future demand as expressed by the trend line. It is likely that the demand for medical services will continue to increase in the same historical pattern as

Fig 5. Pediatrician workforce projection for the years 1991-2010.

Fig 6. Pediatrician workforce projection for the years 1996-2015.
observed since the mid-1960s. For pediatricians, this increased demand has a twofold origin. First, improvements in technology and the care of very ill newborns and children continue to require an increasing commitment of time by pediatric specialists. As more of the most vulnerable children survive conditions previously fatal, additional effort will be required to care for their complex problems. The second component of increased demand stems from the ever-growing list of preventive services recommended to be provided by primary care pediatricians. These include services ranging from additional immunizations to an expanding list of preventive counseling and behavioral interventions including those directed at obesity, injury prevention, substance abuse, and safety concerns. Currently, pediatricians are already unable to provide many components of the anticipatory guidance recommended by the American Academy of Pediatrics.

It is important to note that certain factors that are becoming prominent in the pediatric workforce are not accounted for in our model. Specifically, there is an increasing proportion of women in the pediatric workforce, from 36% in 1993 to 45% in 2000. The proportion is expected to grow, because there is a majority of women in pediatric residency training programs. Previous studies have shown that women pediatricians are more likely than men to desire part time positions, and the rate of both men and women seeking to limit their work hours is increasing. However, the capacity of the job market for part time pediatricians is unknown. Regardless, any increase in the part time labor pool will result in the need for a greater number of pediatricians to deliver the same amount of care and will create an even greater shortage relative to the number of pediatricians predicted by our model.

Many have postulated that future variation and growth in the nonphysician medical workforce will have a significant effect on the physician workforce. Our predictive model did not include adjustments for this segment of the health care delivery system. However, during the period of our analysis, there were significant changes and trends in the nonphysician medical workforce because of variation in reimbursement, prioritization of certain health care delivery systems, and training practices. Regardless, the close correlation of pediatrician workforce to our trend line (based on per capita GDP) remained seemingly dominant over these other factors.

Another factor that is likely to create additional demand for pediatrician labor is the new Residency Review Committee limits on resident work hours. These limitations will result in the need for additional pediatricians in training or in practice to meet the patient care demands of our nation's teaching hospitals. Hospital desire to maintain an inexpensive source of labor by hiring more house staff will conflict with recent US policy to limit spending on graduate medical education. To compensate, the previously used safety valve of international medical graduates may be called on again to provide needed services. However, as a result of both increased requirements for certification and heightened barriers to entry of foreign nationals, the number of international medical graduate candidates seeking to qualify for residency positions decreased by 45% from 1995 to 2001.

It is important to note that research using any listing of physicians has specific limitations. Although the AMA Masterfile is the most complete listing of physicians nationwide, a variety of sources, including self-designation of specialty, are used. As such, there is some uncertainty in the exact numbers of any specialty nationwide.

These findings in and of themselves do not predict a future shortage of pediatricians; they only demonstrate the historic trends of pediatrician supply and the expected supply relative to that trend in the future. There may be efforts on the part of professional or governmental authorities to adjust the supply of pediatricians based on patient demand or other factors that may result in the projection moving closer to the historic trend line. Alternatively, there may be a prolonged slowdown in the economic growth of the United States, resulting in a deviation of the historic trend line from its previously constant path.

We do not imply that the previous or the current supply of pediatricians is appropriate for the nation. Rather, we note only that the supply has tracked very closely to certain economic indicators. Society will determine whether the same level and proportion of pediatrician supply are desirable in the future.

**REFERENCES**

7. California Medical Association. And then there were none: the coming physician supply problem San Francisco (CA): California Medical Association; 2001.