Physician and nurse supply in Serbia using time-series data: A Case Study

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Abstract

Background: Unemployment among health professionals in Serbia has risen in the recent past and continues to increase. This highlights the need to understand how to change policies to meet real and projected needs. The study identified variables that were significantly related to physician and nurse employment rates in the public healthcare sector in Serbia from 1961 to 2008 and used these parameters to forecast physician and nurse supply in the public healthcare sector through 2015.

Methods: The relationship among six variables used for planning the physician and nurse employment in public healthcare sector in Serbia was identified in two periods: 1961-1982 and 1983-2008. Those variables were the annual number of population; gross domestic product in real prices in 1994; inpatient care discharges; outpatient care visits; students enrolled in the first year of medical studies at public universities; and graduated physicians. Based on historic planning method, physician supply and nurse supply in the public healthcare sector by 2015 (with corresponding 95% confidence level -CL) have been forecasted with Autoregressive Integrated Moving Average (ARIMA) / Transfer function (TF) models.

Results: The ARIMA/TF modelling yielded stable and significant forecasts of physician supply (stationary-R squared = 0.71) and nurse supply (stationary-R squared = 0.92) in the public healthcare sector in Serbia by 2015. The predictors for physician employment were the population number and GDP. The supply of nursing staff was predicted according to the
number of physicians. Physicians and nurses rates per 100000 of population would increase by 13%. The seven-year mismatch between the supply of graduates and vacancies in the public healthcare sector is forecasted at 8759 physicians.

Conclusion: The significant mismatch between forecasted supply of physicians and vacancies should be used as a pointer to decision-making on the intake planning for the medical schools in Serbia. Serbia needs an inter-sector strategy for HRH development that is more coherent with healthcare objectives and more accountable in terms of professional mobility.
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Background

Policy makers often promote strategic planning of human resources for health (HRH) as a part of reforms aimed at improving healthcare system performance. Strategic HRH planning for attaining improved health goals and objectives encompasses the understanding of the interplay among many factors within and beyond the healthcare system. Those factors include: economic policies, legislation, rules and procedures that guide health workforce production, education, deployment, performance, payment and management, as well as system health strategies, programmes, and action plans designed to be delivered by a range of providers in settings with different socio-economic and demographic characteristics, responding to environmental threats and targeting a changing demographic structure. Along with that, HRH planning can include projections about cross-cutting problems regarding HRH production, employment and management, such as attractiveness of health professions, private sector role and migration of health professionals.

During the last sixty years various tools have been developed and used for HRH planning. Developed countries often used workforce supply and demand methods based on population needs-based requirements, others use benchmarking or a combination of those two methods. There are qualitative approaches (e.g. Delphi method), and some studies use quantitative dynamic modeling of HRH stock and flow that may include a sensitivity analysis.

A country may lack a coherent plan for HRH development, as well as valid data on HRH shortage or excess because of inaccurate databases, pitfalls in general planning, presence of a significant private sector, or lack of a responsible body and support system.
In all former Yugoslav republics including Serbia, HRH planning was driven by simple, normatively determined physician/dentist/nurse/pharmacists-to-population ratio. This was done in a diffused manner without clear connection to overall population need as, the Ministry of Education had no legal obligation to consult the Ministry of Health on the number of medical students enrolled in medical school. In the South East European countries, including Serbia, systematic and strategic workforce planning has been underdeveloped and understanding of migratory flows is lacking. For example, Romania has a *numerus clausus* and a relatively stable number of vacancies in the public sector mainly due to limitations in teaching capacity, while overproduction and overspecialization in Bulgaria were the result of the lack of clear criteria for HRH planning.

Specific studies of HRH planning are limited in Serbia. Since the Second World War, the public sector has been the major employer and producer of health workforce in the Republic of Serbia. Before 1961, country had five-year economic plans, which included HRH development. Due to scarce teaching capacity a *numerus clausus* was in place. HRH decision-making was decentralized to “self managed interest communes” that aimed to increase population access and equity.

From 1961 to 2010 there have been three HRH strategies: the first two were long-term strategies created within the health care development plans, by 1990 and 2000 respectively; and the third was part of planned activities for the reconstruction of the health care provider network during 2005–2010.

The first HRH development plan by 1990 followed the new Constitution (in 1974), Labour Law (in 1976) and Law on Education (1976) that brought broader decentralization to all former Yugoslav republics and provinces. However, after the global oil crises in 1976 the economy stagnated, the national debts rose and separatist tensions emerged. By 1978
the number of employed physicians and enrolled medical students slowly increased, but in 1979 the number of enrolled medical students doubled and stayed at that level for several consecutive years. The financial restrictions on the healthcare system and banned private practice forced many health workers to emigrate. At the beginning of the 1980s, Constitutional amendments limited the autonomy of republics and Serbian provinces (1981); this led to new approach and centralized HRH planning.

A new development plan for Serbia was enacted and was applicable between 1982 and 2000. It included a reduction of enrolment in medical studies, vocational education, specified the number of posts based on health worker to population ratio and sanctioned private practice (for dentists in 1987 and for pharmacists and physicians in 1989). However, military conflicts and Yugoslavia’s break-up during 1990s curtailed the inter-sector activity over HRH development. The private practice wasn’t making profit and many health professionals emigrated.

At the end of the 20th century Serbia was an economically degraded and isolated country, overburdened with hyperinflation, and an influx of refugees and internally displaced persons (both healthcare workers and patients). Many health development plans were subsequently proposed by various experts, but none was formally accepted.

In 2000, the new Ministry of Health collaborated with the World Bank on the master plan for the reconstruction of the healthcare provider network and a new HRH strategy for 2006–2010. In order to fit with the reconstructed network of public healthcare providers, and attain healthcare equity, access, and to increase efficiency, the recommended staff rationalization in the public sector was aligned with private sector increase estimates (private sector was estimated to absorb rationalized staff or early retired workers). Despite the fact that unemployment of medical workers was high, and that production of health workforce at state faculties was publicly funded as was the health care, the enrolment and graduation rate on
medical studies were not priority issue in HRH strategy 2006-2010. The planning process posited several demand-based scenarios for primary, secondary and tertiary healthcare institutions and included population and economic growth, healthcare services utilization, and performance benchmarking for the public sector.

The following year, by-laws on physician and nurse staffing and operation norms were adopted. By the new Health Care Law (2005), the private health care providers, besides staffing conditions, had limitations in terms of health care services that they can provide. In accordance with the Law of Private Entrepreneurs (2005) and Law of Private Companies (2004) they may be established and operate as private practices or companies with limited liability.

Though staffing rations had been set, there were no explicit boundaries deviation from a standard for health workforce coverage as in Slovenia (a 10% boundary on each side of the national averages). The territorial staff imbalance (up to 2.74-fold for physician density and over 3-fold for specialists; and up to 1.98-fold for nurse density and over 6-fold for midwives) has persisted (Table 1). This is due to population and health workforce rural-to-urban migration, difference in natural population increase, and noncompliance with staffing rules and little flexibility for health workforce movement (95% of physicians and nurses have permanent full or part-time employment). Meanwhile, annual unemployment for physicians had been growing from 2000 by 5.6% and by 1.5% for nurses. Two-thirds of approximately 2,000 unemployed physicians were aged less than 30 years, and half of almost 10,000 unemployed nurses were under 25 years of age.

Table 1
The new Health Development Plan between 2010 and 2015 period anticipated the conception of a parallel HRH strategy but it has not yet been created. The Health Care Law is extended with new articles by which the Ministry of Health annually sets the highest number of post per public healthcare institution in their ownership. Current annual staffing targets and the minimum required number and skill-mix of workers were unchanged and are based on population number per square kilometers, age and sex structure. The proposed performance measures for public healthcare institutions were unaffected as well.

This is the first study that explores the past planning approaches (between 1961 and 2008) and uses trend data from those years for forecasting physician and nurse supply. Its purpose is to meet the requirement for the inter-sector activity over HRH development set out in the new Health Development Plan between 2010 and 2015 period.

Methods

Study design and data sources

The method used to develop estimates of the Serbian physician and nurse workforce made use of a multivariate auto-regressive integrated moving average (ARIMA) approach. The predicted values (Y-variables) were the estimated number of physicians and nurses. The analysis focused on the total number of physicians (y1: general practitioners and specialists) and nurses (y2: general, paediatric nurses and midwives with secondary and high education) employed in the public healthcare sector of Serbia from 1961 to 2008 and their forecast numbers as of 2015. Other variables used in the study were the annual number of population (x1: estimates and census data for 1961, 1971, 1981, 1991 and 2002); GDP (x2: real value at 1994 prices); inpatient care discharges (x3: proxy to physicians and nurses productivity in secondary and tertiary healthcare institutions), outpatient care visits (x4: proxy to physicians
and nurses productivity in primary healthcare institutions include prevention, curative and rehabilitative visits in ordination and at home); students enrolled at the first year of medical studies at state universities (x5: proxy of high education enrolment policy); and graduated physicians (x6: proxy of high education production). The analyses were separated into two periods, 1961–1982, and 1983–2008 in order to explore the shift in policy predictors of HRH planning in Serbia.

Data on physicians, nurses, outpatient care visits and inpatient care discharges in the Network plan of the health institution in the Republic of Serbia as of 2000 (the public healthcare sector) were obtained from the Institute of Public Health of Serbia. The public healthcare sector (state ownership) is the major employer of health workforce in Serbia and is financed predominantly via compulsory health insurance taxes and public taxes. HRH data from private practice and other institutions that were not included in the public healthcare sector were not included in the study. A precise overview of the number of entrepreneurs, companies and personnel that provide health care services is not available from public sources, since the Republic Statistical Office publishes aggregate data related to the activity of “Health and social work”. As with all other private business entities, such method of data collection is often accompanied by inadequate presentation of certain statistic indicators.

Recent estimates are that private sector provides approximately 3% of the overall healthcare services in Serbia. The Medical Chamber of Serbia has information on licensed and unlicensed, and employed and unemployed physicians. Of total 29847 licensed physicians, 3618 were private practitioners (12.12%). Private practitioners comprise 11.49% of the total number of licensed and unlicensed physicians. The Medical Chamber reports 1761 unemployed doctors, a little less than is registered in the National Employment Biro database. The number of unemployed doctors equals 5.90% of all licensed physicians (or 5.59% of the sum of licensed and unlicensed physicians). In 2013, in the private sector operates 1668
entities, while 155 were closed. Private practitioners are employed at 11 general hospitals, 123 policlinics, and 631 physician's offices (748 earlier this year).

Data on population size, GDP and enrolled and graduated students were taken from the Statistical office of the Republic of Serbia. The analysis of the education sector captured data on all the state Medical Faculties’ students in Serbia (financed via public taxes) but does not include enrolments at postgraduate or specialists studies. At the time of the analysis there were no graduation data from private faculties as they have only been recently established; the estimated annual intake at private faculties is less than 3% of the total enrolment at state faculties. For consistency reasons, all data refer to Republic of Serbia and exclude data from Kosovo and Metohia.

Statistical analyses

Basic descriptive statistics of variables in the study are given in table 2. The table includes longitudinal analysis of relationship among selected potential predictors and employment of physicians and nurses included analyses of all variables time-series (from 1961 to 2008) and their forecasting by 2015 (estimates with corresponding 95% lower confidence level - LCL and upper confidence level - UCL).

Table 2

Predictors of physician and nurse employment have been included in time-series models for the period 1983–2008 (potential predictors: x1, x2, x3, x4, x5, and x6) to forecast the numbers of physicians and nurses (key dependent variables: y1 and y2) employed from 2009 to 2015. Forecast outputs include absolute numbers of physicians and nurses with a
corresponding 95% LCL and UCL. These estimates represent the workforce employed in the Serbian public healthcare sector per year, assuming the relationships among the observed input variables (number of population, GDP, outpatient visits, inpatient discharges, enrolments and graduates at state medical universities) do not change significantly by 2015. Because of the world economic crisis, whose effects started to influence the Serbian economy in 2009, we included a "pessimistic" scenario of GDP contraction (i.e. GDP 95% LCL) instead of the GDP central projections. Forecast outputs will differ from their realized annual values by 2015, if identified predictors or the HRH planning approach significantly change the period 2011–2015.

The Autoregressive Integrated Moving Average (ARIMA)/Transfer function (TF) time-series models [33] were the key statistical analysis and forecasting tools applied in this study. The ARIMA/TF procedure also includes an Expert Modeler component that identifies and estimates an appropriate model for each output variable series and predicts its values. The specification of the model also identifies outliers, i.e. non-standard values. Model stability, significance and fit have been tested with stationary-$R^2$ and Ljung-Box statistics. Kolmogorov-Smirnov Z test has been used to verify normal distribution of residuals in the model. The statistical tool was IBM SPSS Statistics (ver. 20). [34]

Results

*Physician and nurse deployment in the public healthcare sector of Serbia from 1961 to 2008*

From 1961 to 1982, the number of employed physicians increased by 174%; the number of nurses by 282%, the population by 15%, GDP by 200%, the number of inpatient
discharges by 132%, the number of outpatient visits 67%, the number of enrolments at the first year medical studies by 206%, and the number of graduated physicians by 114%. From 1961 to 1982, change in the employment of physicians was significantly related only to GDP change while nurse employment grew independently of changes in the independent variables. Both physician and nurse employment models were statistically stable without outliers and with a normal distribution of residuals (Table 3). The number of inpatient care discharges was related to the number of employed physicians and GDP, while the number of outpatient care visits was related only to the number of employed physicians.

Table 3

In the second period, from 1983 to 2008, the numbers of employed physicians and nurses increased by about 43% each. The population decreased by 6%, GDP by 50% and the number of outpatient visits by 11%. However, the number of inpatient discharges increased by 28%. Both the number of students enrolled in the first year medical studies and the number of graduated physicians decreased by 50%. Physicians employment correlated with population and GDP, while nurses to the number of employed physicians (Table 4).

The physician-to-nurse ratio remained the same, 1:2. However, the population, GDP, inpatient care discharges and outpatient care visits were not significantly related to the number of enrolled students at the first year medical studies (x5) or graduated physicians (x6).

Table 4

The physician employment model was statistically stable, without outliers and with a normal distribution of residuals (Figure 1). The nurse employment model was statistically
stable, with two outliers, and with a normal distribution of residuals (Figure 2). The modeled non-standard values in the nurses’ employment model were: additive in 1995 \((t = -8.22; \ p < 0.01)\) and level shift in 2005 \((t = -3.61; \ p < 0.01)\). In 1995, the nursing staff was significantly reduced, by about 3.88% due to flexible retirement and beneficial disability pensions, ceased deployment, and in 2005 by about 4.27% due to planned rationalization and early retirement schemes in the public healthcare sector.

In the second period, ARIMA/TF models of almost all input variables had outliers, with the exception of the model of outpatient care visits.

The ARIMA \((1, 2, 0)\) model of population size time-series had 4 outliers: level shift in 1991 \((t = -25.00; \ p < 0.01)\), additive in 2001 \((t = 32.79; \ p < 0.01)\) and in 2002 \((t = -38.18; \ p < 0.01)\), and local trend in 2005 \((t = 10.31; \ p < 0.01)\). Reduced population in 1991 by about 0.95% and in 2002 by about 2.96% was most likely the result of negative natural population growth rate, and emigration prior to the introduction of international sanctions and after they were lifted. It also reflected the difference in the methodology used for estimating the population between the two censuses and methodology used to enumerate the population in 1991 and 2002 census years. Increased population in 2001 by about 0.50% perhaps reflected the pull effect of the national politics that changed in 2000. The economic reform and international aid that began the following year probably influenced the decrease of population by about 0.30% in 2005.

The ARIMA \((0, 2, 0)\) model of GDP time-series had one local trend outlier in 1994 \((t = 3.40; \ p < 0.01)\), likely a result of currency reform after hyperinflation in 1993 (which
decrease GDP value by about 30.76%).

The model of inpatient care discharges had an additive outlier in 1999 by about 17.05% (t = -6.14; p < 0.01), perhaps because of reduced financial resources (GDP was a predictor and in 1999 it decreased by about 18.33%), which induced the 3.30% cut back of the hospital bed number and changed operational plans of institutions before and during the two and half-month long NATO bombing of Serbia (Figure 3). The model of outpatient care visits had no outliers (Figure 4).

Figure 3

Figure 4

The innovation outlier recorded a decrease in the time-series model of enrolled medical students in 1985 by about 51.42% (t=-8.72; p < 0.01), which could have been a sign of the influence of the second HRH strategy enacted in 1982 (Figure 5). In 1985 the number of enrolled students has been reverted to below the level of 1978. However, during socially destabilized years in the period 1990-1994 it increased again by 30%. Shortly after political changes in the period 2000-2004, it decreased by 29%. In following years it started to increase again and in 2008 there were almost 1800 new students at the first year of state owned medical studies.

The number of graduates reflected the intake flows. The increased number of graduated physicians in 2008 (t=2.84; p=0.01) was innovation outlier, recorded after adoption of the Bologna declaration that changed curricula and length of medical studies (from five to six years)\textsuperscript{25} (Figure 6).

Figure 5
According to our forecast, in 2015 there will be 1207 more physicians (or 5.86%) and 2459 more nurses (or 5.76%) employed in the public sector than in 2008 (Table 5). The physician and nurse rates per 100,000 of population will rise by 12.5% and by 12.8% respectively, i.e. from 272 to 306 for physicians and from 562 to 634 for nurses.

Table 5

With regard to annual forecasts, by 2015, the annual number of enrolments (1771) will be higher by about 20% than the current number of graduates at state medical faculties (1415). The annual workforce generation ratio \(^{[13]}\), calculated as ratio of the number of physician graduates and the total number of physicians employed in public sector will be around 6.58% for every year in the forecast period. The new deployment of physicians per year is projected to be 0.7% on average. The sum of annual differences between the new supply of physician graduates and their deployments in public healthcare sector is therefore projected to be 8698 persons (9905 vs. 1207).

Discussion

This study analysed the relationships found in six models that could be used for planning the physician and nurse requirements for the public healthcare of Serbia. The projections made use of over 50 years of data. Based on those models the number of
physicians and nurses required in the public health care of Serbia (the supply) by 2015 were estimated. This study has identified that the most significant predictors of physician and nurse staff for the last twenty-five years were GDP and population. That relationship between changes in the economy and in physician service’ demand was well documented in the literature. \[4-7\] This study revealed that the GDP is significant predictor for the number of inpatient care discharges in Serbia, and that the supply of physicians was an incentive for healthcare service utilization in general.

Besides natural population increase, social instability and migration, other factors like health policy (i.e. changes in the health institutions ownership and structure, voluntary specializations, HRH rationalization and piloting new health technology), and economic changes and policy (i.e. GDP, hyperinflation, currency reform and flexible retirement schemes) have affected the upward and downward workforce density slopes from time to time in Serbian public healthcare sector. While changes in population have small impact on healthcare workforce, the economy interventions had somewhat greater effects (for instance, the currency reform decreased GDP by 31%, the decrease of GDP by 18% influenced downsize of the hospital bed number by 3%). Emigration also affected the public workforce density, in particular before and after the country break-up and international sanctions (the UN Security Council imposed economic sanctions during 1992–1995 period, the remaining international sanctions were lifted in September 2001). Policy changes had the major impact (for example, the HRH strategy in 1982 has reduced the intake by 51% and the staff rationalization decreased the number of physicians by 4%). The introduction of flexible retirement as a (macro)economic intervention for staff reduction is estimated to generate a 3.5% difference between the forecast and registered number of health workers. \[9\] In our study about 3.9% of nurses left the public sector of Serbia due to more favourable terms for retirement introduced in 1995.
Earlier studies pointed to a significant rise of physicians (specialists in particular) and nurses (but not the midwives) in the public sector of Serbia. This study provided evidence that enrolment and graduation rates at state medical faculties were self-directed; the explicit link to the number of vacancies in public healthcare sector was not observed. The constant increase of physician and nurse density suggest that access to healthcare and to education have been traditional social values in Serbia that could resist political and economic upheavals. The prediction models showed that if current physician supply policy (enrolment and graduation at state medical faculties, and their deployment) is seen as adequate by policy makers and maintained at the same level in the future it will result each year in almost eight times the number of graduated physicians than the number of vacancies in the public healthcare sector. Even if almost 80% of all future graduates emigrate, or the state faculties stop the intake in the next three years, there still will be enough number of physicians to match the public healthcare sector requirements by 2015. The number of unemployed physicians will likely increase. Responsive partnership between government-funded medical schools, healthcare sector and other health stakeholders is needed. Health experts agree that addressing population health needs should be solved by doing more than creating more health workers.

The country has spent US$ 9-12 billions on the education of emigrated physician specialists (the lower sum corresponds to the total Serbian public debt in 2009). The real financial losses would have been much higher if the calculation covered the total estimated 10,000 Serbian health professionals working abroad, lost profits, replacement costs and other indirect losses. Given the actual tendency of Serbian health workers to emigrate, the return of investments in their education and fiscal income should be assessed.
Shifts in the macroeconomic contexts were dominant source of forecasting failures in many studies. To overcome this problem, in this study we included a "pessimistic" scenario of GDP contraction instead of the GDP central projections since the GDP growth rate in Serbia fell from 5.5% in 2008 to -3.0% in 2009 and to 1.8% - 2.0% growth in 2010. Thus, time-series models in the study generated result that were reasonably similar to current situation. There is no difference between forecasted and registered number of physicians and nurses (only 0.1% in 2011) in public healthcare sector. Thus the approach can be used for projecting future workforce trends in Serbia.

*Study limitations*

Models are simplifications of the actual situation. With changes in migration of population and health workforce the forecasted physician and nurse supply may alternate as well. The introduction of prolongation regulations for age-related retirement in Serbia (due to an ageing workforce) may alternate the overall outflow rate from the public healthcare sector (Ministry of Health of Serbia has estimated it at 2-2.5% per year\(^\text{[22]}\)). Therefore, future forecasts should include the age and gender analyses of the workforce.

Having complete and valid data on the number of private practitioners is difficult in almost all countries. In Serbia it is also a complex issue since publicly employed health workers are allowed to provide specialist, consultative and/or training services in the private sector and as volunteers outside the public healthcare sector. Also according to the official methodology, only the number of full time employees was presented, while the number of consultants was unknown and very variable. The health professionals’ authorities regularly reported the consecutive increase among licensed private health workers. For example from
2,931 physicians and 800 nurses and health technicians in one year to 3,093 physicians and 1,000 nurses and health technicians in the next year. At the moment, the number of private practitioners equals to 10.8% of total number of licensed and active physicians and 1.6% of total number of licensed and active nurses and health technicians. The greatest number of staff was recorded in various specialty clinics, then in hospitals, women health care facilities and physical medicine. The climate for private business is still unstable in Serbia. Each year, a large number of new private healthcare entities enter the economy while some disappear, transform or merge (e.g. in one year there were 3000 private practices including 98 clinics and 8 primary care centers, while a year later there were 1200 entities out of which 74 were polyclinics and 9 primary care centers). According to the assessment of Institute of Economic and Social Research, the private sector was still poorly presented in the delivery of health care services to Serbian population in 2009: outpatient services for 1.2% of population, and inpatient services for 0.6% of population.

**Study implications for policy and practice**

The future inter-sector HRH strategy and action plan should develop careful health development plans, goals and objectives. To deliver an inter-sector HRH strategy the government should commission a high-level and independent body to analyze and forecast dynamics of cross-cutting problems regarding HRH production, employment and performance. The essence of its activity should be the harmonization of HRH-related policies in all sectors with the health development plan.

Possible options to maintain health system efficiency with unrevised staffing plans include expansion of the user groups’ number and/or services and partnership with other HRH labor markets. Future research should estimate how many of the physicians would
be employed in the private sector or abroad, and its effect in preventing future mismatches between demand and supply of physicians in the emerging economic scenario.

Though the increasing number of unemployed health professionals ensures that there will be an available supply in the future, it also makes Serbia another source country for well qualified health workers. The WHO Global Code of Practice on the International Recruitment of Health Personnel should be implemented in order to strategically govern the mobilization and development of national HRH.

The number of other health professions (such as dentists, pharmacists, laboratory technicians, radiographers, physiotherapists etc) grew in line with the expansion of the public health sector, particularly during the introduction of programmed healthcare and extension of guarantied healthcare benefit basket in mid 1970s and in the beginning of 1980s. Since they represent 21% of total health professionals in public sector now, and their skills are important, particularly in teams needed to provide specialized services, their relationship with physician and nurse staffing and ratio should be explored in future research.

Conclusions

The significant mismatch between forecast supply of physicians and available posts should be used as pointer to decision-making on intake planning for the medical schools in Serbia. Serbia needs an inter-sector strategy for HRH development that is more coherent with healthcare objectives and more accountable in terms of professional mobility. The ARIMA-TF model may be used to improve understanding of the impact of the traditional HRH governance in other countries. The relative dimension, not the specific accuracy of the continued upward trend in numbers of physicians and nurses is important for HRH stakeholders. This study may serve for comparison with other forecasts of physician and nurse
supply in Serbia whilst creating future HRH policies.

Conflicts of interest: None to declare.

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Authors' contributions: MSM, VV and JM conceived and designed the study and have made substantial contributions to analysis and interpretation of data. MSM and VV collected data and drafted the manuscript. All authors have given the final approval.

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Table 1. Districts with the highest and the lowest number of health workers in the public healthcare sector per 100,000 population in the Republic of Serbia

<table>
<thead>
<tr>
<th>Year</th>
<th>Nisavski Physician</th>
<th>Nisavski Nurse</th>
<th>Belgrade Physician</th>
<th>Belgrade Nurse</th>
<th>Sremski Physician</th>
<th>Sremski Nurse</th>
<th>Macvanski Physician</th>
<th>Macvanski Nurse</th>
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<tr>
<td>2005</td>
<td>428</td>
<td>631</td>
<td>353</td>
<td>693</td>
<td>143</td>
<td>332</td>
<td>186</td>
<td>430</td>
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<tr>
<td>2006</td>
<td>437</td>
<td>634</td>
<td>355</td>
<td>712</td>
<td>145</td>
<td>324</td>
<td>189</td>
<td>430</td>
</tr>
<tr>
<td>2007</td>
<td>437</td>
<td>673</td>
<td>358</td>
<td>725</td>
<td>151</td>
<td>331</td>
<td>195</td>
<td>442</td>
</tr>
<tr>
<td>2008</td>
<td>443</td>
<td>700</td>
<td>368</td>
<td>745</td>
<td>162</td>
<td>343</td>
<td>205</td>
<td>461</td>
</tr>
<tr>
<td>2009</td>
<td>421</td>
<td>676</td>
<td>368</td>
<td>742</td>
<td>175</td>
<td>364</td>
<td>206</td>
<td>455</td>
</tr>
<tr>
<td>2010</td>
<td>444</td>
<td>700</td>
<td>371</td>
<td>748</td>
<td>178</td>
<td>373</td>
<td>206</td>
<td>465</td>
</tr>
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</table>

Table 2 Basic descriptive statistics of all variables in the study in the period 1961-2008

<table>
<thead>
<tr>
<th>Name</th>
<th>Labels</th>
<th>MAX</th>
<th>MIN</th>
<th>Net change</th>
</tr>
</thead>
<tbody>
<tr>
<td>y1</td>
<td>Number of physicians</td>
<td>20668</td>
<td>4618</td>
<td>3.24</td>
</tr>
<tr>
<td>y2</td>
<td>Number of nurses</td>
<td>42480</td>
<td>6422</td>
<td>4.10</td>
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<tr>
<td>x1</td>
<td>Population size number of inhabitants</td>
<td>7897937</td>
<td>6678239</td>
<td>0.20</td>
</tr>
<tr>
<td>x2</td>
<td>GDP value in real prices</td>
<td>48857</td>
<td>13662</td>
<td>2.75</td>
</tr>
<tr>
<td>x3</td>
<td>Number of inpatient care discharges (in thousands)</td>
<td>1214</td>
<td>379</td>
<td>2.51</td>
</tr>
<tr>
<td>x4</td>
<td>Number of outpatient care visits (in thousands)</td>
<td>50261</td>
<td>21849</td>
<td>1.20</td>
</tr>
<tr>
<td>x5</td>
<td>Number of students enrolled at the first year of medical studies (at state faculties)</td>
<td>3946</td>
<td>945</td>
<td>1.35</td>
</tr>
<tr>
<td>x6</td>
<td>Number of graduated medical doctors (at state faculties)</td>
<td>1724</td>
<td>553</td>
<td>1.68</td>
</tr>
</tbody>
</table>
Table 3 Implicit description of all Transfer function models from the first period 1961–1982

<table>
<thead>
<tr>
<th>Dependent variable (labels and name)</th>
<th>Potential predictors in Start model (only name)</th>
<th>Significant predictors in Final model (only name)</th>
<th>Model type</th>
<th>Stationary R2</th>
<th>Number of outliers</th>
<th>Q-stat (p value)</th>
<th>Z-stat (p value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicians (y1)</td>
<td>x1, x2, x3, x4, x5, x6</td>
<td>x2</td>
<td>TF (0,1,0)</td>
<td>0.63</td>
<td>0</td>
<td>1.52 (0.96)</td>
<td>0.81 (0.52)</td>
</tr>
<tr>
<td>Nurses (y2)</td>
<td>y1, x1, x2, x3, x4, x5, x6</td>
<td>none</td>
<td>ARIMA (0,2,0)</td>
<td>0.76</td>
<td>1</td>
<td>4.67 (0.59)</td>
<td>0.93 (0.35)</td>
</tr>
<tr>
<td>Inpatient care discharges (x3)</td>
<td>y1, y2, x1, x2, x4, x5, x6</td>
<td>none</td>
<td>ARIMA (0,1,0)</td>
<td>0.96</td>
<td>3</td>
<td>8.30 (0.22)</td>
<td>0.89 (0.40)</td>
</tr>
<tr>
<td>Outpatient care visits (x4)</td>
<td>y1, y2, x1, x2, x3, x5, x6</td>
<td>y1</td>
<td>TF (0,1,0)</td>
<td>0.61</td>
<td>0</td>
<td>6.00 (0.42)</td>
<td>0.70 (0.72)</td>
</tr>
<tr>
<td>Students enrolled at the first year of studies (x5)</td>
<td>y1, y2, x1, x2, x3, x4, x5, x6</td>
<td>x6</td>
<td>TF (0,1,0)</td>
<td>0.98</td>
<td>4</td>
<td>0.60 (0.99)</td>
<td>0.55 (0.92)</td>
</tr>
<tr>
<td>Graduated medical doctors (x6)</td>
<td>y1, y2, x1, x2, x3, x4, x5, x6</td>
<td>none</td>
<td>ARIMA (0,1,0)</td>
<td>0.85</td>
<td>3</td>
<td>3.85 (0.70)</td>
<td>0.84 (0.48)</td>
</tr>
</tbody>
</table>

Legend: stationary R – measure goodness of fit of model. Range is from negative infinity to 1; Q-stat – is Ljung-Box Q(6) statistics that test null hypotheses of no autocorrelation in residual series; Z-stat – is Kolmogorov-Smirnov statistics that test null hypotheses of normal distribution of residual series.
Table 4 Implicit description of all Transfer function models from the second period 1983–2008

<table>
<thead>
<tr>
<th>Dependent variable (labels and name)</th>
<th>Potential predictors in Start model (only name)</th>
<th>Significant predictors in Final model (only name)</th>
<th>Model type</th>
<th>Stationary R2</th>
<th>Number of outliers</th>
<th>Q-stat (p-value)</th>
<th>Z-stat (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physicians (y1)</td>
<td>x1, x2, x3, x4, x5, x6</td>
<td>x1, x2</td>
<td>TF (0,1,0)</td>
<td>0.71</td>
<td>0</td>
<td>5.35 (0.50)</td>
<td>0.63 (0.82)</td>
</tr>
<tr>
<td>Nurses (y2)</td>
<td>y1, x1, x2, x3, x4, x5, x6</td>
<td>y1</td>
<td>TF (0,1,0)</td>
<td>0.92</td>
<td>2</td>
<td>7.34 (0.29)</td>
<td>0.53 (0.94)</td>
</tr>
<tr>
<td>Inpatient care discharges (x3)</td>
<td>y1, y2, x1, x2, x4, x5, x6</td>
<td>x2</td>
<td>TF (0,1,0)</td>
<td>0.78</td>
<td>1</td>
<td>7.34 (0.29)</td>
<td>0.51 (0.96)</td>
</tr>
<tr>
<td>Outpatient care visits (x4)</td>
<td>y1, y2, x1, x2, x3, x5, x6</td>
<td>y1</td>
<td>TF (0,1,0)</td>
<td>0.44</td>
<td>0</td>
<td>6.31 (0.39)</td>
<td>0.59 (0.88)</td>
</tr>
<tr>
<td>Students enrolled at the first year of studies (x5)</td>
<td>y1, y2, x1, x2, x3, x4, x5, x6</td>
<td>none</td>
<td>ARIMA (0,1,0)</td>
<td>0.73</td>
<td>1</td>
<td>4.97 (0.55)</td>
<td>0.67 (0.77)</td>
</tr>
<tr>
<td>Graduated medical doctors (x6)</td>
<td>y1, y2, x1, x2, x3, x4, x5, x6</td>
<td>none</td>
<td>ARIMA (0,1,0)</td>
<td>0.23</td>
<td>1</td>
<td>4.73 (0.58)</td>
<td>0.68 (0.74)</td>
</tr>
</tbody>
</table>

Legend: stationary $R^2$ – measure goodness of fit of model. Range is from negative infinity to 1; Q-stat – is Ljung-Box Q(6) statistics that test null hypotheses of no autocorrelation in residual series; Z-stat – is Kolmogorov-Smirnov statistics that test null hypotheses of normal distribution of residual series.
Table 5 Forecasts with 95% confidence level and realized values of physicians and nurses’ supply in the public sector of Serbia through 2015

<table>
<thead>
<tr>
<th>Year</th>
<th>Physicians</th>
<th>Nurses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Forecast value</td>
<td>Lower value of 95% CL</td>
</tr>
<tr>
<td>2009</td>
<td>20983</td>
<td>20590</td>
</tr>
<tr>
<td>2010</td>
<td>21245</td>
<td>20690</td>
</tr>
<tr>
<td>2011</td>
<td>21448</td>
<td>20767</td>
</tr>
<tr>
<td>2012</td>
<td>21600</td>
<td>20815</td>
</tr>
<tr>
<td>2013</td>
<td>21709</td>
<td>20831</td>
</tr>
<tr>
<td>2014</td>
<td>21779</td>
<td>20818</td>
</tr>
<tr>
<td>2015</td>
<td>21814</td>
<td>20776</td>
</tr>
</tbody>
</table>
Figure 1. Observed and fitted number (with 95% LCL and UCL) of physicians employed in public healthcare sector of Serbia (1983-2008) and the forecast by the year 2015.
Figure 2. Observed and fitted number (with 95% LCL and UCL) of nurses employed in public healthcare sector of Serbia (1983-2008) and the forecast by the year 2015
Figure 3. Observed and fitted number (with 95% LCL and UCL) of inpatient care discharges
Figure 4. Observed and fitted number (with 95% LCL and UCL) of outpatient care visits (000) in public healthcare sector of Serbia (1983-2008) and the forecast by the year 2015.
Figure 5. Observed and fitted number (with 95% LCL and UCL) of students enrolled at the first year of medical studies at state faculties in Serbia (1983-2008) and the forecast by the year 2015.
Figure 6. Observed and fitted number (with 95% LCL and UCL) of graduated medical doctors at state faculties in Serbia (1983-2008) and the forecast by the year 2015.