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1. Modeling of Hong Kong healthcare manpower

- The overall model for Hong Kong doctor manpower projection comprises two sub models: the demand model and the supply model.
- The difference between the demand and supply projections is the manpower 'gap' or 'surplus/shortfall'.
- Modelling is a methodology that describes the interaction of elements inside the system by an equation or a series of equations, in form of numerical and/or logical equations.
- Modelling of a system is driven by two factors: 1) nature of the system and 2) data availability.
- A complicated system cannot be easily explained by physical phenomena and is with many variables, curve fitting (although confounded by interactions between elements/variables) is a common modelling approach.

1. Modeling of Hong Kong healthcare manpower

- The historical data sample size necessary for obtaining an accurate curve is exponentially proportion to the number of variables included in the model.
- System modelling involves two sets of approximation: approximate full variable spectrum by a limited number of variables and approximate the interactions amongst the variables by (numerical and/or logical) expression(s), to which the modelled system is an approximation of the real system.
- Hong Kong healthcare manpower is an extremely complicated system which cannot be easily described by physical phenomena.
- The core assumption of this model (an essential and common assumption of system models) is that the manpower projection follows historical trends in the data.

2. Projecting doctor demand

2.1 Demand indicators

Public

i.	Daycase discharge	$d_{HA}^{daycase}$
ii.	Acute inpatient discharge	$d_{HA}^{inpatient}$
iii.	Long-stay discharge	$d_{HA}^{longstay}$
iv.	Acute inpatient bed-day	$b_{HA}^{inpatient}$
v.	Long-stay bed-day	$b_{HA}^{longstay}$
vi.	General outpatient visit	n_{HA}^{GOP}
vii.	Specialist outpatient visit	n_{HA}^{SOP}
viii.	A&E attendance	$n_{HA}^{A\&E}$
ix.	DH-based outpatient clinic visit	n_{DH}^{i}

Private

i.	Daycase discharge	$d_{private}^{daycase}$
ii.	Acute inpatient discharge	$d_{private}^{inpatient}$
iii.	Acute inpatient bed-day	$b_{private}^{inpatient}$
iv.	Outpatient visit	$n_{private}^{outpatient}$

2. Projecting doctor demand

2.2 Converting healthcare utilisation to Full Time Equivalents (FTEs)

- FTE is expressed as a weighted sum of utilisation
- Weight coefficient '*c*' and '*w*' represents number of FTE professions per utilisation

Hospital Authority

$$FTE_{HA}^{inpatient}(y) = \left(d_{HA}^{daycase}(y) + d_{HA}^{inpatient}(y) + d_{HA}^{longstay}(y)\right) \times c_{discharge} + \left(b_{HA}^{inpatient}(y) - 2d_{HA}^{inpatient}(y)\right) \times c_{inpatient}^{bedday} + \left(b_{HA}^{longstay}(y) - 2d_{HA}^{longstay}(y)\right) \times c_{longstay}^{bedday}$$

$$FTE_{HA}(y) = FTE_{HA}^{inpatient}(y) + n_{HA}^{SOP}(y) \times c_{HA}^{SOP} + n_{HA}^{GOP}(y) \times c_{HA}^{GOP} + n_{A\&E}(y) \times c_{A\&E}$$

Department of Health

$$FTE_{DH}(y) = c_g \sum_{i \neq 4} n_{DH}^{i}(y) + 20$$

2. Projecting doctor demand

2.2 Converting healthcare utilisation to Full Time Equivalents (FTEs)

Hospital Authority

Inpatient & SOP coefficients

$$[c_{discharge}, c_{inpatient}^{bedday}, c_{longstay}^{bedday}, c_{HA}^{SOP}] = arg \min_{[p,q,r,z]} \sum_{y} \left(\left(d_{HA}^{daycase}(y) + d_{HA}^{inpatient}(y) + d_{HA}^{longstay}(y)\right) \times p + \left(b_{HA}^{inpatient}(y) - 2d_{HA}^{inpatient}(y)\right) \times q + \left(b_{HA}^{longstay}(y) - 2d_{HA}^{longstay}(y)\right) r + n_{HA}^{SOP}(y) \times z - D_{HA}^{inpatient}(y) - D_{HA}^{SOP}(y) \right)^2$$

GOP coefficient

$$c_{HA}^{GOP} = \frac{1}{7} \sum_{y=2005}^{2011} \frac{D_{HA}^{GOP}(y)}{n_{HA}^{GOP}(y)}$$

where D_{HA}^{GOP} is the number of doctors in HA GOPD

A&E coefficient

$$c_{HA}^{A\&E} = \frac{1}{7} \sum_{y=2005}^{2011} \frac{D_{HA}^{A\&E}(y)}{n_{HA}^{A\&E}(y)}$$

where $D_{HA}^{A\&E}$ is the number of doctors in A&E dept.

Department of Health

outpatient coefficient

$$c_g = c_{HA}^{GOP}$$

2. Projecting doctor demand

2.2 Converting healthcare utilisation to Full Time Equivalents (FTEs)

Private sector

$$FTE_{private}^{inpatient}(y) = d_{private}^{daycase}(y) \times w_{daycase}^{discharge} + d_{private}^{inpatient}(y) \times w_{inpatient}^{discharge} + \left(b_{private}^{inpatient}(y) - 2d_{private}^{inpatient}(y)\right) \times w_{inpatient}^{bedday}$$

$$FTE_{private}(y) = FTE_{private}^{inpatient}(y) + n_{private}^{outpatient}(y) \times w_{private}^{outpatient}$$

Inpatient coefficients

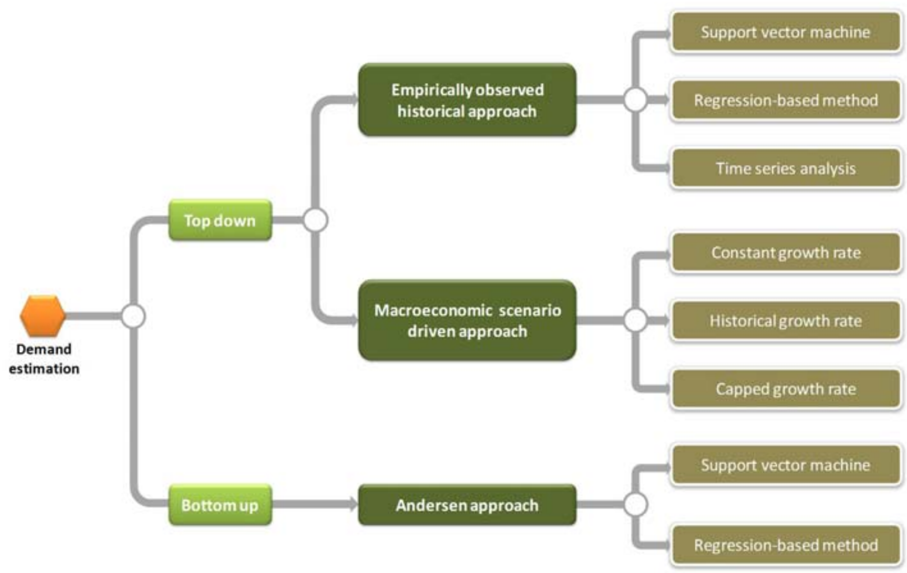
$$[w_{daycase}^{discharge}, w_{inpatient}^{discharge}, w_{inpatient}^{bedday}] = arg \min_{[p,q,r]} \sum_{y} \left(d_{private}^{daycase}(y) \times p + d_{private}^{inpatient}(y) \times q + \left(b_{private}^{inpatient}(y) - 2d_{private}^{inpatient}(y)\right) \times r - D_{private}^{inpatient}(y)\right)^2$$

Outpatient coefficient

$$w_{private}^{outpatient} = \frac{1}{7} \sum_{y=2005}^{2011} \frac{D_{private}^{outpatient}(y)}{n_{private}^{outpatient}(y)}$$

2. Projecting doctor demand

2.3 Modeling doctor demand



2. Projecting doctor demand

2.3 Modeling doctor demand

Utilisation *z*(*y*) is expressed as $\sum_a \sum_s \mathrm{P(a,s,y)R(a,s,y)}$

where *P*(*a*,*s*,*y*) is the Hong Kong population size of age-sex group (*a*,*s*) at year *y*

R(*a*,*s*,*y*) is the utilisation rate (i.e. inpatient discharge rate, SOP visit rate) of age-sex group (*a*,*s*) at year *y*

A. Support Vector Machine (SVM)

- SVM is a kernel-based neural network that maps an input **x** to an output *y* by means of weighted sum of kernel functions:

$$\mathrm{y} = \sum_{\mathrm{i}} \mathrm{w_i} \kappa(\mathbf{x}_\mathrm{i}, \mathbf{x}) + \mathrm{B}$$

- SVM has the flexibility to 'evolve' an optimal structure according to historical data and it is proved as an 'univerisal approximator'.
- The structure is well regularised, and the generalisation ability of the network is maximized

2. Projecting doctor demand

2.3 Modeling doctor demand

B. Regression-based method

$$\hat{R}(a,s,y) = \alpha(a,s) + \beta(a,s)y$$

which assumes

$$N(a,s,y) \sim Poisson(O(a,s,y)R(a,s,y))$$

where N(*a*,*s*,*y*) is the utilisation volume

O(*a*,*s*,*y*) is an offset term in age group , sex , and year

C. Time series approach

Linear trend $u(y) = ay + b$

Exponential decay trend $u(y) = we^{-\alpha y} + c$

Constant trend $u(y) = u_0$

2. Projecting doctor demand

2.3 Modeling doctor demand

D. Constant growth rate

$$R(a, s, y) = R(a, s, 2011) \times (1 + x)^{y-2011}$$

where x = 0.2% for public sector and 1% for private sector

E. Historical growth rate

$$R(a, s, y) = R(a, s, 2011) \times (1 + x)^{y-2011}$$

The rate *x* is computed by minimizing $\sum_{y} |N(y) - z(y)|$

F. Capped growth rate

$$R(a, s, y) = R(a, s, 2011) \times \left(\frac{w}{1 + e^{-\alpha(y - y_0 - \mu)}} + B\right)$$

2. Projecting doctor demand

2.4 Model comparison

The performance of a model is represented by the sum of absolute error

$$E(\theta, u) = \sum_{a} \sum_{y} \sum_{s} \left|\widetilde{M_u}(a, s, y|\theta) - R_u(a, s, y)\right|$$

$E(\theta, u)$ is the sum of absolute rate error of model $\theta \in$ {EOH-SVM, MSD-constant growth rate, MSD-historical growth rate} on utilisation *u*

$\widetilde{M_u}(a, s, y|\theta)$ is the estimated utilisation rate on *u* of age-sex group (*a*, *s*) at year *y* by model θ and

$R_u(a,s,y)$ is the actual utilisation rate on *u* of age-sex group (*a*, *s*) at year *y*.

Regression-based method: It involves an artificial cap value and year of capping

Capped growth rate: The corresponding parameter calibration is not always converged

Anderson model: Data for constructing the model is not available

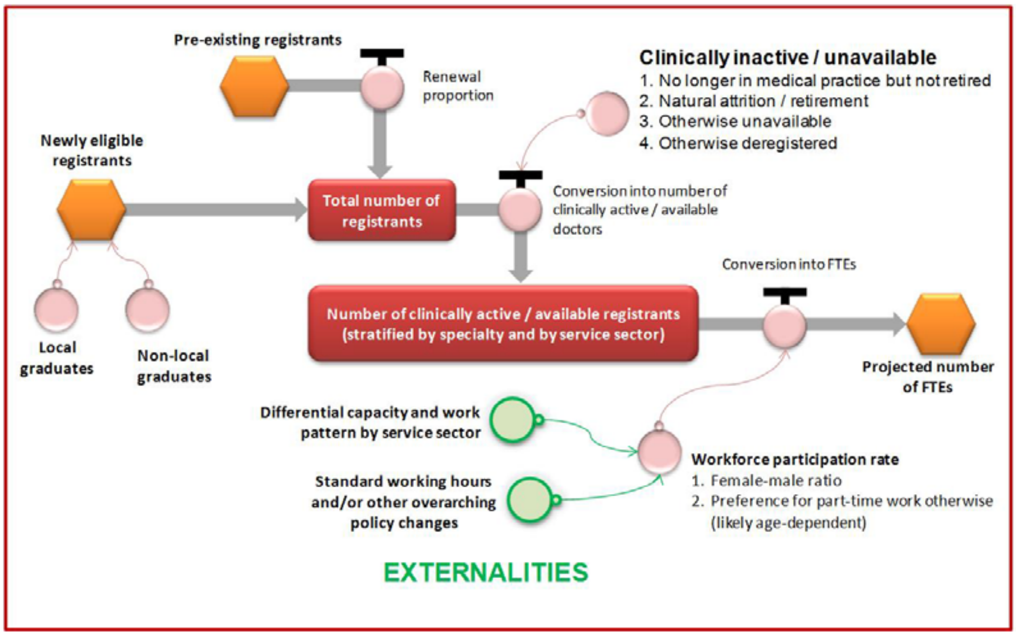
2. Projecting doctor demand

2.4 Model comparison

	EOH-SVM	MSD (constant growth rate)	MSD (historical growth rate)
Day case discharge rate (public)	0.93	7.56	1.53
Acute care in-patient discharge rate (public)	0.82	3.83	2.05
Acute care in-patient bed day rate (public)	7.29	44.65	17.19
Long stay discharge rate (public)	0.03	0.08	0.05
Long stay bed day rate (public)	11.09	28.42	20.21
SOP visit rate	3.67	8.09	8.08
GOP visit rate	4.04	16.95	10.06
A&E attendance rate	2.26	5.30	4.69
Day case discharge rate (private)	0.18	0.57	0.48
Acute care in-patient discharge rate (private)	0.11	0.42	0.33
Acute care in-patient bed day rate (private)	1.06	2.45	2.28
Private outpatient rate	99.03	252.69	251.94

3. Projecting doctor supply

3.1 Models for doctor supply



3. Projecting doctor supply

3.2 Determinants of supply: projecting stock and flow

Number of current registrants

$$n_{current}(a,y,s) = p_{renewal} \times n_{pre}(a,y,s) + n_{local}(a,y,s) + n_{non-local}(a,y,s)$$

where
- n_{pre} number of pre-existing registrants
- n_{local} number of local graduates
- $n_{non\text{-}local}$ number of non-local graduates
- $n_{current}$ number of current registrants
- n_{active} number of active and available registrants
- $p_{renewal}$ licence renewal proportion

Number of active and available registrants

$$n_{active}(a,y,s) = n_{current}(a,y,s) \times p_{active}(a,s)$$

where $p_{active}(a,s,y)$ is the active proportion of age-sex group (a,s)

3. Projecting doctor supply

3.3 Converting workforce supply to full time equivalents (FTEs)

$$FTE_{supply}(y) = \frac{\sum_a \sum_s (n_{active}(a,y,s) \times \sum_c p_{sector}(a,s,c) \times h(a,s,c))}{Standard\ working\ hours\ per\ week\ per\ FTE}$$

where $p_{sector}(a,s,c)$ is the proportion of doctors working in the service sector c at year y

$h(a,s,c)$ is the average number of working hours per doctor

4. Gap analysis

4.1 Annual number of FTE

The number of FTE doctors in year *y* is stratified into the number of FTE demand doctors and the number of FTE supply doctors

$$FTE_{supply}\ (y)$$
$$FTE_{demand}\ (y) = FTE_{HA}(y) + FTE_{DH}(y) + FTE_{private}\ (y)$$

4.2 Year-on-year FTE gap

$$a(y) = FTE_{demand}\ (y) - FTE_{supply}(y)$$

4.3 Annual incremental FTE

$$I(y) = a(y) - a(y-1)$$