Prospective of Medical Cost for Renal Failure for Sex and Age Group in Range 2012-2050: Case of Mexico

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Abstract: Medical costs are calculated for renal failure for all age groups of Mexican people and sex in range of 2012-2050. Probabilities of entrance or disease detection, permanence or in treatment and departure or death are calculated for each age group and sex. The maximum probabilities for each case are 5.36% (60-64), 6.25% (0-4) and 0.48% (85+) for male. Analogously, for female are 5.56% (60-64), 5.24% (0-4) and 0.32% (85+), respectively. The treatment medical costs are not similarly between men and women. The maximum number of people in treatment is between (0-4) and (20-24, male. 25-29, female) years old. The number of patients varies between 5 and 19 years of age, from 30 years of age decreases the number of patients up to age 69 years. After that it increase again.

Key words: Medical costs, prospective, aging, health, renal failure.

1. Introduction

Mexican food is varied but rich in carbohydrates and fats, recent advances in medicine have shown that the change of cane sugar by fructose as a sweetener in the Mexican diet is largely responsible along with hereditary factors of physical deterioration of the Mexican population: obesity, diabetes mellitus, hypertensive diseases, renal failure (RF) and chronic-disease degenerative [1, 2].

This work shows the economic impact over a horizon of 2012-2050 of RF in terms of percentages of GDP (gross domestic product), for the three scenarios: base, optimal and worse. The base scenario is calculated by adjusting a model AR (2) MA (2) [3] with weighting, the other two are given by experts and both depend on the effect of energy and labor reforms.

Population projections by CONAPO whose methodology appears on the official website [4] and

decadal cohort of number of patients and unit costs for some diseases IMSS beneficiaries were used [5, 6]. IMSS information is not showed by age group neither sex (patients in treatment). New cases information appears since 1980 up to 1990 by big age group and sex and 1991-2011 by age group. Deceased people by RF are presented by age and sex.

The available information is from public institutions: Ministry of Health (Secretaria de Salud, SS [7-10]), National Population Council (Consejo Nacional de Poblacion, CONAPO [4]), Mexican Institute of Social Security (Instituto Mexicano del Seguro Social, IMSS [5, 6, 11]), National Institute of Statistics and Geography (Instituto Nacional de Estadística y Geografía, INEGI [12]) and private: Mexican Association of Insurance Institutions (AMIS (Asociación Mexicana de Instituciones de Seguros)) and hospitals.

The cost of this disease is high for its treatment and its duration. As insured persons by IMSS represent 40% of the population, IMSS data are taken as

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sampling. The Mexican health system (SS) covers the following institutions: IMSS, Institute for Social Security and Services for State Workers (Instituto Mexicano de Seguridad Social y Servicios para los Trabajadores del Estado, ISSSTE), Popular Insurance (Seguro Popular, SP-IMSS), Oil Company (Petroleos Mexicanos, PEMEX), Ministry of Defense (Secretaria de la Defensa Nacional, SEDENA), Ministry of Navy (Secretaria de Marina, SEMAR), private institutions and other public institutions, so the numbers of deaths and new cases are representative of the population.

The paper is organized as follows: Section 2 explains the methodology used to solve the problem of calculating medical costs for this disease; Section 3 presents results and Section 4 expresses the conclusions.

2. Methodology

The proposed model is stochastic [13] with entrance, in treatment and death probabilities by RF, population, number of patients and unitary cost at time t by age group and sex (stock).

The probabilities are calculated for each year, t , as

$$\frac{Pr(\text{death}, \text{age}, \text{sex}; t) = \# \text{ death by the disease}(\text{age}, \text{sex}; t)}{\text{population}(\text{age}, \text{sex}; t)} \quad (1)$$

$$\frac{Pr(\text{new cases}, \text{age}, \text{sex}; t) = \# \text{ new cases or } \# \text{ detected disease}(\text{age}, \text{sex}; t)}{\text{population}(\text{age}, \text{sex}; t)} \quad (2)$$

$$\frac{Pr(+1, \text{age}, \text{sex}; t) = \# \text{ people who have survived the disease one more year}(\text{age}, \text{sex}; t)}{\text{population}(\text{age}, \text{sex}; t)} \quad (3)$$

The model diagram is showed in Fig. 1. Several considerations must be taken by each patient's condition.

Deaths. It works with the records of the SS with respect to age, sex and cause key, excluding unspecified. It has the historical 1990 to 2011. Curve fitting are applied to these data by OLS (ordinary least-squares) after the made the transformation of Eq. (4). In most cases it is the exponential. The growth

rates are denoted as λ . Prospective is constructed following behavior given these rates, for 2012-2050 taken as input data 2011. The correlation coefficients of curve fitting are showed in Table 1.

$$\text{death}_t = \text{death}_0 e^{\lambda t} \Rightarrow$$

$$\ln(\text{death}_t) = \ln(\text{death}_0 e^{\lambda t}) = \ln(\text{death}_0) + \lambda t \quad (4)$$

The Eq. (1) is calculated using both prospective, the population and the exponential behavior of deaths by RF. This latter based on the high correlation coefficients by age group and sex shown in Table 1.

Behavior of deaths was analyzed. The age groups 5-9 and 15+ showed an exceptional exponential behavior with correlation coefficients greater than 96% for female and 98% for male.

New cases. From the database of the SS tables of major diseases are obtained by age group (<1, 1-4, 5-9, 10-14, 15-19, 20-24, 25-44, 45-49, 50-59, 60-65 & 65+). Information was obtained from 1990-2011 data which its trend behavior and basic statistics (mean and standard deviation) were analyzed. In case non-trend was chosen to simulate an exponential growth between the extreme values for the entire period. As a base scenario was chosen the trend values as first option and minimum among all the options as second choice.

Eq. (2) is calculated using both prospective, the population and the exponential behavior of new cases by RF.

For new cases exhibit this behavior with correlations of 56% for women and 86.05% for men in general. The probabilities of entrance, in treatment

Table 1 Correlation coefficients for exponential behavior (death).

Age groups	Male	Female	Age groups	Male	Female
0-4			45-49	0.89	0.80
5-9	0.85	0.81	50-54	0.91	0.85
10-14			55-59	0.95	0.87
15-19	0.92	0.94	60-64	0.95	0.81
20-24	0.97	0.78	65-69	0.95	0.75
25-29	0.93		70-74	0.97	0.91
30-34	0.88		75-79	0.95	0.94
35-39	0.93	0.78	80-84	0.97	0.96
40-44	0.95	0.80	85 +	0.98	0.92

and death to RF are dynamics and they are different in each stage. Their dynamic changes are gotten by LSO. Tables of these dynamic changes by age group are shown in the appendix.

In treatment, IMSS data were used to rebuild the intermediate years. The method Runge-Kutta was applied to the exponential growth rates per period. Then data were redistributed according to death rates of SS for age groups. Subsequently normalized with respect to the prospective of the IMSS. The initial value is the amount of the average proportion of deaths¹ by age group by sex (2003-2011) multiplied by the number of patients treated according to IMSS prospective.

Data from 2011 patients in treatment are obtained by extrapolating the values of 2012 compared to exponential growth rates (2012-2020) of its prospective. The cases of initial values are the maximum, minimum and average in the period. After these are distributed by age and sex as mentioned in the previous paragraph.

Eq. (3) is calculated using both prospective, the population and the exponential behavior of in treatment patients by RF. As the number of in treatment patients are IMSS data (sample), these were analyzed and calculated their behavior and prospective of both beneficiaries of the IMSS and beneficiaries who have survived the disease one more year. Latter, the probabilities by age group by sex by each year were gotten applying Eq. (3). After, these probabilities were input to make inference to population.

The AMIS published in 2011 the morbidity rate of RF for each 10,000 (Table 2).

Redistribution by age group (2012-2050) can be calculated using standard growth rates (about the death) following the general prospective IMSS or initial values using any of the three values obtained from the ratios of deaths by group age by sex by disease (1990-2012): average, maximum or minimum, and from the initial value to apply the before mentioned growth rates. The scenarios I, II and III use the average, maximum and minimal values as initial value (2011), respectively.

2.1 Gross Domestic Product Scenarios: Basis, Optimal and Worse

Base Scenario. Quarterly GDP (gross domestic product) data since 1996-I up to 2012-IV current prices are applied to AR (2) MA (2) model (Eq. (5)). Adjusted data are deflated to base year 2012. In an ideal situation, the sequence diagram should capture the requirements in the forms of good scenarios. Bad scenarios need to be detected automatically. Users tend to over complicate the sequence diagrams. Unfortunately, there is little or no indication of what constitutes a good sequence diagram. Ideally, it should be possible to lift off an executable specification for checking the validity of the diagram.

$$\begin{aligned}
 PIB_t = & 1.037568 PIB_{t-2} + \\
 & + [AR(2) = 0.730942, MA(2) = -0.937709] \quad (5) \\
 & 1996 \leq t \leq 2012
 \end{aligned}$$

From Table 3, AR process is stationary and ARMA model is invertible. The model presents positive serial correlation because of Durbin-Watson statistical is between 1 and 2. Covariance matrix values appear in Table 4.

Table 2 Morbidity rate of renal failure for each 10,000 (2011).

Age group	Distribution of insured male	RF (N10-N19)	Age group	Distribution of insured female	RF (N10- N19)
0-20	29%	63	0-20	26%	78
21-35	30%	92	21-35	33%	119
36-50	29%	112	36-50	29%	125
51-65	10%	279	51-65	10%	172
+ 65	2%	3,846	+ 65	1%	4,109
TOTAL	100%	4,391	TOTAL	100%	4,603

$\text{Pr}(\text{entrance}/\text{age}/\text{sex}/t)$: Entrance or detected disease probability for age for sex at time t

$\text{Pr}(+1/\text{age}/\text{sex}/t)$: Suffering a year over the disease probability by age by sex at time t

$\text{Pr}(\text{death}/\text{age}/\text{sex}/t)$: Death probability by RF by age by sex at time t .

Fig. 1 Schematic model. Started CONAPO population projections estimated population with hypertensive diseases, new cases and dying from renal failure from 2012 to 2050.

Fig. 2 Curves fitted for each scenarios of gross domestic product are showed.

Table 3 Statistical parameter of model AR (2) MA (2).

Parameters	
$R^2 = 98.99\%$	Inv. AR Root (0.85,-0.85)
	Inv. MA Root (0.97,-0.97)
$s_e = 3.66 \times 10^8$	t-Student(433.15,8.79, -23.86)
$n = 64$	D-W = 1.160196

Table 4 Covariance matrix of model AR (2) MA (2).

coefficients			
	GDP(-2)	AR (2)	MA (2)
GDP(-2)	5.74E-06	-7.41E-05	-2.26E-05
AR (2)	-7.41E-05	0.006918	-0.000999
MA (2)	-2.26E-05	-0.000999	0.001545

The increasing GDP was 2.5% (January 2013) fall down 1.7% (December 2013). Average rate in June 2014 was 3.1% (fall down up to 2.5%) and last semester is expected 1.7%. The government expects increasing rates during 2015 between 2.5%-3.5%. In 2016, rates could be of 3.0%-3.1% and in 2017-2050 of 3%. If energy and labor reforms are successful, the GDP growth rates could be of up to 7% from 2020.

Optimum scenario. Upper limits of the ranges of the above paragraph.

Worse scenario. Lower limits of the ranges of the above paragraph.

2.2 Probabilities of Entrance, in Treatment and Death for Renal Failure.

Dynamics probabilities prospective by patient condition by age group by sex by year are gotten from IMSS prospective for in treatment patients (Table 5) and applied to Runge-Kutta approximation to reconstruction year by year. Late, death data historic distribution by age groups and its prospective was applied to Table 6 data. Maximal rate for male is 0.47% and 0.54% for female at 2012. These rates are larger for women as men throughout the period. NOTE: In the IMSS prospective of in treatment patients, their rates are decreasing from 2021 to differences obtained from the analysis of historical data from 1990 to 2011.

In the cases of death and new cases condition, dynamics probabilities prospective are fitted by LSO. SS data are age groups.

3. Results

From Figs. 3 and 4, comparing two arbitrary years,

2019 and 2040, RF medical costs are higher for women than men about 0.053% and 0.088% of GDP, respectively, for base scenario. To worse scenario the differences are 0.076% and 0.161% for each reference year. To optimum scenario are 0.067% and 0.074%. All are in absolute terms.

If the initial value of patients in 2011 is the historical minimum, the differences in medical costs versus maximum are 0.093% (2019) and 0.0975% (2040) for male. For female, the costs differences are 0.128% and 0.134%, respectively.

For historical minimum initial value versus average initial value, the differences in medical costs for male are 0.0398% (2019) and 0.0415% (2040) and for female are 0.0544% and 0.0568%, respectively.

From Figs. 5, 6 and 7, the medical costs represent 5.97% (2019) and 9.35% (2040) for 50 and more years old male respect all disease population. For female, the costs are 8.31% and 13.97%, respectively.

The maximum number of people in treatment is between 0-4 and (20-24 (male), 25-29 (female) years old. The sick RF cases are going to shoot up after 70+ years old for male and 80+ for female.

Table 5 IMSS prospective for in treatment patients of renal failure.

Parameters Increasing range [9, 10]:	Rates of in treatment patients for
λ_1 2012-2020	9.7%
λ_2 2021-2030	4.2%
λ_3 2031-2040	2.3%
λ_4 2041-2050	1.0%
λ 2012-2050	4.0%

Table 6 Probabilities by patient condition by sex by year (2012-2050).

year	Enter		Treatment		Death	
	male	female	male	female	male	female
2010	0.37%	0.53%	0.53%	0.33%	0.01%	0.01%
2011	0.44%	0.69%	0.54%	0.37%	0.01%	0.01%
2012	0.46%	0.71%	0.79%	0.60%	0.01%	0.01%
2013	0.48%	0.73%	0.85%	0.64%	0.01%	0.01%
2014	0.49%	0.76%	0.92%	0.69%	0.01%	0.01%
2015	0.51%	0.78%	0.99%	0.74%	0.01%	0.01%
2016	0.54%	0.81%	1.06%	0.80%	0.02%	0.01%
2017	0.56%	0.83%	1.15%	0.86%	0.02%	0.01%
2018	0.58%	0.86%	1.24%	0.93%	0.02%	0.01%

(table 6 continued)

year	Enter		Treatment		Death	
	male	female	male	female	male	female
2019	0.60%	0.89%	1.33%	1.00%	0.02%	0.01%
2020	0.63%	0.92%	1.43%	1.07%	0.02%	0.01%
2021	0.65%	0.95%	1.46%	1.09%	0.02%	0.01%
2022	0.68%	0.98%	1.49%	1.11%	0.02%	0.01%
2023	0.71%	1.01%	1.52%	1.13%	0.02%	0.02%
2024	0.74%	1.04%	1.54%	1.15%	0.02%	0.02%
2025	0.77%	1.08%	1.57%	1.17%	0.02%	0.02%
2026	0.80%	1.11%	1.60%	1.19%	0.02%	0.02%
2027	0.83%	1.15%	1.63%	1.21%	0.02%	0.02%
2028	0.86%	1.18%	1.66%	1.24%	0.02%	0.02%
2029	0.90%	1.22%	1.69%	1.26%	0.02%	0.02%
2030	0.93%	1.26%	1.72%	1.28%	0.02%	0.02%
2031	0.97%	1.30%	1.72%	1.28%	0.02%	0.02%
2032	1.01%	1.34%	1.72%	1.28%	0.03%	0.02%
2033	1.05%	1.39%	1.72%	1.28%	0.03%	0.02%
2034	1.10%	1.43%	1.72%	1.28%	0.03%	0.02%
2035	1.14%	1.48%	1.72%	1.28%	0.03%	0.02%
2036	1.19%	1.53%	1.72%	1.28%	0.03%	0.02%
2037	1.23%	1.58%	1.73%	1.28%	0.03%	0.02%
2038	1.28%	1.63%	1.73%	1.29%	0.03%	0.02%
2039	1.34%	1.68%	1.73%	1.29%	0.03%	0.02%
2040	1.39%	1.73%	1.74%	1.29%	0.03%	0.02%
2041	1.45%	1.79%	1.72%	1.28%	0.03%	0.02%
2042	1.50%	1.85%	1.70%	1.26%	0.04%	0.03%
2043	1.57%	1.91%	1.68%	1.25%	0.04%	0.03%
2044	1.63%	1.97%	1.66%	1.23%	0.04%	0.03%
2045	1.70%	2.03%	1.64%	1.22%	0.04%	0.03%
2046	1.76%	2.10%	1.63%	1.21%	0.04%	0.03%
2047	1.84%	2.16%	1.61%	1.19%	0.04%	0.03%
2048	1.91%	2.23%	1.59%	1.18%	0.04%	0.03%
2049	1.99%	2.31%	1.58%	1.17%	0.04%	0.03%
2050	2.07%	2.38%	1.56%	1.16%	0.05%	0.03%

Fig. 3 Medical cost as a percentage of GDP for male and female since 2012 up to 2050 for three scenarios: base, optimum and worse.

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Fig. 4 Medical cost as a percentage of GDP for male and female for base scenario.

Fig. 5 Medical cost as a percentage of GDP for male and female for base scenario.

Fig. 6 Comparative unit cost for male and female all age group vs. 50 and more years old.

Fig. 7 Comparative number of patients of RF for male and female all age group vs. 50 and more years old.

4. Conclusions

The renal failures are more expensive than diabetes mellitus [14] and hypertensive disease [15]. After of 50 years old RF increasing costs conceivably owing to others illness linking like neuronal diseases and renal failure. RF appears at early age 0-4 and 20-29 for both sex and increase from 70 years old. The RF is more expensive for female then male (unit cost). The male patient number is bigger than female. AMIS reported that there are more women (51.18%) than men (48.82%) insured by this disease. The different results are because of these patients belong to wage levels above 8 minimum wages and they acquired a major medical insurance.

It is necessary to construct consistent data bases for new cases and in treatment condition patient for age by sex by year to better models.

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