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ORIGINAL PAPER

Modeling the Economic Impact of Pandemic Influenza: A Case Study in Turkey

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Abstract Influenza pandemics have occurred intermittently throughout the 20th century and killed millions of people worldwide. It is expected that influenza pandemics will continue to occur in the near future. Huge number of deaths and cases is the most troublesome aspect of the influenza pandemics, but the other important trouble is the economic impact of the influenza pandemics to the countries. In this study, we try to detect the cost of a possible influenza pandemic under different scenarios and attack rates. We include the vaccination and antiviral treatment cost for direct cost and we add the work absenteeism cost to the calculations for indirect cost of influenza pandemics. As a case study, we calculate the economic impact of pandemic influenza for Turkey under three different scenarios and three different attack rates. Our optimistic estimation shows that the economic impact of pandemic influenza will be between 1.364 billion dollars and 2.687 billions dollars to Turkish economy depending on the vaccination strategies.

Keywords Pandemic influenza · Economic impact · Cost analysis · Turkey

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Introduction

Influenza pandemics have threatened the humankind over centuries and killed millions of people during worldwide. Despite the important developments at the medical sciences influenza pandemics are still keeping up to date due to the nature of the influenza virus. Influenza viruses are the members of the Orthomyxoviridae family and include three types of viruses (A, B and C). Influenza C viruses have some structural differences from influenza A and B viruses, and do not cause severe epidemic disease. Both influenza A and B may cause severe epidemic disease in humans, only influenza A virus can cause pandemic influenza [1].

Pandemic influenza occurred in 1918–19, 1957 and 1968–69, the pandemic of 1918–19 which is called ‘Spanish’ influenza, is estimated to have killed more than 20 million lives [1]. Studies based on the past pandemics estimate that the next pandemic influenza will have 15% to 35% gross clinical attack rate in the U.S. Gross clinical attack rate refers to the percentage of the population that becomes clinically ill due to an influenza pandemic. [2, 3].

To mitigate an influenza pandemic, control interventions include two strategies—one, a non-pharmaceutical approach such as social distancing and infection control and the other, a pharmaceutical approach such as the use of influenza vaccines and antiviral for treatment and prophylaxis [4].

Vaccination is the most effective tool to prevent influenza and reduce the impact of epidemics. Several types of vaccines have been used for more than 60 years, and are safe and effective in preventing both mild and severe effects of influenza [5].

The other pharmaceutical control intervention for influenza is using antiviral especially specific chemotherapeutic agents, which offer a potential approach to control pandemic influenza. Generally, two classes of antiviral agents reduce the effect of influenza, first, the adamantanes such as, amantadine and rimantadine, and, second, the neuraminidase inhibitors, such as zanamivir and oseltamivir [1].

It is not surprising that influenza is still the most discussed pandemic threat in the world. An outbreak of avian influenza ,which caused by the H5N1 strain of the influenza A virus, in Asia, Africa and Europe has resulted in the deaths of over 200 million birds in recent years [6]. The H5N1 virus doesn't have ability to transmit efficiently from human to human yet, but many health authorities across the world agree that H5N1 or another lethal virus will cause a catastrophic influenza pandemic in the near future [7, 8]. Due to the potential magnitude of this disaster, World Health Organization (WHO) traces the virus from 110 national laboratories in 52 countries with the responsibilities of the original World Influenza Centre shared by four Collaborating Centers, located in Atlanta, London, Tokyo and Melbourne [1]. In addition to fatal impact, pandemic influenza also has socio-economic impact, sourcing from direct healthcare costs and indirect costs. Direct healthcare costs include vaccination cost, antiviral treatment cost and hospitalization cost. Due to the characteristic symptoms of pandemic influenza, patients may need several days of bed rest at home or may require intensive care unit (ICU) care and non-ICU care at hospitals. Pandemic influenza also affects the services and economy, through illness, absenteeism, and lost production. All these factors constitute the indirect cost of pandemic influenza.

There is a wide literature about the pandemic influenza. But the literature which investigates the economic impact of pandemic influenza is restricted. The literature on pandemic influenza's economic impact is made in different countries by the several researchers. Meltzer, I. et al. [2, 3] modeled the economic impact of pandemic influenza in the United States and tried to find implications for setting priorities for intervention. Bloom and Wit made brief looks to the possible economic consequences for Asia of a mutation of avian flu leading to human-to-human transmission, using different assumptions about the duration and virulence of the flu pandemic. They claimed that a pandemic will likely slow or halt economic growth in Asia and lead to a significant reduction in trade, particularly in services. In the long run potential economic growth will be lower and poverty will increase [9]. Akazawa et al. investigated the economic costs of influenza-related work absenteeism. They assumed the average number of workdays missed due to influenza like illness (ILI) 1.30 days, and the average work loss value US$137 per person. They provided a simple framework within which competing considerations of disease epidemiology, worker productivity, and economic costs [10]. Postma et al. reviewed some selected studies which were related influenza vaccination in combination with cost, cost-benefit, cost-effectiveness, efficiency, economic evaluation, health-policy, and pharmacoeconomics according to several criteria such as i. benefit-to-cost (B/C) ratio; ii. vaccine effectiveness; iii. relative cost of vaccine [11]. Ryan et al. aimed to establish the number of people who may be eligible for influenza vaccination in the European Union (EU), and estimated the costs and consequences of not vaccinating this population for five EU member states, France, Germany, Italy, Spain and the UK [5].

Table 1 Risk groups

	High risk	Low risk
0–19 age	G 1	G 4
20–64 age	G 2	G 5
65 +	G 3	G 6

Table 2 Assumed proportions of risk groups within the population

Risk group	Assumed proportion (%)
G1	2.24
G2	8.32
G3	2.83
G4	32.88
G5	49.45
G6	4.25

Material and method

In this study, our objective is to estimate the economic impact of pandemic influenza to the society. We chose Turkey for case study due to its potential risk for pandemic influenza. The outbreak of H5N1 caused the human deaths and millions annihilation of poultry in Turkey in 2006. The economic impact of pandemic influenza consists of direct healthcare costs and indirect costs. The vaccination costs, antiviral treatment costs, non-ICU care costs, ICU care costs and ventilator usage costs are assumed direct healthcare costs (DHC). Impact to the economy such as loss of production, work absenteeism constitutes the indirect costs of pandemic influenza.

Risk groups

A definite percentage of people may have more medical risk in the population, so it should break downs to the risk groups. The specific risk groups are generally defined in the literature as;

- Age groups
- Population with medical risk factors (respiratory, cardiovascular, diabetes, HIV/AIDS etc.)

Table 3 Assumed population of risk groups

Risk groups	Assumed population
G1	1,587,162
G2	5,873,279
G3	2,001,270
G4	23,212,262
G5	34,913,378
G6	3,001,905

- To transmit influenza to persons at high risk such as healthcare workers [5].

In this study the population is divided into six risk groups according to age and medical risk. Table 1 shows the notation of the risk groups.

Risk groups and their assumed proportions in the total population are shown in Table 2. These proportions are derived from Zhang and others [12].

The data about the assumed population of risk groups are shown in Table 3. The age data are obtained from Turkish Statistical Institute's official website [13].

Pandemic data

Another important problem during a pandemic influenza is to guess the number of deaths, hospitalizations, cases, ICU care and ventilator needs in order to estimate the economic impact of pandemic influenza. At the history of the pandemic influenza, it is possible to find different deaths, cases, hospitalizations ratios depending on the harmful effect of the pandemic influenza. The studies must concern these different ratios. In this study, we used the Zhang and others [12] ratios for deaths, cases and hospitalizations rates for three different scenarios, minimum, most likely and maximum. The calculations of the cases, deaths, etc. are based on these ratios which are shown in Table 4. Economic impact is analyzed according to three scenarios that are minimum, most-likely and maximum.

Model assumptions which are related to the relevant scenarios are given in Table 5.

Calculation of the cases

We calculate the number of cases by the following formula;

$$x_i = \alpha_i P_i^+ + \beta_i P_i^- (i = 1, \ldots, 6) \qquad (1)$$

where

i risk group index (i=1,…,6)

x_i the number of cases from ith risk group. i=1,…,6

α_i the probability of being influenza if taken preventive vaccination at risk group i. i=1,…,6

β_i the probability of being influenza if not taken preventive vaccination at risk group i. i=1,…,6 (We assumed that it is equal to gross attack rate)

P_i^+ the number of people from risk group i who take preventive vaccination.

P_i^- the number of people from risk group i who do not take preventive vaccination

Table 4 Population-based rates (per 1,000 persons) of illness and death in an influenza pandemic [12]

Rate for 1,000 persons			
Influenza outcome	Minimum	Most likely	Maximum
Hospitalizations			
High risk			
0–19 years old	2.10	2.90	9.00
20–64 years old	0.83		5.14
65+ years old	4.00		13.00
Non-high-risk			
0–19 years old	0.20	0.50	2.90
20–64 years old	0.18		2.75
65+ years old	1.50		3.00
Deaths			
High risk			
0–19 years old	0.13	0.22	7.65
20–64 years old	0.10		5.72
65+ years old	2.76		5.63
Non-high-risk			
0–19 years old	0.01	0.02	0.13
20–64 years old	0.03	0.04	0.09
65+ years old	0.28	0.42	0.54

Table 5 Model assumptions [12]

Assumptions	
Average length of non-ICU hospital stay for influenza-related illness (days)	5
Average length of ICU hospital stay for influenza-related illness (days)	10
Average length of ventilator usage for influenza-related illness (days)	10
Average proportion of admitted influenza patients will need ICU care (%)	10
Average proportion of admitted influenza patients will need ventilators (%)	7.5
Average proportion of influenza deaths assumed to be hospitalized (%)	70

The following equation can be written as;

$$P_i^- + P_i^+ = G_i \text{ for } i = 1, \ldots, 6. \quad (2)$$

where

G_i the number of people in risk group i

We use α_i=0.1 for all risk groups for calculation of the cases and we assume that β_i is equal to gross clinical attack rate for all risk groups. Calculation of the cases is based on Flessa' approach [14, 15].

Work loss value

Employment data for employed individuals between the ages of 22 and 64 showed that the average number of workdays missed due to influenza-like illness ranges from 1.30 days to 4.9 days [5]. We assume average 3 days of work loss in this study which is the bed rest time generally advised to patients by doctors for influenza-like illness in Turkey.

Cost of absenteeism

Many workers need bed rest during the pandemic influenza and it will cause the lost of workdays. We calculate the cost of lost workdays (C_{lw}) by multiplying the estimated number of workdays missed by the average daily minimum wage for each individual.

$$C_{lw} = mwd * dw * qwf \quad (3)$$

Where

mwd average number of workdays missed due to pandemic influenza
dw average daily minimum wage (US$)
qwf quantity of workforce affected from influenza

Table 6 Assumed antiviral treatment and vaccine cost [3]

Risk groups	Antiviral treatment cost (US$ per patient)	Vaccine cost (US$ per person)
G1	26	21
G2	42	21
G3	41	21
G4	26	21
G5	36	21
G6	41	21

The quantity of workforce from affected from influenza is equal to the following sum;

$$qwf = x_2 + x_3 + x_4 + x_5 \quad (4)$$

x_1 and x_6 has not been included in eq. (4), because x_1 denotes the number of sick people aged under 18 years, and x_5 denotes the number of sick people aged over 65 years. These two groups of people are generally outside the workforce. The daily minimum wage is approximately 18 US$ in Turkey hence this value is used for *dw* value in the calculations.

Pharmacoeconomic data

There are limited published studies estimating the cost of vaccination and antiviral treatment for pandemic influenza. Costs of vaccination and antiviral treatment can be different for each country. In this study, we used the Meltzer [3] values for vaccination and antiviral treatment cost. The details for costs are shown in Table 6.

The ICU care, non-ICU care and ventilator usage costs are taken from a university hospital, located in Adana-Turkey and shown in Table 7.

Calculation of total cost

Total cost consists of the sum of direct healthcare costs and indirect costs.

$$C_{av} = \sum_{i=1}^{m} P_i^+ * vc + \sum_{i=1}^{m} x_i * av_i \quad (5)$$

Table 7 Hospitalization cost

Type	Cost(US$/day)
Non-ICU	42
ICU	76
Ventilator usage	170

Table 8 The total cost pandemic influenza for the minimum scenario

Vaccination percentage (%)	Attack rate (%)	Total cost (million US$)
20	20	1,364
20	25	1,601
20	30	1,838
40	20	1,542
40	25	1,720
40	30	1,898
60	20	1,720
60	25	1,838
60	30	1,957
80	20	1,898
80	25	1,958
80	30	2,016
100	20	2,075
100	25	2,372
100	30	2,668

$$C_{icu} = \sum_{i=1}^{m} x_i * p_{icu} * dc_{icu} * d_{icu} \tag{6}$$

$$C_{n-icu} = \sum_{i=1}^{m} x_i * p_{n-icu} * d_{n-icu} * dc_{n-icu} \tag{7}$$

$$C_{vu} = \sum_{i=1}^{m} x_i * p_{vu} * d_{vu} * dc_{vu} \tag{8}$$

$$TC = C_{av} + C_{icu} + C_{n-icu} + C_{vu} + C_{lw} \tag{9}$$

where

- vc unit cost of preventive vaccine (US$/person)
- av_i unit cost of antiviral treatment for risk group i (US$)
- C_{av} total cost of vaccination and antiviral treatment (US$)
- C_{icu} total cost of ICU-care (US$)
- $C_{n\text{-}icu}$ total cost of non-ICU care (US$)
- C_{vu} total cost of ventilator usage (US$)
- p_{icu} the rate of ills which need ICU care (%)
- $p_{n\text{-}icu}$ the rate of ills which need non-ICU care (%)
- p_{vu} the rate of ills which need ventilators (%)
- dc_{icu} unit cost of ICU-care (US$/day)
- dc_{vu} unit cost of ventilator usage (US$/day)
- $dc_{n\text{-}icu}$ unit cost of non-ICU care (US$/day)
- d_{icu} average length of ICU hospital stay for influenza-related illness (days)
- $d_{n\text{-}icu}$ average length of non-ICU hospital stay for influenza-related illness (days)
- d_{vu} average length of ventilator usage for influenza-related illness (days)
- TC total cost (US$)
- m the number of risk groups

The direct healthcare costs and indirect costs are calculated eq. (5) through eq. (8). Equation (5) calculates the antiviral treatment and vaccination costs. Equations (6) through (8) calculate the total cost of ICU care, non-ICU are and ventilator usage costs respectively. Finally, eq. (9) calculates the expected total cost of pandemic influenza.

Results and discussion

Pandemic influenza occurs in one or more waves of approximately 15 weeks in duration. Generally, it has an inter-wave period between 3 months and 6 months prior to

Table 9 Estimated direct health costs and number of cases for the minimum scenario

Vaccination percentage (%)	Attack rate (%)	Number of cases	Vaccination cost (million US$)	Antiviral treatment cost (million US$)
20	20	12,706,000	296	423
20	25	15,529,636	296	517
20	30	18,353,207	296	612
40	20	11,294,281	592	376
40	25	13,411,959	592	447
40	30	15,529,636	592	517
60	20	9,882,496	889	329
60	25	11,294,281	889	376
60	30	12,706,066	889	423
80	20	8,470,711	1,186	286
80	25	9,176,603	1,186	305
80	30	9,882,496	1,186	329
100	20	7,058,926	1,482	235
100	25	10,588,388	1,482	353
100	30	14,117,851	1,482	470

Table 10 Estimated indirect cost of pandemic influenza for the minimum scenario

Vaccination percentage (%)	Attack rate (%)	Affected work force (person)	Estimated workforce loss cost (million US$)
20	20	11,880,000	641
20	25	14,520,000	784
20	30	17,160,000	926
40	20	10,560,000	570
40	25	12,540,000	677
40	30	14,520,000	784
60	20	9,240,026	498
60	25	10,560,000	570
60	30	11,880,000	641
80	20	7,920,000	427
80	25	8,580,000	463
80	30	9,240,026	498
100	20	6,600,000	356
100	25	6,600,000	356
100	30	6,600,000	356

the second wave appearing. The initial wave of the pandemic probably has the most severe impact, due to lack of vaccines and antiviral. After the first wave, vaccines can be developed and can be used to mitigate the impact of pandemic influenza. The calculations in this study are based on this assumption. We assume that vaccine exists and the effect of the vaccine is known and given. We distribute the vaccines to the population according to different strategies based on the given rate of population to be vaccinated, such as 20%, 40%, 60,... etc.,. We calculate the number of cases, hospitalizations, ICU, non-ICU, and ventilator needs depending on these vaccination strategies.

The total cost of the pandemic influenza according to the minimum scenario is shown in Table 8. The cost range is between 1.364 billion dollars and 2.668 billion dollars depending on the attack rates and vaccination strategies.

The number of cases, vaccination costs and antiviral treatment costs are shown in Table 9 for minimum scenario under different vaccination strategies.

The work absenteeism costs and affected work force due to pandemic influenza are shown in Table 10. It can be easily seen from Table 9 and Table 10, there is a negative relationship between the vaccination cost and antiviral treatment cost.

The total cost of pandemic influenza for three different scenarios is shown in Table 11.

Table 11 Estimated total cost of pandemic influenza for different scenarios

Vaccination percentage (%)	Attack rate (%)	Total cost (million US$)		
		Minimum	Most likely	Maximum
20	20	1,364	1,366	1,381
20	25	1,601	1,604	1,622
20	30	1,838	1,841	1,863
40	20	1,542	1,543	1,557
40	25	1,720	1,722	1,738
40	30	1,898	1,900	1,920
60	20	1,720	1,722	1,733
60	25	1,838	1,840	1,853
60	30	1,957	1,959	1,974
80	20	1,898	1,899	1,909
80	25	1,958	1,958	1,963
80	30	2,016	2,018	2,029
100	20	2,075	2,076	2,085
100	25	2,372	2,374	2,386
100	30	2,668	2,671	2,687

Conclusion

Estimating the economic impact of pandemic disease is usually very difficult. The outbreak of SARS in 2003 showed that even a disease with relatively small health impact can have a major economic effect. It is believed that 8.000 people have been exposed to the SARS and, 800 people have died [16]. The Asian development Bank estimated the economic impact of SARS near US$18 billion in East Asia. The health impact and economic impact can be inversely proportional for pandemic diseases. In this study, we estimate the economic impact of the pandemic influenza according to different scenarios and different attack rates. Our optimistic calculations show that the economic impact will be between 1.364 billion dollars and 2.687 billions dollars to Turkish economy. The speculative items are not included in the calculations such as increasing vaccine and antiviral drugs. If we add the speculative items, the cost will absolutely be more severe to the economy.

References

1. Gust, I. D., Hampson, A. W., and Lavanchy, D., Planning for the next pandemic of influenza. *Rev. Med. Virol*. 11:59–70, 2001 doi:10.1002/rmv.301.
2. Meltzer, M. I., Cox, N. J., and Fukuda, K., Modelling the economic impact of influenza pandemic in the United States: implications for setting priorities for intervention [background paper]. Available from http://www.cdc.gov/ncidod/eid/vol5no5/melt_back.htm.
3. Meltzer, M. I., Cox, N. J., and Fukuda, K., The economic impact of influenza pandemic in the United States: priorities for intervention. *Emerg. Infect. Dis*. 5:659–671, 1999.
4. Global pandemic influenza action plan to increase vaccine supply. Immunization, vaccines and biological epidemic and pandemic alert and response. WHO/CDS/EPR/GIP. 5–6, 2006.
5. Ryan, J., Zoellner, Y., Gradl, B., Palache, B., and Medema, J., Establishing the health and economic impact of influenza vaccination within the European Union 25 countries. *Vaccine*. 24:6812–6822, 2006 doi:10.1016/j.vaccine.2006.07.042.
6. World Health Organization (WHO). Cumulative number of confirmed human cases of avian influenza A/(H5N1) reported to WHO. March 2007. Available http://www.who.int/csr/disease/avian_influenza/final.pdf.
7. Geberding, J. L., Current status of avian influenza and pandemic threat. Institute of Medicine of the National Academies. In: La Montagne, J. R. (Ed.), *Memorial Symposium On Pandemic Influenza Research, Meeting Proceedings*National Academies Press, Washington, DC, p. (p.12), 2005.
8. Knox, N., Europe braces for avian flu. USA Today. Available http://www.usatoday.com/news/health/2005-10-09-europe-avian-flu_x.htm., October, 2005.
9. Bloom, E., Wit, W., Potential economic impact of an avian flu pandemic on Asia. ERD Policy Brief. No:42, 2005.
10. Akazawa, M., Sindelar, J. L., and Paltiel, D., Economic costs of influenza-related work absenteeism. *Value Health*. 6:2107–115, 2003 doi:10.1046/j.1524-4733.2003.00209.x.
11. Postma, M. J., Jansema, P., Genugten, M. L. L., Heijnen, M. L. A., Jager, J. C., and Jong-Van Den Berg, L. T. W., Pharmacoeconomics of influenza vaccination for healthy working adults. *Drugs*. 62:71013–1204, 2002 doi:10.2165/00003495-200262070-00003.
12. Zhang, X., Meltzer, M., and Wortley, P., FluSurge—A tool to estimate demand for hospital services during the next pandemic influenza. *Med. Decis. Making*. 26:617–623, 2006 doi:10.1177/0272989X06295359.
13. Turkish Statistical Institute. http://tuikapp.tuik.gov.tr./adnksdagitimapp/adnks.zul.
14. Flessa, S., Where Efficiency saves lives : A linear programme for the optimal allocation of health care resources in developing countries. *Health Care Manage. Sci*. 3:3249–267, 2000.
15. Flessa, S., Priorities and allocation of health care resources in developing countries : A case-study from the Mtwara region, Tanzania. *Eur. J. Oper. Res*. 150:67–80, 2003 doi:10.1016/S0377-2217(02)00786-5.
16. Cooper, S., and Coxe, D., *An investor's guide to avian flu*. BMO Nesbitt Burns Research, Montreal, 2005.