The impact of a novel preventive care service on the incidence of hip fractures among the elderly

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Methods: We estimate an ARMA-model for the time series of hip fractures in the Höganäs municipality in Sweden for the years 1987-2008. By means of intervention analysis and out of sample forecasts we estimate the short-run and long-run impact of the novel preventive care service.
Results: We find that there is a statistically significant short run impact of the PCS with about 8.27 less incidents of hip fractures. This corresponds to a long-run effect of about 3.74 less incidents of hip fractures per year.
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Response to Reviewers: Dear Editor!

Reviewer 1 is according to the latest review satisfied with the changes made. However, I do not quite understand the reviewer 2 comments, which seem to refer to the initial submission and not to the final review. For example, table 1 is not part of the last revise and the method and results section are separated. Please, see details below.

However, reviewer 2 comments are coinciding with the reviewer 1 comments in previous reviews, which is positive I think.

Best regards,

Niclas

Reviewer #1: The authors made all the requested amendments and now the manuscript is suitable for publication on the Journal

Reviewer #2: The topic is of high interest, regarding the impact of a novel preventive care service on the incidents of hip fractures among elderly.
However the following issues should be addressed by the Authors.

Methods and results
Statistical procedures (e.g. the augmented Dickey-Fuller test) should be more appropriately described and referenced.

Answer: The method section is more extensive in the final revise.

Results should be separated from methods.

Answer: This is done in the final revise.

Table 1, concerning ARMA regression results, should be re-edited.

In the final revise, it is re-edited and appears as Equation 1.

Discussion
The discussion is too short, especially if compared with the introduction. The added value of this work and the implications of its findings are not fully discussed. Moreover in my opinion, the social costs associated with hip fractures should be discussed.

This is done now in the final revise.

References
The references do not seem to be sufficiently numerous and updated. Please check, supplement and update.
Answer: The list is updated and more extensive in the final revise.

Moreover references should be numbered and inserted in the text.

*Title Page

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Keywords: Time series analysis; Hip fractures; Cost-benefit analysis

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Introduction

Due to the increasing share of elderly people aged 65 years or older the problem with hip fractures and falling accidents is getting increased attention in Sweden, both in media and by politicians. It has been estimated that the social costs of falling accidents amount to about 4.8 billion Swedish kronor (about 0.48 billion Euro) each year. For those killed by falling accidents 80 percent are 65 years or older (Swedish Rescue Services Agency, 2003). Often falling accidents among elderly leads to hip fractures which causes permanent pain and reduced mobility. The problem of falling accidents and hip fractures among elderly is similar throughout the Western world. Cooper, Campion and Melton (1992) point out that demographic change and the associated increase in the share of elderly will lead to increased problems with hip fractures also in Asia, South America and Africa. They project the number of hip fractures to be 6.26 million by 2050 (from 1.66 million in 1990).

Previous literature on the prevention on hip fractures among elderly has either focused on the effect of hip protectors (Parker et al. 2006; Telser and Zweifel 2002; Kannus et al. 2000) or the prescription of vitamin D and calcium (Torgerson and Kanis 1995). The focus has also been on care homes and hospitals and not the home environment. The study by Cox et al. (2008) examines on the contrary the impact of home care personal education on hip fracture prevention.

One quite well-known recent measure in Sweden to prevent both falling accidents and hip fractures among elderly is a special kind of preventive care service (PCS) for elderly people (age 65 or older) employing outreach by non-physician experts. The service includes help with certain activities in the home environment which imply a relatively high risk of injury, a control of the home environment with regard to risk factors and, if possible, removal of risk factors and consultation regarding possible improvements and education about risk factors. The measure is not linked to traditional home care. Typical activities associated with increased risk of falling and hence injuries are the following activities which the PCS can perform if called:

- Change of light bulbs and curtains
- Installation of carpets with glide protection
- Installation of extra handles above the bath tube
- Removal of high carpets edges, loose electric cables, slippery surfaces and insufficient lighting

All inhabitants aged 65 years or older and who need help with activities mentioned above or similar household activities with risk for falling, are eligible to call the PCS. About 6 visits are conducted on average each day (that is, 1500 visits per year) and over 400 persons are regularly calling the PCS. In the Höganäs municipality the PCS is free of charge. Even if the main purpose of the measure is to reduce falling accidents and hip fractures, other benefits which have been mentioned by the Höganäs municipality is increased feeling of security among elderly and their relatives, diminished demand pressure on care homes and less costs for rehabilitation and benefits for the elderly derived from social interaction during the home visits. Höganäs was the first municipality to introduce this kind of service, but by now a majority of Swedish municipalities have a similar service. However, the service has been implemented differently across municipalities. In this paper we set out for the first empirical test of the impact of the preventive care service (PCS) outlined above on the number of hip fractures in the Höganäs municipality in Sweden, which was the first municipality in Sweden to implement the PCS.

Data and method

The number of hip fractures in the Höganäs municipality is obtained from the Centre for Epidemiology at the Swedish National Board of Health and Welfare for the years spanning 1987-2008 (see Figure 1).

[Figure 1]

Because of the increasing number of person who are 65 years or older we expect a deterministic trend in the number of falling accidents and hip fractures. However, the number of falling accidents is not suitable for analysing the impact of PCS since there has been a change in classification of falling accidents in 1998 which makes a comparison before and after the year 1998 to a large extent impossible. Therefore we focus in our analysis on the number of hip fractures. The number of hip fractures among elderly people exhibits a more clear-cut time trend. However, there are large fluctuations around this time trend.

The method applied in this paper is time series intervention analysis. It is based on the so called Box-Jenkins methodology, for an introduction see Enders (2004). First, the time series has to be checked for stationarity. If stationary (or at least, trend-stationary), inspection of the autocorrelation function and partial autocorrelation function might reveal how to model the underlying data generating process. Also, lag-selection tests are often applied in this stage and model selection is governed by the principle of parsimony. If we assume that the causal dynamics is from the intervention to the time series of hip fractures only, a maximum-liklihood based ARIMA-regression with dummy-variable approach is appropriate to estimate the impact of the PCS. The effect can be valued in economic terms by using risk valuations available (and used by Swedish authorities) for heavy injuries.

Results

We use the augmented Dickey-Fuller test for unit roots in the time series of hip fractures in order to test for stationarity. The results indicate that we can reject a random walk with drift (p-value=0.002) and a random walk with drift and trend (p-value=0.0004). Since we clearly have a trend in the time series we can conclude that the stochastic process underlying the hip fractures is trend stationary.

The pre-estimation lag-order selection test based on the Schwartz-Bayesian information criterion suggests that we should include 2 autoregressive lags for an optimal trade-off between parsimony and goodness-of-fit. Moreover, the Box-Jenkins-methodology based on the examination of the autocorrelation function and the partial autocorrelation function also proposes an AR(2)-specification for the detrended time series. The impact of the PCS is modelled as a dummy variable, taking a value equal to one for the years 2001-2008. The final empirical model based on ARMA-regression in STATA is given by (p-values in parenthesis):

$$\underset{}{FRACT_t} = \underset{(0.000)}{-2421.51} + \underset{(0.000)}{1.23}YEAR - \underset{(0.000)}{8.27}PCS - \underset{(0.004)}{0.60}FRACT_{t-1} - \underset{(0.009)}{0.61}FRACT_{t-2} + e_t \qquad (1)$$

Where s_t are the number of hip fractures among elderly in year *t* and *v* is a dummy variable for the PCS. Hence, given the time trend and the autoregressive process, the PCS on average prevents 8.27 hip fractures the first year. From the results we can see that all coefficients in the model are highly significant (p-value<0.01).The second order equation $y_t = a_0 + a_1 y_{t-1} + a_1 y_{t-2}$ has the solution (a long-run expected value) $\bar{y} = a_0/(1 - a_1 - a_2)$ if it converges. In order to converge, we must have that $|a_2| < 1$, $a_1 + a_2 < 1$ and that $a_1 - a_2 < 1$. Convergence implies that past errors have a successively smaller influence on the current value of the time series and it is a necessary condition for stationarity. It is easily checked that the conditions for convergence are satisfied here, which is line with the stationarity test of the detrended time series. Substituting the estimated coefficients into the solution of the second order difference equation and comparing with and without the PCS (the coefficient of the PCS changes the intercept a_0) yields that 3.74 less hip fractures per year are expected to occur in the long run after the installation of the PCS .

The autoregressive character of the process suggests that there is a high risk group among the elderly (for falling and/or attaining hip fracture), so that if there is an above average number of hip fractures one year we would expect a below average number of hip fractures the following year.

We try different specifications for the intervention function, since the special caretaker service was a halftime employment during the first year (2001) and because, like all other innovations, its acceptance can exhibit a time lag due to diffusion and adoption processes among the target group. When changing the specification so that the dummy is 0.5 for the year 2001 and 1 thereafter we get a larger magnitude for the PCS coefficient and a slightly improved log likelihood value (results not shown here).

Another way to estimate the impact of the PCS is to estimate the AR(2)-process for the longest available time period without structural break, in this case the period 1987-2000. Next we perform an out of sample forecast for the following five years and compare the forecasted values with the actual outcome in the years 2001-2008. We also calculate the 95%-confidence interval to see in what interval we would expect that 95% of the cases are lying in the forecasts. When constructing the confidence interval for the forecast errors we have both to consider the stochastic variations in the future values and the error in the estimation of the coefficients (see Enders 2004, p. 82). Figure 2 shows the results of the forecasting experiment.

[Figure 2]

As can be seen from the above figure, the forecasted values (and the confidence intervals) lie clearly above the actual outcome. This implies that given the data for the period 1987-2000 we would expect that the number of hip fractures in Höganäs is higher than the actual observed during 2001-2008. For comparison, the estimated model in Equation (1) fits relatively well to the observed outcomes, as is demonstrated Figure 3.

[Figure 3]

If we compare the estimation results we get from the two models (estimating 1987-2000 and estimating 1987-2008 with a dummy) the coefficients are quite stable so that the difference seems to be explained by the installation of the PCS measure.

$$FRACT_t = -2678.27 + 1.36YEAR - 0.89FRACT_{t-1} - 0.79FRACT_{t-2} + e_t \qquad (2)$$
$$(0.000) \quad (0.000) \quad (0.011) \quad (0.006)$$

We have however an influential observation for the year 1999. Including a dummy for 1999 yields predictions more closely to (but still above) the actual outcome. However, the dummy approach should be related to a special event in that year. As we have no indications of such an event and since the dummy is not significant at the 5-percent level, we discard the dummy approach. Nonetheless, the qualitative results are not dependent on the observation in 1999, since the dummy approach for 1999 yields an estimated coefficient of -4.78 (p-value=0.009) and discarding the observation for year 1999 completely we get an estimated coefficient of -4.73 (p-value=0.016). The other coefficients in the ARIMA-estimation are stable (including the autoregressive terms).

Given the magnitudes of the effect we can compare the social costs and benefits of the PCS. Taking the value of a statistical heavy injured used in road traffic evaluation by Swedish authorities (about 3.48 million SEK or 348,000 Euro for the risk of heavy injury, without material costs, see SIKA 2008 for details), we estimate that the benefits are approximately 13 million SEK per year (130,000 Euro). This heavily exceeds the annual costs of the project mainly consisting of wages and fuel costs, which are estimated to be about 0.5 million SEK per year (500,000 Euro).

According to the major of the Höganäs municipality Peter Kovacs (November 11, 2005) the cost savings for the municipality is about 1 million SEK (100,000 Euro) in total per prevented hip fracture for aftercare and rehabilitation. Moreover, there is less demand pressure on sheltered accommodation since the elderly choose to stay in their regular homes.

Discussion

We have found an effect of the special caretaker service on the number of hip fractures in the Höganäs municipality, in the sense that we have detected a statistical discernible correlation between the implementation of the PCS and a structural break in the time series of hip fractures. It is a demonstration of the usefulness of time-series intervention analysis in the area of public health and health economics, especially since time series data become more common and facilitates measures outside of artificial experimental situations. It is however possible, but not likely, that other factors coinciding with the installation of the PCS measure may affect our estimation results. We are not able to compare the effect to a control group as in experimental studies. Hence, in order to explore the issue of causality, we are in need of some more general considerations. We would expect an effect since the elderly can avoid risk taking in their home environment by phoning the special caretaker, which has resulted in about 1,300 visits per year. However, there might be some caveats, since people are inpatient, have the preference of doing things by themselves or have imperfect self-insight. These behavioural aspects may reduce the overall effect of the measure, but still the effect is large enough to change the time series of hip fractures among elderly. Given the magnitudes of the effect we find that the social benefits of the PCS heavily exceed the costs of the project. In addition, we have not taken into account soft factors like increased perceived safety. However, the usage of risk values from other areas as road traffic could be problematic, since both initial risk levels and mean age differs between heavily injured in traffic and in falling accidents. A general recommendation we can draw from our analysis give is that an evaluation of such a measure by means of time series analysis has to cover a long time window and that the nature of the underlying the stochastic process has to be considered.

Since the PCS is a quite recent measure, it will take some time until a quantitatively evaluation is feasible for more municipalities, for example by means of panel-regressions. However, the relatively low costs to implement the PCS might be an explanation for the increased adoption of a similar service for elderly by municipalities observed in Sweden. It is important to think of new preventive methods as other measures as hip protectors, contrary to early results from randomized trials, have been found to be ineffective (Parker et al, 2006). Other measures like physical exercise for elderly have been found to be effective during the experimental phase in Sweden, but without effect on the trend of increasing hip fractures as the measures were subsequently implemented (Räddningsverket, 2003). NICE (2004) has selected a range of studies using restrictive criteria in order to shed light onto the issue of cost-effectiveness of preventive measures among older people. Using inflation adjusted costs for the base year 2007 from Gyllensvärd (2009) for the countries and years included in NICE (2008) (USA 1996; Australian 1998 and 2000; New Zealand 2001), we find that the cost per prevented fall lies between 930 euro and 3,700 euro. The cost per prevented fall decreases with the age of the target group. Two studies (Smith 1998 and Salkeld, 2000) resemble in part the Preventive Care Service outlined here, in that it is concerned with risk modifications in the home environment. Gillespie et al (2009) conclude however that home safety improvements only had effect in high risk groups of falling. All studies in NICE (2004) have as measured outcome the number of fall reductions, whereas we directly evaluate the impact on hip fractures. It is therefore difficult to compare our study with the studies included in NICE (2004). Considering that less than 10 percent of all falls result in hip fractures (Campbell 1990; Tinetti 1988), we can calculate that the cost per prevented hip fracture is more than ten times higher, that is, the range for the cost per prevented hip fracture is at least between 9,300 and 37,000 euro for the studies included in NICE (2004). This can be compared to our estimated cost per prevented hip fracture that is approximately about 13,000 euro and hence, in the lower range of the other studies. The cost-effectiveness of the PCS could possibly be improved by increasing the age limit for the target group.

Conflict of Interest

The authors declare that they have no conflict of interest.Financial support from the Swedish Civil Contingencies Agency is gratefully acknowledged.

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Figures

Figure 1: Hip fractures and falling accidents among elderly in Höganäs 1987-2008

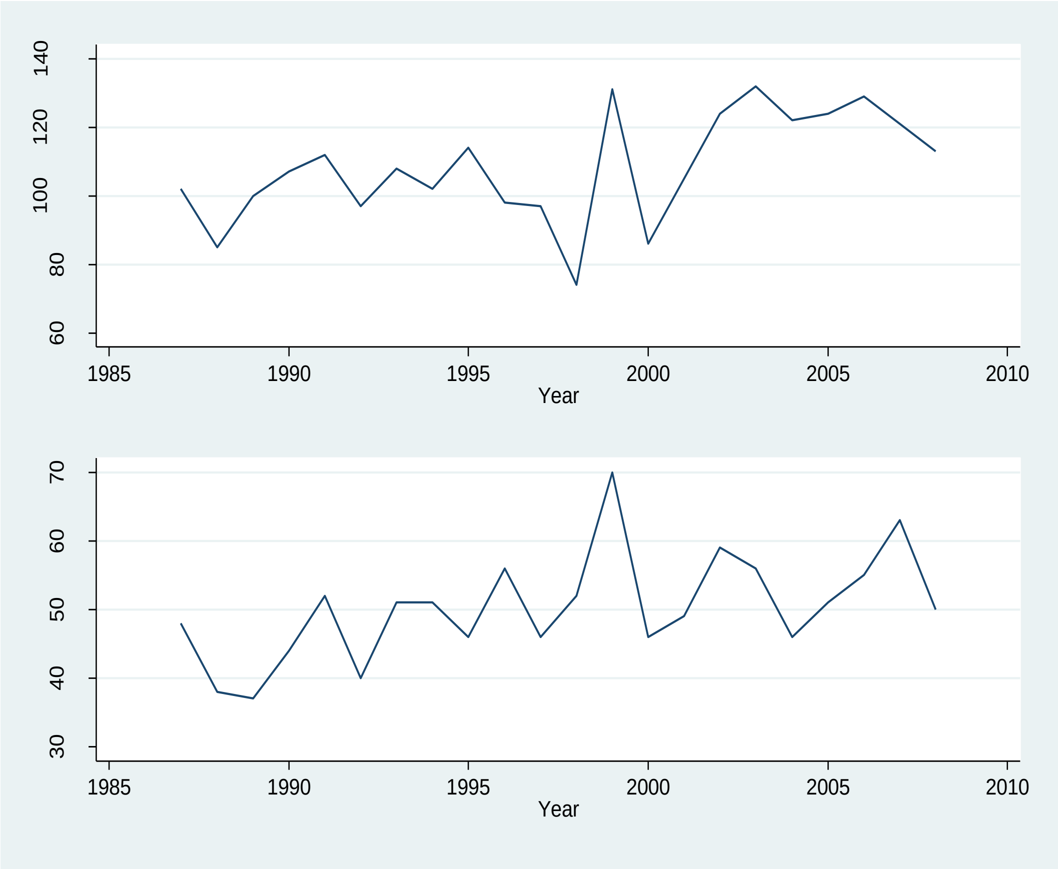

Figure 2: Forecasts for 2001-2008 based on 1987-2000

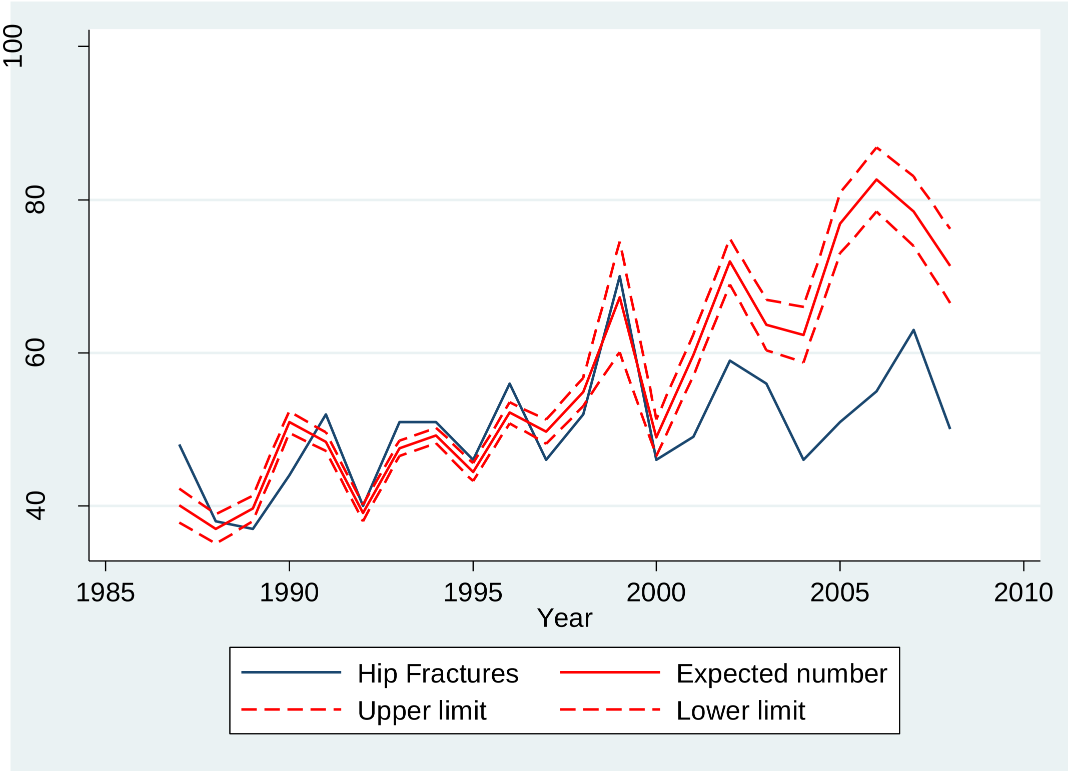

Figure 3: Comparison of actual outcome and model fit