Productivity change and efficiency in the Swiss nursing home industry*

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Abstract

Enhancing nursing home efficiency and productivity is a challenging task for health policy makers due to population ageing trends and increasing health care costs. In this study, we analyze nursing home efficiency and productivity using data from the universe of Swiss nursing homes for the period 2007-2015. We estimate a translog cost frontier via generalized true random effects models, which allow to disentangle the transient and the persistent components of inefficiency. In particular, we apply the simulated maximum likelihood approach proposed by Filippini and Greene (2016), and then improve our estimates with a Mundlak correction. We find that total factor productivity change has dropped in recent years, and both efficiency components show scope for improvement. However, the marginal gains from transient efficiency measures are potentially larger, and could provide a more valid contribution to reverse the decreasing trend in total factor productivity change.

Keywords: Nursing homes, Total factor productivity change, Transient and persistent efficiency, Cost frontier
JEL codes: D24, I11

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1 Introduction

Population aging and the consequent increase of health care costs for the elderly population is a relevant concern for public authorities in many developed countries. Between 1960 and 2012, life expectancy increased on average by 9 years among the EU member states, and it is expected to further increase by 7 years by 2060 (European Commission and Economic Policy Committee, 2014). This phenomenon is driven by the aging of baby boomers. Total expenditures for long term care (LTC), which includes nursing home and home care services, is currently approaching 1.7% and 1.1% of GDP in EU member states, respectively, and these shares are expected to grow. The above trends suggest that increasing effort should be put on improving efficiency in the LTC sector, particularly in the provision of nursing home services. Nursing home efficiency and productivity is of relevance not only because it is a matter of survival of businesses (Syverson, 2011), but also because it is a highly regulated sector strictly related to the efficient use of public resources. The identification of policies that allow to improve productivity by optimizing the utilization of inputs is a challenging task because the LTC sector is highly labor intensive and current technological improvement has limited scope for the substitution of labor inputs. Indeed, labor productivity in the Swiss health and social care industry between 2000 and 2015 increased less than the economy-wide average and much less than in the manufacturing industry. At the end of the period, data provided by the Swiss Federal Statistical Office suggest that labor productivity in the manufacturing industry was about 45% higher than in 2000, while in the health and social care industry the variation was less than 15%.

In this paper, we analyze productivity and efficiency in the Swiss nursing home industry. To this aim, we use detailed data on costs, staff and patients from the universe of Swiss nursing homes for the period 2007-2015 provided by the Swiss Federal Office for Statistics. We estimate a translog cost frontier using generalized true random effects (GTRE) models that allow us to disentangle both the persistent and the transient components of inefficiency. In particular, we apply the simulated maximum likelihood approach proposed by Filippini and Greene (2016). We also compare cost frontier estimates between baseline models and models with the Mundlak correction that allows to account for time-invariant nursing home characteristics. Finally, we derive total factor productivity (TFP) change from the cost frontiers and analyze its development over time and the contribution of its components.

We find that the Mundlak correction improves the precision of parameter estimates. Moreover, both persistent and transient efficiency components show scope for improvement, with the latter component being more crucial in determining overall efficiency. TFP change follows a strictly decreasing trend between 2007 and 2015, which allows to conclude that the Swiss nursing home sector suffers from a productivity loss over time. This points at stagnant labour productivity, a situation that characterizes non-progressive sectors such as the LTC industry and is known in the economic literature as the Baumol's cost disease (Baumol, 1967).[1]

Nursing home efficiency has been analyzed in several studies, although with different approaches and focuses. Many studies focus on economies of scale and explore differences between urban and rural nursing homes (e.g. Yu and Bradford, 1995) and among types of ownership (e.g. Crivelli et al., 2002; Vitaliano and Toren, 1994). Other studies focus on economies of scope. For instance, Christensen (2004) finds that small multi-output nursing homes are more cost efficient than big nursing homes. Finally, some scholars investigate how the omission and the endogeneity of quality indicators in nursing homes affect cost function estimates (McKay, 1988; Gertler and Waldman, 1992; Mutter et al., 2013).

One major limitation of these studies is the use of cross-sectional data, which does not allow to account for fixed unobserved nursing home heterogeneity and to analyze changes in productivity (Hollingsworth, 2008), nor to decompose components of inefficiency. Exceptions are the studies by Chattopadhyay and Ray (1996) and Vitaliano and Toren (1994) who use 2-year panel datasets, but they do not analyze productivity changes. More recent studies use longer panel data for nursing home efficiency analysis. For instance, Farsi et al. (2008) and Di Giorgio et al. (2015) use panel data from Swiss nursing homes and estimate transient inefficiency using the true random effects model proposed by Greene (2005a,b). Unfortunately, this model does not allow to estimate the persistent inefficiency component and risks to overestimate transient inefficiency.[2] Filippini (2001), Di Giorgio et al. (2014) and Di Giorgio et al. (2016) analyze nursing home cost efficiency in Southern Switzerland using 3, 10 and 5-year long panels, respectively. Finally, Yang et al. (2017) use 3-year panel data to measure productivity growth of residential LTC services in the UK using a

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[1] Non-progressive sectors are defined as sectors with a very low productivity growth rate, such as labor intensive sectors.

[2] Farsi et al. (2008) use also pooled and random effects cost frontier models which allow to estimate transient and persistent inefficiency components, respectively.

non-parametric approach.

The recently developed GTRE model allows to simultaneously estimate persistent and transient inefficiency components and to overcome the limitations of the previously used methods that investigate only one of the two inefficiency components. Recent studies in other sectors suggest that the GTRE model outperforms previous methods because it improves the precision of inefficiency estimates (e.g. Filippini et al., 2018; Tsionas and Kumbhakar, 2014; Colombi et al., 2014). To our knowledge, our study is the first one to use GTRE models to disentangle persistent and transient efficiency in the nursing home sector, and to compare efficiency estimates resulting from two different approaches to estimate the GTRE model. A further contribution to the literature arises from the fact that we analyze nursing home efficiency and productivity using a unique, detailed and relatively long dataset (9 years) including the universe of Swiss nursing homes.

The remainder of the paper is structured as follows. Section 2 describes the institutional framework for the Swiss nursing home industry, and Section 3 presents the cost model that characterizes nursing homes organizations. Section 4 describes the data and the empirical approach used to estimate the cost model and the efficiency components. Section 5 discusses the results of the analysis in terms of cost determinants, efficiency components, total factor productivity change and its decomposition. Some concluding remarks are then provided in Section 6.

2 Institutional setting

The Swiss health care system is based on compulsory private health insurance coverage. The organization of LTC is highly decentralized, leaving much of the decision power to the 26 cantons in which the country is subdivided. The Federal Constitution (Article 3) grants autonomy to the single cantons in the organization and regulation of the LTC sector. This autonomy determines heterogeneity in the provision of LTC services across cantons. The LTC sector is made of over 1500 nursing homes with a variety of institutional forms (private for-profit, non-profit private and public organizations). Also, there are more than 2000 home care firms (called "Spitex"), with almost 600 non-profit or public home care organizations, about 400 private for-profit organizations, and 1000 independent nurses (BFS, 2018).

Since 1996, the costs of health care provided in nursing homes are fully covered by health insurance companies.[3] However, this financing system was not sustainable because of the fast growing health care costs. Therefore, in 2011 the federal government introduced a change in the cost reimbursement of health care providers, including nursing homes.[4] This change is based on a shared reimbursement system of LTC health care costs that involves insurers, patients and local public authorities (cantons and municipalities). As a result, health insurance now covers about 65% of costs with reimbursement tariffs defined at the federal level, patients need to contribute up to 20% and residual cost funding needs to be regulated by the cantonal governments.[5] The residual cost funding system applies to all types of providers, including private nursing homes that were not subsidized by cantonal and/or municipal governments before 2011.

3 Cost model

To estimate efficiency components and derive TFP change, we first specify and estimate a cost function for nursing homes. Following the previous literature, we define nursing homes as production units that transform labor, capital and materials into days of care. Accordingly, we define a nursing home's total cost function as follows:

$$TC = f(Y, P_L, P_K, P_M, D, Q, t) \tag{1}$$

where TC are total costs, and Y is the amount of patient days. P_L, P_K and P_M are input prices of labor, capital and materials, respectively. The remaining variables are the average dependency level of patients (D), a quality index measured as the share of nurse-hours worked by skilled nurses (Q) and a time-trend (t). The dependency level and the share of nurse-hours worked by skilled nurses allow us to account for heterogeneity in output levels and cost structure between nursing home providers determined by differences in patients' requirements of care (Di Giorgio et al., 2016). Since we are able to measure only structural quality (Q), we assume quality of process and outcome to be the same among nursing homes.[6]

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[3] Swiss federal health insurance law, 1996. This law defines rules for the payment of health care services supplied by LTC providers. Instead, residential care services are covered by out-of-pocket expenditure and, eventually, supplementary LTC insurance or cantonal/municipal subsidies.

[4] The change was adopted in 2011 based on the Federal Law of June 13, 2008.

[5] Patients' out-of-pocket contributions are regulated by cantonal governments. Most of the cantons set the contribution share to its maximum level (20%), two cantons set it equal to 10% and two cantons relate it to patients' dependency level or wealth.

[6] This definition of quality refers to the framework proposed by Donabedian (1988) who defines structure as the set of characteristics of the nursing home provider (e.g. characteristics of the staff), process as the

In order to satisfy the duality theory of production, the specification of the cost function in Equation 1 requires some restrictions (Cornes, 1992). Total costs need to be non-decreasing, concave and linearly homogeneous in input prices, and non-decreasing in output. We impose linear homogeneity in input prices by setting the price of materials as the numeraire.

We estimate the cost function using a translog functional form. The translog functional form is preferable to the Cobb-Douglas specification because the latter assumes constant returns to scale, while the former is more flexible and does not impose any restriction on technology which is allowed to vary over time. Consequently, the translog functional form allows productivity to vary with output and all the other factors affecting costs. We can specify the translog cost function model based on Equation 1 as follows:

$$
\begin{aligned}
ln\left(\frac{TC}{P_M}\right) = {} & \alpha + \beta_Y \, ln\, Y + \sum_w \beta_w \, ln\, w + \sum_q \beta_q \, ln\, q + \beta_t \, t \\
& + \frac{1}{2}\beta_{YY}\,(ln\, Y)^2 + \frac{1}{2}\sum_w \beta_{ww}\,(ln\, w)^2 + \frac{1}{2}\sum_q \beta_{qq}\,(ln\, q)^2 + \frac{1}{2}\beta_{tt}\, t^2 \\
& + \sum_w \beta_{Yw}\,(ln\, Y)\,(ln\, w) + \sum_q \beta_{Yq}\,(ln\, Y)\,(ln\, q) + \beta_{LK}\left(ln\,\frac{P_L}{P_M}\right)\left(ln\,\frac{P_K}{P_M}\right) \\
& + \sum_w \sum_q \beta_{wq}\,(ln\, w)\,(ln\, q) + \beta_{QD}\,(ln\, Q)\,(ln\, D) + \beta_{Yt}\,(ln\, Y)\, t \\
& + \sum_w \beta_{wt}\,(ln\, w)\, t + \sum_q \beta_{qt}\,(ln\, q)\, t + \varepsilon_{it}
\end{aligned}
\tag{2}
$$

where w is the vector of input prices $\left(\frac{P_L}{P_M}, \frac{P_K}{P_M}\right)$, q is the vector of time-varying nursing home characteristics (Q, D) and t is the time trend. α is the intercept term, the βs are the parameters to be estimated, and ε_{it} is an *iid* error term.[7]

After the estimation of Equation 2, we can verify the remaining restrictions required to satisfy the duality theory (non-decreasing and concave input prices, and non-decreasing output). Moreover, we normalize the variables by their sample median values in order to obtain the sample median as the approximation point.[8]

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set of activities performed by medical staff to provide care (e.g., implementation of appropriate treatment), and outcome as patients' change in health status.

[7] Remember that TC, P_L and P_K are divided by the price of materials (P_M) to impose linear homogeneity in input prices.

[8] Also, the mean value can be used as the approximation point. We prefer the median value because it is less sensitive to outliers.

4 Data and econometric approaches

4.1 Sample and variables

The current study uses data from the yearly survey of Swiss nursing homes provided by the Swiss Federal Office for Statistics (SOMED A). The sample is composed of 1,577 nursing homes for the period 2007-2015. However, we exclude 263 nursing homes because they show evident measurement errors in the data and other 352 nursing homes because of incomplete data. Therefore, our final sample is composed of 8,658 nursing home×year observations from 962 nursing homes. For each of these homes, we have very detailed balance sheet data (costs by cost center and revenues) and information on nursing home characteristics (number of beds, institutional form), characteristics of personnel (education, age, yearly working hours), investments, patient characteristics (age, day of entry and exit, destination after exit), and treatment provided (minutes-of-care and period of treatment). We express all monetary values in real values at 2010 prices.

We measure nursing home output as the number of days of care provided, i.e. the sum of each patient's length of stay per year. Then, we measure prices of the three input factors, namely labor, capital and materials. We calculate the price of labor as the yearly wage per full-time equivalent employee. We consider only medical staff (nurses and doctors) since this is the main labor input for nursing homes, representing 67% of the employed staff on average. Since data to calculate capital stock using the capital inventory method are not available, we approximate the capital stock with the number of beds, following Crivelli et al. (2002). Therefore, the price of capital is measured as the cost of interests, amortization and depreciation per bed. Following Di Giorgio et al. (2016), we compute the price of materials as the residual costs per meal. The number of meals are estimated assuming that each patient staying in a nursing home over night consumes two meals, while patients that receive only daily care consume one meal.

Nursing home outputs and costs may be heterogeneous due to differences in the severity of patients treated and in the skill level of nurses. Therefore, we build a measure of output characteristics, namely the dependency level, and a measure of staff composition, namely the share of nurse-hours worked by skilled nurses.[9] In Switzerland, a number of instruments are used to measure the dependency level of residents, each of which classifies patients on a scale based on minutes of care they require. Following Gentili et al. (2017),

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[9] We consider skilled nurses as those who followed at least one additional year of professional course after the high school, or achieved a university or professional degree in nursing.

we harmonize the different instruments and build a scale ranging from 0 to 4, where scores represent increasing amounts of hours of care per day that a patient requires. Using this information, we obtain a measure of the nursing home case mix which is a proxy for the intensity of care provided and justifies heterogeneous levels of input utilization and costs.

Over the whole period 2007-2015, the average cost of a day of care in a nursing home is 269.58 CHF (1 CHF $\approx$ 1 USD). Labor, capital and materials account for 73.09%, 10.16% and 16.75% of total costs, respectively. Figure 1 shows that the unit cost increased steadily over the period 2007-2015 (blue solid line). Except for the slight drop of 4.36 CHF between 2007 and 2008, the unit cost grew from 252.72 to 286.69 CHF per day of care by the end of 2015, representing an increase of 13.44% relative to the 2008 levels. Indeed, the annual unit cost growth rate (red dashed line) was equal to 2.4% in 2009, dropped to 1.1% in 2010, and reached a peak of 3.6% in 2011. Afterwards, the growth rate remained stable at 1.3%

Table 1 reports descriptive statistics for the variables of interest. Nursing homes provide on average 23,396 days of care per year (about 64 treated patients per day). The output size is very heterogeneous among nursing homes, with the largest home producing more than 5 times the average output. Labor prices are also very heterogeneous and range between 37,221 and 121,306 CHF per full-time equivalent employee per year, with the average value being equal to 65,338 CHF. The average price of capital is much lower (9,542 CHF per bed/year), while the average price of materials per meal is 23.38 CHF.

The average dependency level is equal to 2.24, indicating that nursing homes provide about 2 hours and 15 minutes of care per day to each patient (a unit change in the dependency level corresponds to additional 60 minutes of care). The sample includes also some outlying nursing homes that treat severe patients only (dependency level close to 4) or healthy patients (dependency level close to 0). Nevertheless, the majority of nursing homes treat a heterogeneous mix of patients. Finally, 27% of the nurse-hours are performed by skilled staff, but there is large heterogeneity among nursing homes. Indeed, the share of hours worked by skilled nurses ranges from 0.23% to 100%.

4.2 Econometric approaches

Several models could be used to estimate nursing home inefficiency. The model proposed by Pitt and Lee (1981) is a random effects model that allows to estimate only the persistent component of inefficiency since the nursing-home-specific noise term is considered to be a time-invariant inefficiency term. The true random effects (TRE) model proposed by Greene (2005a,b) extends the stochastic frontier model (SF) proposed by Aigner et al. (1977) by including nursing-home-specific random effects, but this implies that efficiency is overestimated. Moreover, it allows to estimate only the transient component of inefficiency because the persistent component is captured by the nursing-home-specific term. More recently, a four-way random component model, called generalized true random effects (GTRE) model, has been developed and several estimation approaches have been proposed. This model allows to decompose the error term into time-invariant and time-varying noise terms, and persistent and transient inefficiency terms. Colombi et al. (2014) provide an estimation method for this model based on full maximum likelihood. Kumbhakar et al. (2014) propose a three-step estimator that first estimates a cost function using a random effects regression model and then decomposes the fixed and time-varying error terms into noise and inefficiency components using standard cross-sectional SF models. Tsionas and Kumbhakar (2014) base their estimation method on Bayesian Markov chain Monte Carlo methods. Filippini and Greene (2016) build on Colombi et al. (2014) and propose a maximum simulated likelihood technique that simplifies the latter approach and uses Halton sequences to estimate the log-likelihood function. They define the disturbance term as composed of two parts, one time-invariant and the other time-varying, each of which is characterized by a skewed normal distribution.

Also non parametric approaches, such as data envelopment analysis (DEA), could be used to estimate nursing home inefficiency. These approaches have the advantage that they do not impose a-priori restrictions on the functional form as stochastic models require. On the other hand, the drawback is that these models do not account for measurement error since they are deterministic and are generally data-driven, while the SF approach relates to the economic theory for the definition of cost frontier models. Moreover, the SF approach is preferable to analyze nursing home efficiency because it allows to partially account for nursing-home specific unobserved heterogeneity in health care services production using the Mundlak correction (Di Giorgio et al., 2015; Farsi et al., 2005).

In this paper, we estimate the cost frontier using a GTRE model since it allows to estimate both persistent and transient efficiency components, as compared to other SF models. In particular, we use the approach proposed by Filippini and Greene (2016), which is a straightforward empirical estimation method for the GTRE. Therefore, the error term in Equation 2 is decomposed as follows:

$$\varepsilon_{it} = k_i + h_i + v_{it} + u_{it} \tag{3}$$

where k_i and v_{it} are time-invariant and time-varying noise terms, respectively, that follow a two-sided normal distribution, and h_i and u_{it} are the persistent and transient inefficiency components, respectively, that follow a half-normal distribution.

Note that the GTRE model is based on random effects models, and hence on the assumption that individual-specific error terms are not correlated with the covariates. Therefore, following Farsi et al. (2005) we also estimate Equation 2 with Mundlak correction to attenuate the bias deriving from possible correlation with the time-invariant error term. As suggested before, this approach is preferable for the analysis of nursing home efficiency since unobserved heterogeneity between providers likely shapes their cost structure and health outcomes.

5 Results

The results from the estimation of the nursing home cost frontier using Equation 2 are reported in Table 2. Column 1 uses the GTRE model proposed by Filippini and Greene (2016), whereas column 2 extends the model in column 1 by including the Mundlak correction.[10] Since all of the variables included in the model are normalized by their median values and are expressed in natural logarithms, the coefficients of the first-order terms can be interpreted as cost elasticities for the median nursing home.

While the coefficients are generally very similar between the two models, some coefficients change when the Mundlak correction is applied. The coefficient of days of care (β_Y) drops from 0.96 to 0.83. Moreover, the coefficient of the dependency level (β_D) loses magnitude and significance. This is due to the fact that the within-variation of the dependency level is very low and, therefore, the mean dependency level, which has a positive and significant coefficient, captures all the variation in that variable. The other coefficients are generally similar in magnitude and significance across the two models. However, the model with Mundlak correction improves the consistence of the estimates and, therefore,

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[10] We estimate the models using 120 random draws. Note, however, that repeating the analysis using a higher number of draws (e.g. 200) provides very similar results. Moreover, we also estimate both models using the approach proposed by Kumbhakar et al. (2014). Again, the results are similar to those obtained with the approach proposed by Filippini and Greene (2016) and are reported in A1 in the Appendix.

we prefer this model as compared to the conventional model reported in column 1.

The levels of output (β_Y) and input prices (β_L and β_K) positively affect costs. In particular, since the coefficient of the level of output is less than 1, nursing homes seem to face increasing returns to scale. Indeed, a 1% increase in the output level increases total costs by 0.83% in the Mundlak correction model, *ceteris paribus*. Moreover, keeping all other characteristics fixed, a 1% increase in the price of labor and capital increases total costs by 0.75% and 0.07%, respectively, which reflects the cost shares of input prices (see Section 4.1).

The significance of the statistic λ, which represents the ratio between the standard deviations of the transient inefficiency term (u_{it}) and the time-varying noise term (v_{it}), in all models suggests that the contribution of the noise term to the decomposition of the error term (ε_{it}) is low. Moreover, the standard deviations of the nursing-home-specific noise term (σ_w) and the persistent inefficiency term (σ_h) are significant in all models.

To estimate nursing homes' efficiency scores, we follow the approach proposed by Filippini and Greene (2016), which builds on a result from Colombi et al. (2014). For each model, transient efficiency is estimated using $exp(-\hat{u}_{it})$, with $\hat{u}_{it}$ being the estimator of the transient efficiency component, and persistent efficiency is estimated using $exp(-\hat{h}_i)$, with $\hat{h}_i$ being an estimator of the persistent efficiency component. Moreover, following Kumbhakar et al. (2014), we estimate overall efficiency as the product between persistent and transient efficiency scores ($exp(-\hat{u}_{it}) \times exp(-\hat{h}_i)$). The results are reported in Table 3.

The average transient efficiency score is equal to 87.2% and 86.6%, respectively for the baseline and the Mundlak correction models (Panel A in Table 3), but the distributions are characterized by a long left-tail since the minimum values are equal to 38.5% and 36.8%. The average persistent efficiency score is higher than the transient efficiency score for both models, but the score is 7.2% larger for the model with Mundlak correction (Panel B). In particular, this is equal to 89.3% and 96.5% for the baseline and Mundlak correction models, respectively. Since the overall cost efficiency is the product of the two efficiency component scores, overall efficiency distributions are similar, but the score for the model with Mundlak correction reported in Panel C is 5.7% higher than the score for the baseline model (83.6% vs. 77.9%). For an illustration of the distribution of overall efficiency scores obtained from the two models see Figure 2.

Our efficiency scores are in line with the results of previous studies. Crivelli et al.

(2002), who analyze efficiency using cross-sectional data from 886 nursing homes in 2002, find an average overall efficiency score equal to 78.6%. In their analysis of 1070 nursing homes for the period 1998-2002, Farsi et al. (2008) find a transient efficiency score of 92% using a TRE model. Their slightly larger estimate than ours may be imputable to the selection of the model which tends to overestimate efficiency (Filippini et al., 2018). Conversely, their persistent efficiency score estimate, which is derived from a random effects regression using the approach proposed by Schmidt and Sickles (1984), is much lower as compared to our estimate (38%). However, note that this approach for persistent efficiency estimation is valid under the assumption that all of the time-invariant cost differences between nursing homes not explained by the covariates included in the cost frontier are determined by inefficiency. This assumption is very restrictive in the nursing home sector, where time-invariant differences are likely determined by heterogeneity in treated patients.

5.1 Total factor productivity change

The literature provides several approaches to estimate TFP change in the nursing home industry. The SF approach and the cost function approach differ only in the distribution of the error term which is not expected to affect the estimated coefficients (Aigner et al., 1977). Thus, TFP change estimates should not differ by using either of the two approaches. Non-parametric approaches (e.g. DEA, Törnqvist index) can also be used, but these approaches are sensitive to outliers and have more strict assumptions as compared to parametric approaches (Caves et al., 1982; Charnes et al., 1978). For instance, the Törnqvist index measures productivity change under the assumption of constant returns to scale (Chan and Mountain, 1983).

In this paper, we derive TFP change from the cost frontier defined in Equation 2 following the approach proposed by Bauer (1990). This approach allows us to derive the following index of productivity growth from a cost frontier that accounts for characteristics that justify a heterogeneous use of input factors across nursing home providers:

$$
\begin{aligned}
TFPC_{it} &= ln\,TFP_{it} - ln\,TFP_{i,t-1} \\
&= \underbrace{CE_{it} - CE_{i,t-1}}_{\text{CEC}} \\
&\quad \underbrace{+\frac{1}{2}[(1-e^{Y}_{it}) + (1-e^{Y}_{i,t-1})](ln\,Y_{it} - ln\,Y_{i,t-1})}_{\text{SEC}} \\
&\quad \underbrace{-\frac{1}{2}\left(\frac{\partial\,ln\,TC_{it}}{\partial t} + \frac{\partial\,ln\,TC_{i,t-1}}{\partial t}\right)}_{\text{TC}} \\
&\quad \underbrace{-\frac{1}{2}\sum_{q}(e^{q}_{it} - e^{q}_{i,t-1})(ln\,q_{it} - ln\,q_{i,t-1})}_{\text{OCC}}
\end{aligned}
\tag{4}
$$

where CE_{it} is the cost efficiency score derived from the estimated baseline or Mundlak cost frontier models $(exp(-\hat{u}_{it}) \times exp(-\hat{h}_i))$, $e^{J}_{it} = \partial\,ln\,TC_{it}/\partial\,ln\,J_{it}$, with $J_{it} \in \{Y_{it}, q_{it}\}$, where Y_{it} is the nursing home output (days of care provided) and q is a set of nursing home characteristics (dependency level and share of nurse-hours worked by skilled nurses), as defined earlier in Equation 2. Note that the first term on the right hand side of Equation 4 represents scale efficiency change (SEC), the second term is technical change (TC), and the last term corresponds to the change in output characteristics (OCC).

Using Equation 4 we derive TFP change based on the estimates from the baseline and the Mundlak correction GTRE models.[11] Both models provide similar trends in TFP change, which is always negative after 2009 and always decreasing over the whole period 2007-2015, except for a slight increase between 2013 and 2014 (see Figure 3). On average, TFP change is equal to -0.72% and -0.68%, respectively for the baseline and the Mundlak correction models, which implies that productivity change is 1.58 and 1.49 times lower in 2015 relative to 2007 levels.

Equation 4 above can be further exploited to decompose TFP change and identify the contribution of four components: technical change (TC), scale efficiency (SEC), cost efficiency (CEC) and output characteristics (OCC). The results of this decomposition are reported in Table 4. These suggest that technical regress is the most important factor that contributes to the reduction in TFP change. Conversely, the components related to economies of scale and cost efficiency mitigate only partially this decrease.

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[11] Note that the additional terms added to the cost model for the Mundlak correction do not change the TFP change derivation procedure described in Equation 4 since those terms are time-invariant.

In summary, the results we obtained in terms of productivity growth may suggest the presence of Baumol's cost disease. Baumol (1967) shows that the unit cost in non-progressive sectors grows faster than in progressive sectors. The reason is that labor productivity grows thanks to technological improvement, which is lacking in non-progressive sectors. Consequently, it is not possible to exploit the improvement in capital-driven productivity to compensate for the increasing costs of labor. Indeed, our data show that the average labor productivity between 2007 and 2015 in the nursing home industry decreased by 2.03% per year while the yearly growth rate of wages was 1.45%, with an overall difference between productivity and wage growth rates of 3.48% per year. The growth of wages exceeded the growth of labor productivity in every period, except for 2013.

6 Concluding remarks

The growing trends in population aging and LTC costs and the consequent increasing burden on public finance call for rigorous scientific investigation of nursing home cost efficiency and productivity growth. In this study, we use data from the universe of Swiss nursing homes for a 9-year period (2007-2015) to estimate cost frontiers using the recent GTRE model proposed by Filippini and Greene (2016), which allow to disentangle the time-invariant (persistent) and time-varying (transient) efficiency components. We improve our specification to account for possible heterogeneity in nursing home costs with some characteristics of the output and using a Mundlak correction. The results in terms of efficiency scores are in line with previous efficiency estimates in the Swiss nursing home industry (e.g. Crivelli et al., 2002; Farsi et al., 2008). However, TFP change derived using the approach proposed by Bauer (1990) is on average negative and decreasing over time, mainly driven by a technical regress. This loss in nursing homes productivity suggests evidence of the presence of Baumol's disease (Baumol, 1967), and represents a remarkable challenge for policy makers who are facing increasing pressure to contain overall costs for LTC services.

Our empirical results that differentiate the transient and the persistent parts of productive efficiency may provide some valuable insights on the performance of nursing homes for managerial purposes. Indeed, managers should disentangle the potential gains in productive efficiency that can be obtained in the short run and in the long run, since this will enhance the selection of best practices to optimize the use of resources over time.

From the policy maker point of view, the challenge of decreasing TFP calls for the introduction of more effective incentive-regulation methods to improve the level of productive efficiency and productivity in the Swiss LTC sector. Better methods consider the distinction between the two parts of inefficiency. For instance, the regulator could set efficiency targets (transient) to be reached in the short term, and efficiency targets (persistent) to be achieved in several years. As shown in other industries (e.g. Filippini et al., 2018), the distinction between transient and persistent efficiency targets in the application of incentive-regulation methods, when quality is not fully observable by the regulator, can improve the effectiveness of government interventions. We have shown that the marginal gains from transient efficiency improvements are relatively larger than the marginal gains from persistent efficiency. This suggests that measures enhancing transient efficiency may provide a better contribution to reverse the decreasing trend in total factor productivity change.

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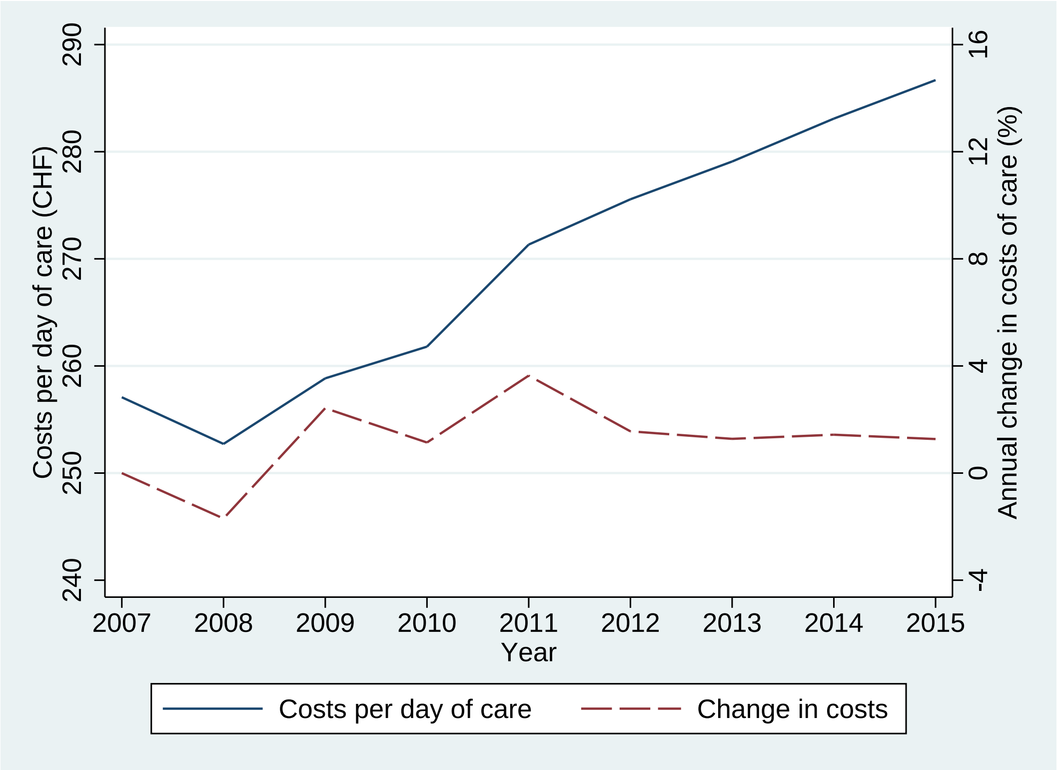
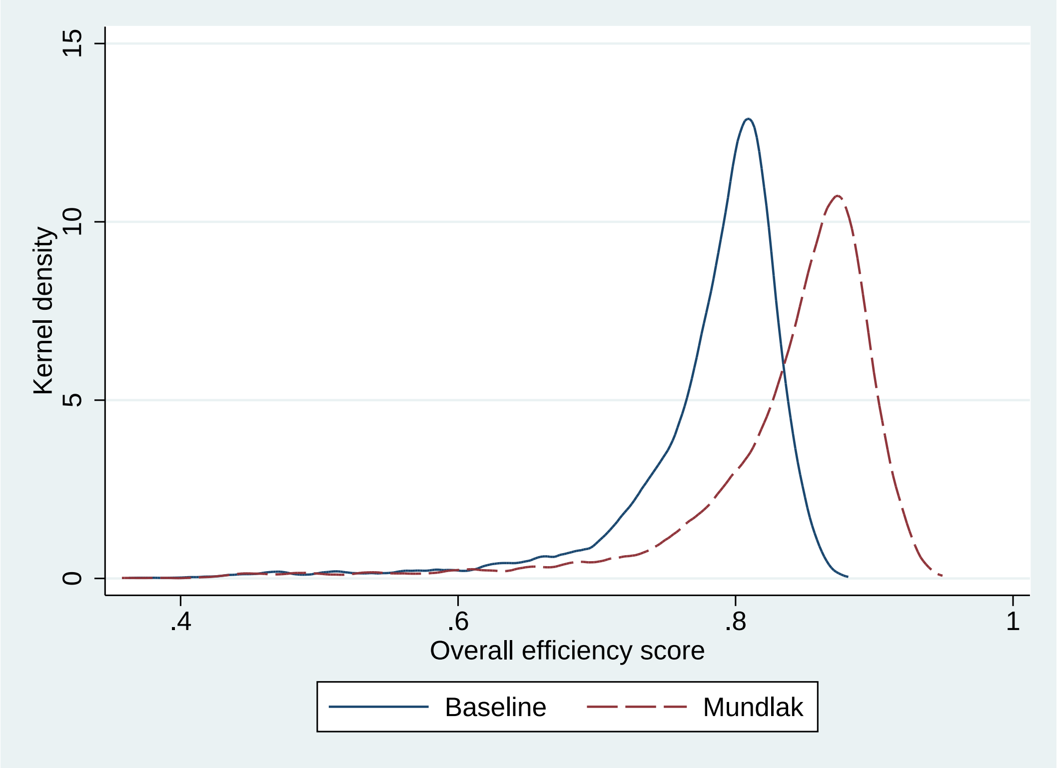
Figure 1: Costs per day of care in nursing homes over time.



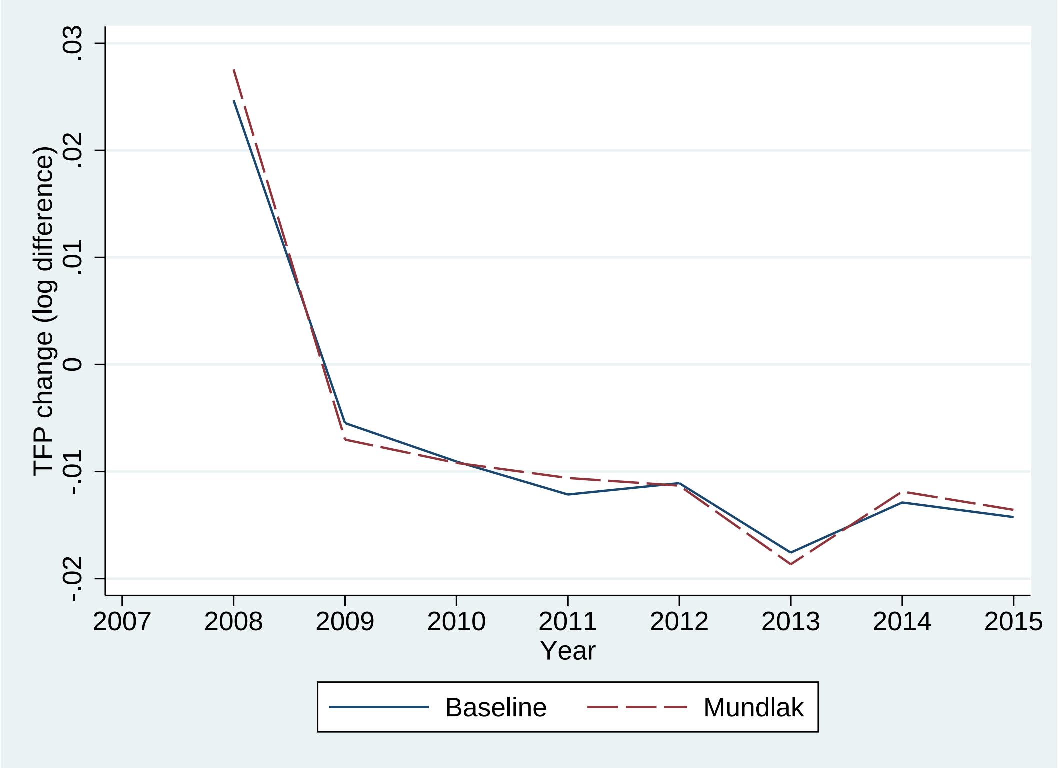
Notes - The figure illustrates the average trend in nursing home costs per day of care (blue solid line) and the average annual percentage change in costs (red dashed line) over time. Costs are deflated at 2010 prices using the consumer price index.
Source: Our elaboration on SOMED A data provided by the Swiss Federal Office for Statistics.

Figure 2: Kernel densities of overall efficiency scores.



Notes - The figure illustrates kernel densities of overall efficiency scores derived from translog cost frontiers estimated using the GTRE model proposed by Filippini and Greene (2016). The blue solid lines represents efficiency scores derived from the baseline model (column 1 in Table 2), and the red dashed lines represents efficiency scores derived from the model with Mundlak correction (column 2 in Table 2).
Source: Our elaboration on SOMED A data provided by the Swiss Federal Office for Statistics.

Figure 3: Trends in TFP change of nursing homes.



Notes - The figure illustrates average trends in TFP change derived from translog cost frontiers estimated using the GTRE model proposed by Filippini and Greene (2016). The blue solid lines represents TFP change derived from the baseline model (column 1 in Table 2), and the red dashed lines represents TFP change derived from the model with Mundlak correction (column 2 in Table 2).
Source: Our elaboration on SOMED A data provided by the Swiss Federal Office for Statistics.

Table 1: Descriptive statistics.

	Obs.	Mean	Std. Dev.	Min	Max
Total costs (TC)	8658	6370581.1	4813163.9	364466.3	85654368
Days of care (Y)	8658	23395.5	15610.6	1039	242563
Price of labor (P_L)	8658	65338.3	9965.1	37221.4	121306.4
Price of capital (P_K)	8658	9542.4	7159.6	0	118552.2
Price of materials (P_M)	8658	23.38	9.133	0.374	70.63
Dependency level (D)	8658	2.240	0.565	0.0253	3.964
Share of skilled-nurse hours (Q)	8658	27.04	13.15	0.234	100

Notes - Monetary values are deflated at 2010 prices using the consumer price index.

Table 2: Panel data cost frontier models.

	(1) Translog cost frontier		(2) Translog cost frontier with Mundlak correction	
	Coef.	SE	Coef.	SE
Days of care (β_Y)	0.962***	(0.00324)	0.832***	(0.00756)
Labor price (β_L)	0.748***	(0.00379)	0.754***	(0.00391)
Capital price (β_K)	0.0640***	(0.00190)	0.0735***	(0.00207)
Dependency level (β_D)	0.0602***	(0.0132)	0.00458	(0.0138)
Share of skilled nurse hours (β_H)	-0.00152	(0.00459)	0.00515	(0.00525)
Time trend (β_t)	0.00525*	(0.00224)	0.00927***	(0.00222)
(β_{YY})	0.0240***	(0.00408)	0.00396	(0.00390)
(β_{LL})	0.108***	(0.00226)	0.106***	(0.00227)
(β_{KK})	0.0138***	(0.000360)	0.0154***	(0.000390)
(β_{DD})	0.0670	(0.0368)	0.0312	(0.0359)
(β_{HH})	0.00267	(0.00189)	0.00500*	(0.00195)
(β_{tt})	0.00123**	(0.000450)	0.000700	(0.000440)
(β_{YL})	0.0274***	(0.00251)	0.0305***	(0.00250)
(β_{YK})	-0.00461***	(0.000980)	-0.00460***	(0.000980)
(β_{YD})	0.0304**	(0.00973)	0.0231*	(0.00936)
(β_{YH})	0.00933**	(0.00346)	0.0118***	(0.00350)
(β_{LK})	-0.0192***	(0.000690)	-0.0198***	(0.000680)
(β_{LD})	0.0135	(0.00741)	-0.00411	(0.00754)
(β_{LH})	-0.00977**	(0.00303)	-0.00379	(0.00297)
(β_{KD})	0.0142***	(0.00363)	0.0111**	(0.00359)
(β_{KH})	0.000500	(0.00122)	0.00225	(0.00121)
(β_{DH})	0.0160	(0.00986)	0.0197*	(0.00960)
(β_{Yt})	0.000250	(0.000520)	0.000340	(0.000530)
(β_{Lt})	-0.00997***	(0.000740)	-0.00974***	(0.000770)
(β_{Kt})	-0.000190	(0.000300)	-0.000410	(0.000300)
(β_{Dt})	0.00259	(0.00259)	0.00256	(0.00264)
(β_{Ht})	0.000390	(0.000750)	-0.00000278	(0.000760)
Mean days of care			0.172***	(0.00767)
Mean price of labor			-0.0584***	(0.00418)
Mean price of capital			-0.00854***	(0.00158)
Mean dependency level			0.592***	(0.0138)
Mean share of skilled nurse hours			0.000620	(0.00437)
Constant	15.16***	(0.00548)	15.24***	(0.00534)
Obs.	8658		8658	
σ_w	0.152***	(0.00144)	0.128***	(0.00117)
λ	2.507***	(0.0445)	2.829***	(0.0486)
σ	0.197***	(0.00105)	0.202***	(0.00102)
σ_h	0.541***	(0.0116)	0.0488***	(0.00984)
Log likelihood	4218.0		4428.0	

Notes - The table reports translog cost frontier estimation results using the GTRE model proposed by Filippini and Greene (2016). The model in column 1 represents the baseline translog cost frontier, and the model in column 2 extends the former model by controlling also for the nursing-home-specific means of the control variables (Mundlak correction). Significance levels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Standard errors are reported in parenthesis.

Table 3: Nursing homes efficiency scores.

	Mean	SD	Min	Max
Panel A: Transient efficiency scores				
Baseline	0.872	0.075	0.385	0.983
Mundlak	0.866	0.080	0.368	0.984
Panel B: Persistent efficiency scores				
Baseline	0.893	0.011	0.868	0.999
Mundlak	0.965	0.001	0.946	0.975
Panel C: Overall efficiency scores				
Baseline	0.779	0.065	0.363	0.881
Mundlak	0.836	0.077	0.358	0.949

Notes - The table reports persistent, transient and overall efficiency scores derived from translog cost frontiers estimated using the GTRE model proposed by Filippini and Greene (2016). *Baseline* efficiency scores are derived from the baseline cost frontier (column 1 in Table 2), and *Mundlak* efficiency scores are derived from the cost frontier with Mundlak correction (column 2 in Table 2).

Table 4: TFP change decomposition.

	(1) Baseline	(2) Mundlak
TC	-0.0113	-0.0128
SEC	0.000305	0.00130
CEC	0.00388	0.00471
OCC	-0.0000961	-0.000000969
TFPC	-0.00722	-0.00683

Notes - The table reports means for TFP change and its components derived from the baseline (column 1) and Mundlak cost frontiers (column 2) for the period 2007-2015. *TC* is technical change, *SEC* is scale efficiency change, *CEC* is cost efficiency change, *OCC* is change in output characteristics and TFPC is TFP change.

Appendix

Table A1: Panel data cost frontier models using the Kumbhakar et al. (2014) approach.

	(1)		(2)	
	Translog cost frontier		Translog cost frontier with Mundlak correction	
	Coef.	SE	Coef.	SE
Days of care (β_Y)	0.958***	(0.00793)	0.834***	(0.0153)
Labor price (β_L)	0.763***	(0.00853)	0.778***	(0.00856)
Capital price (β_K)	0.0553***	(0.00344)	0.0643***	(0.00349)
Dependency level (β_D)	0.0814***	(0.0233)	0.00510	(0.0232)
Share of skilled nurse hours (β_H)	0.00351	(0.00820)	0.00701	(0.00838)
Time trend (β_t)	-0.0110***	(0.00283)	-0.00825**	(0.00278)
(β_{YY})	0.0341**	(0.0109)	0.0228*	(0.0108)
(β_{LL})	0.117***	(0.00560)	0.112***	(0.00555)
(β_{KK})	0.0140***	(0.000868)	0.0157***	(0.000862)
(β_{DD})	0.190**	(0.0597)	0.0989	(0.0586)
(β_{HH})	0.00418	(0.00324)	0.00449	(0.00319)
(β_{tt})	0.00383***	(0.000538)	0.00357***	(0.000527)
(β_{YL})	0.0196**	(0.00621)	0.0201***	(0.00608)
(β_{YK})	-0.00264	(0.00195)	-0.00341	(0.00191)
(β_{YD})	0.0273	(0.0183)	0.0207	(0.0179)
(β_{YH})	0.0191**	(0.00655)	0.0212**	(0.00645)
(β_{LK})	-0.0165***	(0.00145)	-0.0167***	(0.00142)
(β_{LD})	0.0131	(0.0176)	-0.00139	(0.0173)
(β_{LH})	-0.00546	(0.00647)	-0.00148	(0.00633)
(β_{KD})	0.0108	(0.00655)	0.00597	(0.00642)
(β_{KH})	0.00305	(0.00227)	0.00322	(0.00223)
(β_{DH})	0.0246	(0.0184)	0.0228	(0.0180)
(β_{Yt})	0.00211*	(0.000977)	0.00141	(0.000957)
(β_{Lt})	-0.00935***	(0.00143)	-0.00974***	(0.00141)
(β_{Kt})	0.000599	(0.000461)	0.000507	(0.000452)
(β_{Dt})	0.00887*	(0.00418)	0.00480	(0.00410)
(β_{Ht})	-0.000256	(0.00121)	-0.000180	(0.00118)
Mean days of care			0.156***	(0.0158)
Mean price of labor			-0.0650***	(0.0124)
Mean price of capital			-0.00822*	(0.00409)
Mean dependency level			0.535***	(0.0331)
Mean share of skilled nurse hours			-0.0106	(0.00989)
Constant	15.42***	(0.00811)	15.41***	(0.00813)
Obs.	8658		8658	
σ_w	0.127***	(0.000984)	0.0890***	(0.00164)
λ	1.462***	(0.00380)	1.517***	(0.00361)
σ_h	0.000264	(0.233)	0.119***	(0.00361)

Notes - The table reports translog cost frontier estimation results using the GTRE model proposed by Kumbhakar et al. (2014). The model in column 1 represents the baseline translog cost frontier, and the model in column 2 extends the former model by controlling also for the nursing-home-specific means of the control variables (Mundlak correction). Significance levels: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$. Standard errors are reported in parenthesis.