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Technology, Productivity and Costs in Healthcare

Albert A. Okunade & Ahmad Reshad Osmani

Summary

Health care cost encompasses expenditures on the totality of scarce resources (implicit and explicit) given up (or allocated) to produce health care goods (e.g., drugs and medical devices) and services (e.g., hospital care and physician office services are major components). Health care cost accounting components (sources and uses of funds) tend to differ but can be similar enough across most of the world countries. The health care cost concept usually differs for consumers, politicians and health policy decision makers, health insurers, employers and the government. All else given, efficient (least-cost) production of health care implies lower economic cost and higher productivity of the resources deployed in the process. Health care productivity varies across health systems of the world countries, the production technologies used, regulatory instruments and institutional settings. Health care production often involves some specific (e.g., drugs and medical devices, information and communication technologies) or general technology for diagnosing, treating or curing diseases in order to improve or restore human health conditions.

In the last half century, the different health care systems of the world countries have undergone fundamental transformations in the structural designs, institutional regulations and socio-economic and demographic dimensions. The nations have allocated a rising share of total economic resources or incomes (that is, Gross National Product, or GDP) to the health care sector, and are consequently enjoying substantial increases in population health status and life expectancies. There are complex and interacting linkages among escalating healthcare costs,

longer life expectancies, technological progress (or ‘the march of science’) and sectoral productivities in the health services sectors of the advanced economies. Health care policy debates often concentrate on cost containment strategies and search for improved efficient resource allocation and equitable distribution of the sector’s outputs. Consequently, this contribution is a broad review of the body of literature on technological progress, productivity and cost: three important dimensions of the evolving modern health care systems. This review is a logical integration of three strands of work linking health care cost to technology and research evidence on sectoral productivity measurements. Finally, some important aspects of the existing study limitations are noted to motivate new research directions for future investigations to explore in the growing health sector economies.

JEL code: I1 (Health), D24 (Production)

Keywords: Health systems; medical care technology; productivity; national health expenditures; Baumol’s ‘cost disease’

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Introduction

This work collectively presents a condensed review of the literature in attempting to provide a broad understanding of technology, productivity and cost as three different but interrelated dimensions of the contemporary, evolving health care systems in many of the world countries. The rapidly growing literature on healthcare cost identifies the demand side national income (Gross National Product or GDP) and the supply side medical progress (process and product innovations or ‘the march of science’) as the core drivers of economic growth in modern economies (Willemé & Dumont, 2015). Moreover, in demographically ageing societies, medical care technology is specifically identified as a critical input for expanding life expectancy and quality of life (Lichtenberg, 2014) of the world country populations (M. B. Jakovljevic, Vukovic, & Fontanesi, 2016). Country case studies (see, e.g., Abdullah, Siddiqua and Haque (2016), on the developing Asian countries; Murthy and Okunade (2016), focusing on the U.S.) and panel of countries (see, e.g., Baltagi *et al.*, (2017); Okunade, You and Koleyni (2017), on the OECD countries) confirm, that rising national incomes, ageing population (Ogura & Jakovljevic, 2014), and both the health sector and general technology spillover innovations explain a large share of the surge in aggregate healthcare expenditures of the nations for many decades.

On a closer examination, whether or to what extent technological innovations fuel health care cost growth of the nations is challenging to assess empirically for certain reasons. Neumann and Weinstein (1991), for instance, lament that a lack of an agreed upon definition of medical technology hinders the assessment of its impact on health care spending. Standard definitions in frequent use have included but are not limited to new drug entities, medical devices, surgical procedures, number of science and technology graduates per 100,000 population, and institutional support systems as components of medical technology –but these are incomplete.

Researchers assert that measuring the contributions of each component of the medical technology to the health care cost rise is puzzling, even if the most important innovations could be listed and included. Many recent studies have indicated that the health care market entry of new medical devices (ranging from pace makers to large diagnostic and treatment machines) is unavoidably accompanied by substantial additional costs (e.g., the overall organizational and institutional performance) and reimbursement policy changes (Okunade, 2003). These are especially so when third party payers (commercial and public health insurers) and the gate-keeping physicians, on the supply side, and the patients, on the demand side, embrace new technologies before their full (or economic) costs and benefits) are fully evaluated and scientifically understood. (M. Jakovljevic & Yamada, 2017). Nevertheless, medical technology adoptions need not result in higher costs if the new therapies cost less, decrease costs elsewhere, and reduce utilization of related diagnostic and therapeutic procedures (Neumann & Weinstein, 1991; Santerre, 2011).

In general, the cost impacts of medical technologies can be evaluated depending on where they fall within the three-stage typology (Weisbrod, 1991) long ago propounded. First, a “Non-technology” option which provides diagnostic tool to prevent progression of a disease in a relatively inexpensive way. For instance, the traditional blood pressure cuff that enables determination of a patient’s physiologic status is a non-technology. Second, “Halfway technology” which is relatively expensive and it takes a supportive role with minimum or no cure to the disease itself. For example, individuals with renal failure may remain on hemodialysis treatment for extended periods and may need intensive care because of multi-organ system failure, but the typical outcome is poor. As a result, the use of economic resources tends to be large, but the typical prognosis is bleak. Third, “High” technology is

extremely costly while providing direct cure for diseases (e.g., the minimally invasive or non-invasive procedure such as treatment with isotopes).

Additionally, innovative medical technologies have been detected to raise overall health care system productivity (Black & Lynch, 2001). Compared to whole economy, measurement of productivity growth in health care industry has arguably been underestimated. Economic studies attribute this low productivity growth to limitations in the conceptual framework and estimation methods used. Some have successfully argued that most of the productivity growth in health care has come in the form of improved quality rather than lower cost (Bartel, Ichniowski, & Shaw, 2007). In the same line of reasoning, technological innovations in the healthcare sector have reduced incurred costs and increased productivity—such as moving from inpatient to outpatient care— but this cannot be adequately measured explicitly in the standard models. On the other hand, even if the ideal measurements exist and are practicable, productivity growth in the health care sector would remain low given the service nature of the sector with limited opportunities for efficiency improvements (Baumol, 2012).

A vast majority of the body of work on aggregate health care expenditure reports substantial variability in findings across countries, depending on the level of economic development, the time period length studied, study data type (cross-sectional, time-series, panel) and statistical modelling methodology (M. M. Jakovljevic & Pejcic, 2017). During the 1970 to 2004 time period, per capita health expenditures rose markedly among the OECD member countries at an annual average rate of 11.5 per cent. Such temporal dynamics has been characterized by large differences across the countries, leading to marked geographical heterogeneity in the level of spending. For example, a snapshot in 2004 shows that the US, with an average of \$6,0372, has the highest per capita health care expenditure, followed by

Switzerland (\$4,045), Norway (\$4,103), and Germany (\$3,169). On the other hand, countries devoting fewer resource to health care include Turkey and Mexico, with an average annual per capita expenditure of \$562 and \$655, respectively. As a share of Gross Domestic Product (GDP), OECD health care spending has almost doubled over this period, increasing from 4.9 per cent in 1970 to 8.8 percent in 2004. However, there are substantial heterogeneities across the countries. It is important to note a strong, long term shift in global health care spending share from the rich, high-income societies (OECD representing the top performing ones) towards low- and middle-income nations (Jakovljevic and Getzen (2016). This profound evolution has been taking place for most of the last thirty years since the cold war era ended. Furthermore, the percentage point share has almost doubled in these countries from 1995 to 2015. These developing world economies are naturally led by top performing emerging markets, such as the BRICS (Jakovljevec, 2015a; Jakovljevec, 2015b) and the next eleven ones (Rancik and Jakovljevec, 2016).

More precisely, while many countries continue to experience a rise in their health share of the GDP in the 1980s and 1990s, others, for example, India (Kalra, 2014), have experienced modest declines, possibly associated with reforms aimed at limiting the percentage rise in health care spending as a proportion of GDP. Over time, the shares of health care spending as a percentage of GDP, have ranged between 2.5 and 7.0 per cent in the 1970s, compared with the 5.5 and 15.2 per cent range in 2004. The annual growth rate in per capital real health care spending across the OECD countries, for the years 2009/10, 2010/11, 2011/12, 2012/13 and 2013/14 were, respectively 0.2%, 0.5%, 0.7% and 1.0% (OECD Health Statistics, 2015). The consistent rise in health care spending, for the OECD countries and in the emerging economies (M. Jakovljevic, Groot, & Souliotis, 2016), has been attributed to Baumol's 'cost disease'- a phenomenon characteristic of the labor-intensive service industries where human interactions are

important and labor productivity (that is, output growth per worker) lags the rise in wages and salaries of workers (Baumol, 2012). Since labor markets across industries are connected, the rising productivity in the manufacturing industries (e.g., computers) generates cost increases in a labor-intensive service industry such as education and health care (Bates and Santerre, 2013).

The next section of this contribution focuses on the measurement and estimation issues in medical care technology, productivity and costs. This is followed by sections discussing the limitations of existing studies, suggestions for future research directions, and the conclusion.

Measurement and Estimation Issues

Health Care Technology

As indicated earlier in this work, the body of literature considers income and technology as the main health care cost drivers in most advanced economies (Smith, 2016). However, there is controversy in how medical technology escalates costs (Weisbrod, 1991). Previous studies have used some proxies of medical technology in their estimation methods as determinants of national health expenditure (Costa - Font, Gemmill, & Rubert, 2011; Wong, Wouterse, Slobbe, Boshuizen, & Polder, 2012; Zhang, 2013). Among these technology proxies, the health and economy-wide R&D spending, new pharmaceutical chemical entities, training new medical doctors, number of new medical equipment and devices, improved life expectancy at birth are the most documented ones (Wang *et al.*, 2017). A smaller number of studies have used some measure of patents (Getzen & Okunade, 2017). The outcome-based patent measures, as marketed inventions, are appropriate for modeling health care expenditure rise. Furthermore, besides the residual component approach, the econometric estimation techniques used when capturing the impacts of medical technology on healthcare expenditures do matter. The underlying assumption

for these methods is the clinical efficacy for medical technologies with almost no investigation on the negative aspects of medical technology. There is a complementary strand of literature touting the most important factors driving national health care costs, to include: inefficient use of advanced medical technologies, payment mechanisms with perverse incentives, medical liability and the practice of defensive medicine, and so on.

Health Care Productivity

Service sector in the advanced economies makes up in excess of three quarters of their economic activities. Therefore, the concepts and measurements of productivity and innovations are important aspects of service sector research (Gardrey and Gallouj, 2002) of which the health care services industry is a principal component. Using the traditional measurement approaches, health care productivity specifies output as expenditure on health related goods and services—e.g., drugs, hospital services, physicians’ services— deflated by some defined price index to achieve an estimate of real output over time.

Multi-Factor Productivity (MFP) growth in health care, on average, has been reported to be considerably less than the economy-wide MFP or to some extreme even negative. Triplett and Bosworth (2004), using expenditure data and deflators from the U.S. Bureau of Economic Analysis, reported negative productivity growth in U.S. health care sector in 1987-2001, at a rate of about 1 percent annually. Their finding is consistent with another study by Harper, Khandrika, Kinoshita, and Rosenthal (2010) for the years 1987-2006. Focusing on hospitals productivity growth and various measurement methods, Cylus and Dickensheets (2007) used net revenue for hospitals deflated by the producer price index for hospitals as their measure of output. They estimated that the 10-year moving average of growth in hospital MFP for the 10-year period ending in 2005 was between 0.3 and 0.6 percent, depending on the method used to measure

hospital inputs. Over each of the 10-year periods in the 1990-2005 time frame, the average MFP for hospitals was almost less than one-half of average MFP for the whole economy. An effort to augment aforementioned study, Sheiner and Malinovskaya (2016) re-evaluated the Cylus and Dickensheets study by adding more years (1990-2013) in their study timeframe. With a quite similar finding, they estimated that, over the period 1990-2013, the average growth rate of hospital MFP was between 0.1 percent and 0.6 percent, which is less than the average growth of private non-farm business MFP of 1 percent. Given that the health sector labor force, especially the physicians, play substantial roles in determining acceptability and feasibility of medical technology, efforts have been made to estimate labor productivity in health care (Jakovljevic, 2016). Fisher (2007), for instance, also calculated MFP of physicians' and captured extreme variability in the estimates. Based on his study, factor productivity has increased with an average rate of 1.5 percent per annum from 1982 to 1992, decreased -0.6 percent per year on average from 1993 to 2000, and again rose 1.7 percent per year from 2001 to 2004. However, over all the periods, physician MFP was about the same as whole economy. To estimate the overall medical labor force productivity, using U.S. data, the Chansky and Garner (2015) study report an average annual 0.5 percent productivity growth in hospitals between 1993 and 2012 which is much lower than the mean labor productivity at 21.4 percent for the same period.

Health Care Expenditures (Costs)

The empirical studies on the determinants of health care expenditure is abundant, and the growing literature is continues to evolve (Getzen & Okunade, 2017). These studies have been undertaken at the microeconomic, national and international levels (M. M. Jakovljevic & Ogura, 2016). Microdata studies have estimated two-part or double-hurdle models to study the determinants of the health care utilization and expenditures of individuals and households. In this

strand of the literature, a central issue is the relative importance of age versus proximity to death (the ‘red herring’ hypothesis) in explaining the age profile of spending (Werblow, Felder, & Zweifel, 2007). On the other hand, macro level studies tend to use national time-series or international panel data to estimate the determinants of total health expenditures.

There is a large variability across the studies when specifying the determinants of health care expenditure (Dalal, 2017). This includes studies but not limited to income, the age composition of the population and proxies of medical technological progress are the most important ones (Martín, Puerto Lopez del Amo Gonzalez, & Dolores Cano Garcia, 2011). The estimates of these studies are highly dependent on the timeframe (or data coverage period), countries included in the study design, whether input (e.g., R&D spending), output (e.g., patents) proxies or the residual approach or some technological index is used to capture the medical technology effects, and the econometric estimation methods. Some studies include proxies that reflect specific high-tech applications, such as MRI scanner density. However, because measures such as these do not necessarily reflect medical technological progress in general, many authors use a time trend as a generic technology proxy. Unfortunately, a trend variable may capture the effects of all kinds of non-stationary variables, and its introduction severely affects the parameter estimates of the other explanatory variables, in particular income (Roberts, 1999). As a result, the empirical results obtained with models that contain trends are difficult to interpret.

Independent of the considerations for inclusion of some technology proxy, debates on the income elasticity of health spending is far from settled. Even the most recent studies report very different estimates: Baltagi and Moscone (2010) conclude that health care is a necessity rather than a luxury in the OECD, with income elasticities ranging between 0.45 and 0.87 depending on the model specification. Woodward and Wang (2012) on the other hand, report a stable long-run

relationship between per capita health spending and income in the U.S., with an implied income elasticity of 1.39. Both studies lack some technology variable, on the basis of the argument that technology is endogenous as it is ‘enabled’ by the income growth. Econometric health expenditure models do not usually include lifestyle variables such as smoking, physical activity, or dietary habits. This is remarkable, given the evidence of the adverse effects of unhealthy lifestyles on a variety of health outcomes reported in the medical literature and the associated financial burdens to individuals and the society (Dieleman *et al.*, 2017). Obesity, for instance, is a known risk factor for many diseases, including cardiovascular disease, type-2 diabetes, certain cancers, osteoarthritis, and psychological problems (Dixon, 2010; Wang, McPherson, Marsh, Gortmaker, & Brown, 2011). The adverse effects of smoking are further well documented, but the long lags between the unhealthy habits and their health consequences make this variable justify to include in aggregate time series or panel model studies.

Regarding choice between heterogeneous (country specific) time-series or homogeneous panel data models, Baltagi and Griffin (1997) conclude that the efficiency gains from pooling more than offset the bias due to inter-country differences. This result justifies a panel model approach despite that the pooling restrictions are unlikely to be valid (Herwartz & Theilen, 2003). Panel data models entail a particular additional problem, however, in that they require the national monetary data to be converted to a common currency in constant prices. The standard way to do this is to use US dollar purchasing power conversion factors (\$PPP). Unfortunately, the choice of the conversion factor (exchange rates, PPPs for GDP, and PPPs for health care) influences the results and may bias the estimated model parameter (Gerdtham & Jönsson, 2000). The output approach, which aims at reflecting the full cost in health care provision, is considered as necessary for meaningful cross-country comparisons of health expenditures (Schreyer & Mas,

2016).

Following developments in non-stationary time-series econometrics, many authors have examined the unit root properties of health expenditures and GDP, both at the country level and in panels of countries. In general, it is concluded that both variables contain a unit root in levels, but are stationary after differencing (Herwartz & Theilen, 2003). However, some studies reject the unit root hypothesis in tests that allow for structural breaks in the series (Jewell, Lee, Tieslau, & Strazicich, 2003; Narayan, 2006). Of course, to determine whether or not health spending is co-integrated with its determinants requires the specification of a ‘complete’ model, in which the order of integration of all variables matters. An alternative approach to quantifying the effect of medical technology on health spending is proposed by Newhouse (1992) who relied on Solow’s growth accounting model to estimate the contribution of technology to the post-war growth of U.S. health expenditures. Just as in macroeconomic analyses, the effects of ‘known’ determinants on health care spending are subtracted from total health expenditure growth, and the residual growth is attributed to technological progress, whereas it actually captures the effects of all omitted variables and the errors in the attributed effects of the included variables. One of the first few attempts to conduct econometric tests of the Newhouse conjecture is due to (Okunade & Murthy, 2002) who separately use economy-wide and health R&D expenditures to proxy for the effect of technical progress (or the march of science) as a supply side core driver of the aggregate healthcare expenditure. The authors find a stable long-run relationship between real per capita health care expenditure, per capita real income, and R&D expenditures. Somewhat surprisingly, they found that total R&D spending has a stronger and more significant impact than the more specific medical R&D variable. This may be due to spillover effects or the migration of technological improvements from elsewhere in the economy to the health care

sector. It is further noteworthy that the long-run relationship between R&D spending and health care spending is contemporaneous, which does not seem plausible given the (very) long lags between R&D efforts and the resulting marketable products, if any. Pammolli *et al.* (2005) listing the different methodologies that have been used to assess the link between medical technology and health care expenditures, argue that econometric analysis including all potential determinants in principle provides the most rigorous assessment of both the significance and magnitude of each individual determinant. The main problem with this approach is the lack of a direct measure for technological change necessitating the use of some imperfect proxy in place of the 'true' technology measure.

The developing countries spend far less on health care, as a percentage of the GDP, than the developed economies. Relying largely on private health expenditures, most of which is out-of-pocket spending, makes studying sustainability, equity and efficiency of health care delivery systems more difficult in the developing country environment (Dercon & Krishnan, 2000). Moreover in these countries, absence of organizational and institutional capacities in the public sector, lack of sound macroeconomic tools and political commitment hamper well-regulated financing mechanisms in short- and long- runs. In South Asia, for instance, total health expenditure (public and private sources) is mostly around 5% of the GDP (Zaidi, Saligram, Ahmed, Sonderp, & Sheikh, 2017). Similar situation exists in most other low income Asian and African countries with an increasing trend of out-of-pocket health expenditure and lower share of public sector spending (Verguet, Laxminarayan, & Jamison, 2015). In general, developing and transitional economies are highly constrained in their health strategic priority settings and paucity of relevant data hampers empirical evidence of health sector cost impacts of productivity measurements and the increasingly important roles that technological progress plays. This is

partly attributed to the immense focus on needs-based, short term services resulting from disease outbreaks (Baltagi, Lagravinese, Moscone, & Tosetti, 2017) and the lack of sustainable financing schemes aimed at achieving universal health coverage (Mills, 2014).

Moreover, technological change in medicine emanating from R&D in the developed countries benefit both the originating and recipient developing nations. The size of the spillover effects is directly related to importations of these technologies or flow of ideas from originating countries to the rest of the world (Skinner & Staiger, 2015). Further, countries with liberal international trade policies, unlike closed trade policies, achieve maximum benefits from the flow of advanced medical technologies. Given that the effects of technology-intensive imports exist at the micro and macro levels, the flow of R&D capital goods from developed to the developing economies is positively associated with increased total factor productivity in the recipient state (Hoekman, Maskus, & Saggi, 2004). **Some Limitations of the Existing Studies**

The standard measures of productivity growth define health care output as the nominal spending on health care by service providers (hospitals, physicians, etc.) deflated by some price index for health care. In theory, this should yield a measure of units of output over time. However, if the price of health care is inaccurately measured or is conceptually measured with errors in ways devoid of the economic content, then so too will be the output and productivity measures. Thus, any problems with measuring health care prices portend problems for measuring sectoral productivity.

Similarly, two main problems have been identified on the measurement of health care costs. One is in identifying the appropriate good. In the traditional approach, the good is the health care service or good actually purchased: a doctor's appointment, a hospital stay, and a

prescription. But, as noted by (Kendrick, 1985) these purchases are better viewed as intermediate inputs into the production of what the consumer truly wants – better health. By viewing services in different categories as different goods, rather than as inputs in the production of one good, cost savings arising from substitution of one input for another are not taken into account. The second problem in constructing price indexes for medical care is that the nature of the good (particularly, the quality component) is changing. In particular, medical care outcomes have tended to improve over time. Price measurements do not capture these increases in quality would overstate price growth in health care and understate productivity growth (Barber *et al.*, 2017).

Getzen and Okunade (2017) traced the historical evolution of important research on the determinants of aggregate health care expenditure. They list some limitations hampering the usefulness of the existing body of work, to include the following. First, failure of authors to recognize that the growth in health care spending is associated with income growth with a lag. Second, the ‘excess growth’ residual approach to capturing technology change effect on health care spending overstates the effect as it also captures changes in demand, organizational factors, prices and administrative costs. Third, other determinants, e.g., policy and institutions, outside of the national income, technology and demographics are incorrectly treated as secondary whereas they are increasingly detected to be statistically significant (see, e.g., Maisonneuve *et al.*, 2017). Fourth, many of the most important relevant concepts, ranging from culture to health, are not easily amenable to measurement. Fifth, comparability on the research findings is difficult when studies span different data coverage periods, use widely ranged model estimation techniques and cover heterogeneous health systems whose policy change over time. Moreover, there is a large absence of studies useful for forecasting or projecting national health care spending, whereas such studies are important for national economic planning and health sector budgetary proposals.

Jakovljevic *et al.*'s (2017) paper on the BRICS countries and a sketch of how the Murthy and Okunade's (2016) explanatory regression model results can be used for forecasting national health expenditure are recent attempts in the right direction to fill this void in the literature.

Health care sector innovation as economic indicators (e.g., R&D, patents, 'knowledge stock', etc) and industry productivity are related (Griliches, 1998). An important, and commonly reported limitation of studies on service sector productivity and innovation measurements is that many of the existing conceptual and measurement approaches adapted from manufacturing are grossly inadequate for the service sector. This is because the fundamental aspects of innovation and productivity in services are both complex and unique to that sector (Gadrey and Gallouj, 2002). Productivity measures in the health care services, an important aspect of the services economy of the advanced countries, should further include the critical roles that regulations and the service recipients or beneficiaries play as fundamentally important participants when computing the empirical estimates of the outcomes or effectiveness (e.g., compliance, related health behaviors) of the health care services the treated population received (M. Jakovljevic *et al.*, 2017).

Suggestions on Future Research Directions

The solution to the rising national health care costs attributable to health care technology and productivity measurement and capture challenges will likely be difficult to reach anytime soon. A market course alone, through a system of managed competition, has not been able to curtail rising technology costs in health care systems. As a matter of fact, managed competition never was able to get off the ground. We are at present in the scenario described by Drummond

et al. (2008) in which the cost of technology continues to increase and probably would continue doing so into the next decade. The five factors Newhouse (1992) identified -increasing use of insurance, population ageing (Jakovljević, 2017), rising GDP, supplier-induced demand, and factor productivity problems in the service sector - have all continue to fuel health care cost rise of advanced nations.

Economists have long sought to explain the determinants of national health care spending to primarily include income (or GDP) and innovative (expensive and cost increasing) treatment technologies, and other factors. In agreement with Getzen and Okunade (2017), some future research directions to advance the understanding and usefulness of research on the role of technological progress are as follows. First, the productivity or cost effectiveness of innovative technology use in reality would differ from that expected from clinical efficacy estimates. This gap, which is likely due to medical errors variously defined, supports the argument that a variable capturing medical technology harm be included as a cost increasing driver of the aggregate health spending of the nations.

Drawing from Schumpeter (1942) on the ‘creative destruction’ of innovative technologies, our proposal that research on the cost increasing effects of medical technology innovations should include associated ‘technology harms’ as a separate determinant agrees with the recent argument Komlos (2017) on the ‘creative destruction’ of innovative technologies. The argument here is that the creative component of the destruction is a social and economic cost and therefore biases our estimate of the impact of innovations on output (e.g., GDP) such as quality-adjusted life expectancy or number of life years gained through innovative treatment medical technologies (Abajobir et al., 2017). Interestingly, it is further noted that the magnitude of the destructive part of innovation was small compared to the net value added to GDP of nations

during the first and second industrial revolutions; however, the conjecture is that the destructive component of the newer technologies is on the rise relative to the size of the creative component. This is because recent innovations are largely innovations close substitutes for the ones they displaced whose value depreciates rapidly in the process of destruction. This reasoning accords with many new innovations, e.g., drugs, in health care in which newer drugs that are a ‘me too’ treatment technology are common. Consequently, future work should endeavor to focus on more precise measurements and decomposition of the effects of medical technology innovations on health care costs into the ‘creative’ and ‘destructive’ components with the latter accounting for the harms of medical technologies (e.g., inappropriate uses, medical errors, geometric depreciation of the displaced technologies, post-marketing harms detected after FDA approval of a new diagnostic and treatment technologies, etc.). These effects constitute a separate driver of the health care cost rise of the nations.

One final note is on the need to ensure that the various measures researchers use to capture the effects of medical technology innovations on health care costs are context relevant and contain the relevant economic information. As earlier reviewed in this study, omission of some technology proxy among the determinants of health care expenditures tends to yield biased estimation of the numerical magnitudes of the income elasticity of health care spending. More specifically, existing studies have used a number of input (e.g., health sector specific and economy-wide R&D spending, physicians per 100,000 population, number of NCEs and enumeration of specific medical technology devices etc), output (e.g., life expectancy or population proportion age 65 years and older), linear and quadratic time trend, and some technology index constructed using specific drugs and medical devices (number or expenditures). These measures only capturing partial effects also suffer from conceptual

problems. One of the less commonly used but powerful technology proxy variable with better economic information content, that Griliches (1998) and others (Mani, 2002; Jaffe and Trajtenberg, 2002; long ago suggested, which could better capture health care cost technology effects, is patent count data at the firm, industry sector and international levels, depending on the study data structure context (Mothe and Paquet, 2000; Plunket, Voisin and Bellon, 2001).

Okunade, You and Koleyni (2017) sought to offer newer insights into the understanding the major drivers of the escalating health care costs of 34 OECD countries, using 1980-2014 data and both panel ARDL (Autoregressive Distributed Lag Model) procedure and FMOLS estimation. Along with age dependency ratio and GDP, their novel study contribution to the relevant literature is inclusion of the number of international cooperation patents to proxy the technology role in ways that account for cross-country spillover effects. Their robust results suggest that the aggregate OECD health care behaves similar to a necessity good (income elasticity estimate of 1.16 from the panel ARDL procedure), and that through cross-country technology investment spillover effects the health care sectors of OECD countries benefit from cooperating on patented technologies that significantly escalate health expenditures.

Conclusion

The goal of this work was to review the broad literature on health care costs, innovative technologies (innovation) and sectoral productivity. The health care services sector is a major component of the growing services economy of the industrial economies, a high cost and low productivity sector that continues to expand relative to manufacturing. Consequently, it is important to clarify that the services context differs from that in traditional manufacturing, and that the unique attributes of what in reality may constitute the conceptual measures of innovation

in the services industry and these would affect economic model estimates of health care costs, technology effects and productivity. After undertaking both a broad and some particular reviews of the relevant work and their contributions, a number of the existing study limitations are highlighted and some value-adding potential future research directions are given. As a result, this work is positioned to elicit the research interests of academicians and policymakers actively working on the estimation of productivity, innovation measurements, and their impacts on the service economy cost growth with particular reference to the health care services economy.

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