Technology, Productivity, and Costs in Healthcare

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Summary and Keywords

Healthcare cost encompasses expenditures on the totality of scarce resources (implicit and explicit) given up (or allocated) to produce healthcare goods (e.g., drugs and medical devices) and services (e.g., hospital care and physician office services are major components). Healthcare cost accounting components (sources and uses of funds) tend to differ but can be similar enough across most of the world countries. The healthcare cost concept usually differs for consumers, politicians and health policy decision-makers, health insurers, employers, and the government. All else given, inefficient healthcare production implies higher economic cost and lower productivity of the resources deployed in the process. Healthcare productivity varies across health systems of the world countries, the production technologies used, regulatory instruments, and institutional settings. Healthcare 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 healthcare 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 (i.e., Gross National Product, or GDP) to the healthcare 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. Healthcare 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 healthcare systems. It provides a logical integration of three strands of work linking healthcare cost to technology and research.
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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.

Keywords: health systems, medical care technology, productivity, national health expenditures, Baumol’s “cost disease”, health economics

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 healthcare systems in many 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’s populations (Jakovljevic, Vukovic, & Fontanesi, 2016B). Country case studies (see, e.g., Abdullah, Siddiqua, & Haque, 2017, on the developing Asian countries; Murthy & Okunde, 2016, focusing on the United States) and studies of a panel of countries (see, e.g., Baltagi, Lagravinese, Moscone, & Tosetti, 2017; Okunade, You, & Koleyni, 2018, 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 closer examination, whether or to what extent technological innovations fuel healthcare 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 healthcare 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 medical technology to healthcare cost rise is puzzling, even if the most important innovations could be listed and included. Many recent studies have indicated that the healthcare 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
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Scientifically understood (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; Okunade, 2001; 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 provides diagnostic tools 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” is relatively expensive and takes a supportive role with minimum or no cure of 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., minimally invasive or non-invasive procedures such as treatment with isotopes).

Additionally, innovative medical technologies have been seen to raise overall healthcare system productivity (Black & Lynch, 2001). Compared to the whole economy, measurement of productivity growth in the healthcare 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 healthcare has come in the form of improved quality rather than lower cost (Bartel, Ichnowski, & Shaw, 2007). By 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 ideal measurements exist and are practicable, productivity growth in the healthcare 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 healthcare expenditure reports substantial variability in findings across countries, depending on the level of economic development, the time period studied, study data type (cross-sectional, time-series, panel), and statistical modeling methodology (Jakovljevic & Pejcic, 2017). During the 1970 to 2004, per capita health expenditures rose markedly among the OECD member countries at an annual average rate of 11.5%. 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 United States, with an average of $6,0372, has the highest per capita healthcare expenditure, followed by Switzerland ($4,045), Norway ($4,103), and Germany ($3,169). On the other hand, countries devoting fewer resources to healthcare include Turkey and Mexico, with an average annual per capita expenditures of $562 and $655, respectively. As a share of GDP, Organization for Economic Co-operation and Development (OECD)
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healthcare spending has almost doubled over this period, increasing from 4.9% in 1970 to 8.8% in 2004. However, there are substantial heterogeneities across the countries. It is important to note a strong, long-term shift in global healthcare spending share from the rich, high-income societies (OECD representing the top-performing ones) toward low- and middle-income nations (Jakovljevic & 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, 2015B) and the next 11 (Rancik & 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 (Karla, 2014), have experienced modest declines, possibly associated with reforms aimed at limiting the percentage rise in healthcare spending as a proportion of GDP. Over time, the shares of healthcare spending as a percentage of GDP have ranged between 2.5 and 7.0% in the 1970s, compared with the 5.5 to 15.2% range in 2004. The annual growth rate in per capita real healthcare 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 healthcare spending, for OECD countries and emerging economies (Jakovljevic, Groot, & Souliotis, 2016A), 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 (i.e., output growth per worker) lags behind 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 labor-intensive service industries such as education and healthcare (Bates & Santerre, 2013).

The next section 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

Healthcare Technology

As indicated earlier in this work, the body of literature considers income and technology as the main healthcare cost drivers in most advanced economies (Smith, 2016). However, there is controversy about 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 (Chandra & Skinner, 2012; Costa-Font et al., 2011; Wong, Wouterse, Slobbe, Boshuizen, & Polder, 2012; Zhang, 2013). Among these technology proxies, health and economy-wide R&D spending, new pharmaceutical chemical entities, training new medical doctors, the number of new
medical equipment and devices, and improved life expectancy at birth are the most documented (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 healthcare 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 of 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 healthcare costs, including inefficient use of advanced medical technologies, payment mechanisms with perverse incentives, medical liability and the practice of defensive medicine, and so on.

**Healthcare Productivity**

The service sector in 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 (Gadrey & Gallouj, 2002), of which the healthcare services industry is a principal component. Using traditional measurement approaches, healthcare 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 healthcare, 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 the U.S. healthcare sector in 1987–2001, at a rate of about 1% annually. Their finding is consistent with another study by Harper, Khandrika, Kinoshita, and Rosenthal (2010) for the years 1987–2006. Focusing on hospital 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%, depending on the method used to measure hospital input. Over each of the 10-year periods in the 1990–2005 time frame, the average MFP for hospitals was almost less than half the average MFP for the whole economy. In an effort to augment aforementioned research, Sheiner and Malinovskaya (2016) re-evaluated the Cylus and Dickensheets study by adding more years (1990–2013) in their study time frame. With a quite similar finding, they estimated that, over the period 1990–2013, the average growth rate of hospital MFP was between 0.1 and 0.6%, which is less than the average growth of private non-farm business MFP of 1%. Given that the health sector labor force, especially physicians, play substantial roles in determining the acceptability and feasibility of medical technology, efforts have been made to estimate labor productivity in healthcare (Jakovljevic, 2016). Fisher (2007), for instance, also calculated the MFP of physicians and captured extreme variability in the estimates. Based on his study, factor productivity
increased at an average rate of 1.5% per annum from 1982 to 1992, decreased -0.6% per year on average from 1993 to 2000, and again rose 1.7% per year from 2001 to 2004. However, over all the periods, physician MFP was about the same as the whole economy. To estimate the overall medical labor force productivity using U.S. data, Chansky, Garner, and Raichoudhary (2015) report an average annual 0.5% productivity growth in hospitals between 1993 and 2012, which is much lower than the mean labor productivity at 21.4% for the same period.

**Healthcare Expenditures (Costs)**

The empirical studies on the determinants of healthcare expenditure are abundant, and the growing literature is continues to evolve (Getzen & Okunade, 2017). These studies have been undertaken at the microeconomic, national, and international levels (Jakovljevic & Ogura, 2016). Microdata studies have estimated two-part or double-hurdle models to study the determinants of the healthcare 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 large variability across the studies when specifying the determinants of healthcare expenditure (Dalal, 2017; Dieleman et al., 2017). This includes studies not limited to income; the age composition of the population and proxies of medical technological progress are the most important (Martín, Puerto Lopez del Amo Gonzalez, & Dolores Cano Garcia, 2011). The estimates of these studies are highly dependent on the time frame (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, debate 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 healthcare is a necessity rather than a luxury in the OECD, with their estimated 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 United States, with an implied income elasticity of
suggesting that healthcare is a luxury commodity. 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 on 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 difficult 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 intercountry differences. This result justifies a panel model approach although 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 U.S. dollar purchasing power conversion factors ($PPP). Unfortunately, the choice of the conversion factor (exchange rates, PPPs for GDP, and PPPs for healthcare) influences the results and may bias the estimated model parameter (Gerdtham & Jönsson, 2000). The output approach, which aims at reflecting the full cost of healthcare 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 was 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 healthcare 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 attempts to conduct econometric tests of the Newhouse conjecture was made by Okunade and Murthy (2002), who separately used economy-wide and health R&D expenditures to proxy for the effect of technical progress.
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(or the march of science) as a supply-side core driver of the aggregate healthcare expenditure. The authors found a stable long-run relationship between real per capita healthcare 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 healthcare sector. It is further noteworthy that the long-run relationship between R&D spending and healthcare 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 healthcare 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 healthcare, 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 healthcare 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 the short and long runs. In South Asia, for instance, total health expenditure (public and private sources) is generally around 5% of the GDP (Zaidi, Saligram, Ahmed, Sonderp, & Sheikh, 2017). Similar situations exists in most other low-income Asian and African countries, with an increasing trend toward out-of-pocket health expenditure and lower share of public sector pending (Verguet, Laxminarayan, & Jamison, 2015). In general, developing and transitional economies are highly constrained in their health strategic priority settings, and the 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 et al., 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 benefits both the originating and recipient developing nations. The size of the spillover effects is directly related to importation 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 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 healthcare output as the nominal spending on healthcare by service providers (hospitals, physicians, etc.) deflated by some price index for healthcare. In theory, this should yield a measure of units of output over time. However, if the price of healthcare 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 healthcare prices portend problems for measuring sectoral productivity.

Similarly, two main problems have been identified in the measurement of healthcare costs. One is in identifying the appropriate good. In the traditional approach, the good is the healthcare service or good actually purchased: a doctor’s appointment, a hospital stay, 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 that do not capture these increases in quality would overstate price growth in healthcare and understate productivity growth (Barber et al., 2017).

Getzen and Okunade (2017) traced the historical evolution of important research on the determinants of aggregate healthcare expenditure. They list some limitations hampering the usefulness of the existing body of work:

1. Some authors fail to recognize that the growth in healthcare spending is associated with income growth with a lag.
2. The “excess growth” residual approach to capturing technology change effect on healthcare spending overstates the effect as it also captures changes in demand, organizational factors, prices, and administrative costs.
3. Other determinants, for example, 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, Moreno-Serra, Murtin, & Martins, 2017).
4. Many of the most important relevant concepts, ranging from culture to health, are not easily amenable to measurement.
5. Comparing 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 healthcare 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.

Healthcare 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 & Gallouj, 2002). Productivity measures in the healthcare services, an important aspect of the service economy of 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 healthcare services the treated population received (Jakovljevic et al., 2017).

Suggestions on Future Research Directions

The solution to the rising national healthcare costs attributable to healthcare technology and productivity measurement and capture challenges will likely be difficult to reach any time soon. A market course alone, through a system of managed competition, has not been able to curtail rising technology costs in healthcare 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 will 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 continued to fuel a rise in healthcare costs in advanced nations.

Economists have long sought to explain the determinants of national healthcare 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 in the role of technological progress are as follows.

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 of 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 (Hay 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 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 healthcare in which newer drugs that are a “me too” treatment technology are common. (Despite this tendency, revolutionary prescription drug innovations also exist but are rare. One recent illustration is Sovaldi™, a “cure” for chronic Hepatitis C liver disease with a demonstrated cure rate exceeding 90%, marketed by Gilead Sciences, Inc.®, since 2014 and costing $84,000 (non-rebated price) for a 12-week regimen. Gilead® later developed Harvoni™, costing $94,500 for a 12-week treatment course that achieves 96-99% cure rate for treating Hepatitis C, but with possible Hepatitis B virus reactivation tendencies in patients with transplanted livers or advanced liver sclerosis.) Consequently, future work should endeavor to focus on more precise measurements and decomposition of the effects of medical technology innovations on healthcare 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 healthcare cost increase worldwide.

One final note is on the need to ensure that the various measures researchers use to capture the effects of medical technology innovations on healthcare costs are context relevant and contain the relevant economic information. As reviewed earlier, omission of a technology proxy among the determinants of healthcare expenditures tends to yield biased estimation of the magnitudes of the income elasticity of healthcare 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 New Chemical Entities (NCEs) and enumeration of specific medical technology devices, etc.), output (e.g., life expectancy or population age 65 years and older), linear and quadratic time trends and technology indices constructed using specific drugs and medical devices (number or expenditures). These measures that only capture partial effects also suffer from conceptual problems. One of the less commonly used but more powerful technology proxy variables with better economic information content, suggested by Griliches (1998)
and others (Jaffe & Trajtenberg, 2002; Mani, 2002), which could better capture healthcare cost technology effects, is patent count data at the firm, industry sector, and international levels, depending on the study data structure context (Mothe & Paquet, 2000; Plunket, Voisin, & Bellon, 2001).

Okunade, You, and Koleyni (2018) sought to offer newer insights into understanding the major drivers of the escalating healthcare costs of 34 OECD countries using 1980–2014 data and both panel ARDL (autoregressive distributed lag model) procedure and Fully Modified Ordinary Least Squares (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 aggregate OECD healthcare 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 healthcare sectors of OECD countries benefit from cooperating on patented technologies that significantly escalate health expenditures.

**Conclusion**

The goal of this article was to review the broad literature on healthcare costs, innovative technologies (innovation), and sectoral productivity. The healthcare services sector is a major component of the growing services economy of 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 would affect economic model estimates of healthcare 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 healthcare services economy.

**Further Reading**


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