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The contribution of various capital forms to sectoral growth: With emphasis on agriculture

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ABSTRACT- Economy subsectors exhibit considerable variation in terms of production factors, technology, and growth rate, resulting in diverse growth patterns. This study investigates how each type of capital, such as physical, human, social, and environmental, affects the growth of subsectors. Employing the Solow Growth Model and utilizing data from 1970 to 2023, this study examines the distinct dynamics of individual sectors and measures labor productivity (technology) through the Solow residual method. The findings indicate that the production elasticity with respect to physical capital is estimated to be approximately 0.11-0.13 for the agricultural sector, whereas the corresponding figures for manufacturing and services range from 0.20 to 0.22. In contrast, the contribution of human capital, in terms of the elasticity values, is generally below 0.05, and the impact of social and environmental capital is deemed negligible. Productivity growth accounts for 2.4% of the overall agricultural output growth which stands at 3.3%. The corresponding figures for services (manufacturing) are 2.4% (0.7%) and 4.5% (2.8%), respectively. While labor growth does not contribute to agricultural output growth, the output contribution of labor for manufacturing and services are 1.1 and 1.3%, respectively. The contribution of physical capital to the aforementioned output growth is approximately 0.55-0.65%. The time path of "per capita output" for manufacturing is significantly lower than that of the agricultural and services sectors. Given the importance of technology and productivity in driving output growth, it is advisable to shift towards a market-oriented economy, particularly to facilitate access to international markets.

INTRODUCTION

The three primary sectors of economy, i.e., agriculture, manufacturing, and services vary considerably, regarding their level of activity, the characteristics and the nature of their activities. These subsectors vary significantly not only in their production factors and technology but also in terms of their growth rates, all of which hold considerable implications in economic analysis. This divergence in growth rates suggests that different sectors follow their own specific growth paths. As a result, it is essential to evaluate each sector separately to examine its specific dynamics. Furthermore, a comprehensive examination of the determinant factors that lead to these disparities is necessary. Within the three sectors previously mentioned, the manufacturing sector has demonstrated the slowest growth rate, largely due to its heightened vulnerability to sanctions and the dominant role of oil and gas in this sector. While sanctions have severely impacted the manufacturing sector as a whole, their effects have been less pronounced in agriculture. The annual growth loss in manufacturing has been estimated at 0.044 (Ezzati et al., 2020). The pronounced differences in growth rates among sectors, along with divergent performances across subsectors and their underlying determinants, necessitate a thorough investigation into the causes of these variations.

The changes in overall economic growth, which serves as the foundation for variations in production and income, arises from production factors such as physical capital and labor (Batten, 2018), in addition to technological advancements (Farajzadeh et al., 2023). However, it is clear that, over the economic growth path and the passage of time, physical capital has acquired new counterparts. These counterparts are influential and somewhat intangible in form. They are, in order of their emergence, human capital, social, and environmental or natural capital (Farajzadeh et al., 2023; Farajzadeh et al., 2024). The present study examines the impact of each of these capital forms on the growth path of economic subsectors in Iran. The capitals emerge in the following order: human capital, social capital, and environmental or natural capital (Farajzadeh et al., 2023; Farajzadeh et al., 2024).

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Historically, the conventional concept of capital evoked notions of financial assets, buildings, and equipment. Nonetheless, over time, new forms of capital have altered these definitions because of their importance and impact on different economic sectors and the overall economy. For instance, the first seemingly intangible capital to receive attention, before anything, was human capital. Human capital refers to the skills, talents, health, and expertise of the labor force and is considered as a key factor in production (Goldin, 2016). It may be either inherent or acquired (Becker, 2009) and contributes to sustainable economic growth by improving productivity and driving technological innovation (Aghion et al., 2009). As a result, the improvement of human capital fosters economic growth (Fleisher et al., 2010; Romer, 2012).

In the early 1960s, Schultz's theory of human capital addressed the previously overlooked impact of human capital investment on economic growth (Schultz, 1961). He incorporated the amount of capital allocated to human education into the Solow production function. The Solow production function is one of the foundational and earliest models used to explain national economic growth and compare per capita output among different countries. This model, which is characterized by constant returns to scale, was originally built on two primary inputs: physical capital and effective labor. Nevertheless, it did not suitably consider the knowledge and skills possessed by the labor. This shortcoming was later addressed by Schultz and subsequent economists who introduced modifications incorporating human capital features in production function. Following this pivotal development, many scholars examined human capital development, its investment, and its implications for economic growth. For example, Griliches (1964) illustrated the significant role of human capital in production by emphasizing the contribution of education. Denison (1967) employed years of schooling as a metric for labor education in his analysis of economic growth. Lucas (1988) identified human capital accumulation as the driving force behind economic growth. Lau et al. (1991) revealed the varying effects of education investment across different countries and historical contexts. Hall and Jones (1998) established strong correlations between per capita output and levels of formal education, thus serving as indicators of human capital and total factor productivity.

The emphasis on interpersonal relationships within society and their influence on economic growth has led to the conceptualization and establishment of a distinct form of capital referred to as social capital. Bourdieu (1986) defined social capital as a network of relationships among individuals and groups that generates both tangible and intangible resources through interaction. Coleman (1990) later defined social capital as the benefits gained from these interpersonal and intergroup relationships, a definition that has gained widespread acceptance among the economists. Alternative concepts include the World Bank's description of social capital as "the invisible wealth of nations," which encompasses all institutions, relationships, and values that can shape our social interactions (Makiyan et al., 2021). Definitions from Chou (2006) and Ishise and Sawada (2009) collectively highlight its crucial economic role in information acquisition, knowledge exchange, proper innovation, problem-solving capabilities, and mediation of economic interactions. These social networks provide significant economic advantages by reducing transaction costs, enhancing risk tolerance, adding quality standards, and facilitating innovative processes.

Another often-neglected form of capital that has received limited attention is natural or environmental capital. This type of capital has a more recent history compared to the other forms previously discussed. In straightforward terms, natural capital refers to the natural resources and flow of associated resources and services, including forests, air and water quality, land, and erosion control, which are essential for sustaining livelihoods (Monfreda, 2004). Essentially, these represent crucial and irreplaceable ecosystem services that cannot be substituted by other forms of capital, thus forming what is known as natural or environmental capital (De Groot et al., 2003; Dietz & Neumayer, 2007). Mancini et al. (2017) provide an additional definition, characterizing natural capital as those components of natural resources and the environment that are essential for supporting biological life. The concepts of ecological footprint and biocapacity are inseparable concepts linked to the natural resources. In discussions regarding natural resources, it is imperative to consider nature's ability to provide these resources (known as biocapacity) (Monfreda, 2004) and humanity's demand. These needs encompass grazing lands, croplands, forests, fishing grounds, and CO_2 emission levels for ecosystem survival (ecological footprint) (Mancini et al., 2017).

In analyzing the definitions and attributes of natural capital, one should recognize that the classical economist perspective suggests that nations rich in natural resources tend to be more developed. Nevertheless, this perspective exists alongside the theories of "resource curse." The curse points at a contradictory scenario in which nations and areas rich in natural resources, such as fossil fuels, minerals, and various commodities, experience lower economic growth compared to nations with fewer natural resources. "Dutch disease" refers to increases in resource exports, emanating from activities such as the discovery of oil, that lead to a big inflow of foreign currency, which in turn appreciates the national currency. Concurrently, imports become less expensive, thereby undermining domestic producers. This situation results in the economy becoming excessively reliant on a singular volatile commodity, which adversely affects other sectors, especially manufacturing and agriculture. Thus, it can be understood that natural resources may indirectly hinder economic growth. As a result, the connection between natural resources and economic growth produces unclear and contradictory analytical results (Rahim et al., 2021).

Between 1961 and 2022, the economic sectors of Iran demonstrated varying growth path, with agriculture, manufacturing, and services growing at annual rates of 3.72%, 2.64%, and 5.06% respectively (Central Bank of Iran, 2022). This reveals notable sectoral disparities, which are further emphasized by significant variations in the composition of production factors. For example, capital accounts for approximately 70% of value-added in the services sector, whereas it represents only 12% in both manufacturing and agriculture (Farajzadeh et al., 2024). While Iran's overall economic growth of 3.62%

during this period slightly exceeded the global average of 3.51%, this comparative analysis emphasizes the crucial importance of the current study's dual analytical focus: firstly, to identify factors influencing Iran's differential growth performance relative to global standards, and secondly, to understand the distinct growth paths across its economic subsectors.

The Solow growth model was adopted for this study's objectives due to its effectiveness in explaining long-term economic growth through capital accumulation, labor force growth, and enhancements in productivity, which typically signify technological progress. The flexibility of this framework allows for expansion beyond mere physical capital to include human capital, social capital, and environmental capital as factors of production (Farajzadeh et al., 2023). The model is fundamentally based on the neoclassical Cobb-Douglas production function, characterized by constant returns to scale. The selection of the Cobb-Douglas specification is supported by empirical evidence demonstrating its superior compatibility with Iran's economy compared to alternative constant elasticity of substitution (CES). The CES includes a diverse array of functional forms, such as perfect substitutes, Leontief (fixed proportions), Cobb-Douglas, and functional forms. This validation is evident in various studies, including Keshavarz and Farajzadeh (2021), which investigated the influence of natural capital on Iran's economic growth and systematically tested and validated the Cobb-Douglas specification. Further support is provided by Farajzadeh et al. (2023) analysis of climate change impacts on economic growth, which also affirmed the appropriateness of the Cobb-Douglas production function within the context of Iran's economy.

Numerous studies have examined the role of different types of capital in the economic growth of countries. Human capital emerged as the initial form of capital to gain scholarly attention following physical capital, primarily due to its emphasis on individual attributes (Keshavarz & Farajzadeh, 2021). For example, Zana Mozaffari (2021) analyzed the economic growth of Iran by examining the impact of human capital over a 38-years (1981–2019) using the Generalized Method of Moments (GMM). This investigation assessed three key variables influencing human capital formation including education, skills, and health. The findings revealed that improved human capital was associated with increased economic growth. Additionally, the trend in human capital investment exhibited a positive path throughout the study period. Afghah et al. (2022) examined the relationship between Iran's economic growth and the demographic changes alongside human capital. Their findings revealed that life expectancy had a significant effect on growth, whereas secondary school enrollment showed no statistical significance. This implies that enhancing investments in labor skills and welfare improvements aimed at increasing life expectancy could lead to higher economic growth. In a similar vein, Widarni and Bawono (2021) highlighted the essential role of human capital in Indonesia's economic growth. Their research illustrated that advancements in education serve as the foundation for both human capital development and technological progress by improving the quality of the labor force. Furthermore, their results reinforced the notion that an expanding labor force positively affects economic growth.

Sultana et al. (2022) investigated the economic growth of 141 developed and developing countries through the lens of human capital's dual dimensions (education and health). Their findings indicated that all facets of human capital, especially the increase in life expectancy, had positive impact on growth in developing countries, which could be attributed to their demographic transitions. In contrast, developed countries displayed a negative correlation where more life expectancy hindered economic growth, likely due to aging populations and elevated dependency ratios. The sustainability of growth in these countries was only realized when life expectancy was excluded from analysis, while health expenditures were alongside educational factors. Accordingly, Zhang et al. (2023) analyzed the regional economic growth of China via a general equilibrium model that integrated provincial macrodata with individual labor microdata. Their analysis revealed that China's shift from rapid to high-quality economic growth requires a focus on high quality human capital. High-quality human capital refers to individuals who possess both advanced education and high productivity to foster innovation-driven economies. The results demonstrated that enhancements in qualities of human capital promote economic convergence among provinces and account for regional growth disparities, providing key insights for refining China's educational investment strategies across its provinces. Amir et al. (2023) had a study on sustainable economic growth in Pakistan by examining the impact of investments in educational institutions and human capital. The research suggested that educational infrastructure serves as a more appropriate indicator for assessing human capital than conventional school enrollment rates. The results showed that human capital plays a significant role in long-term economic growth, while also highlighting that economic growth enhances labor productivity.

Following investments in human capital, subsequent years and evolutions in growth models brought attention to social relations and functions that help social capital (Farajzadeh et al., 2017a). For instance, Rahmani Fazli et al. (2024) illustrated that the effect of social capital on economic growth was beneficial in both developed and developing countries in the short term, and significantly positive in the long term. Notably, the effect of social capital on economic growth was found to be more pronounced in developed countries than developing ones. In a meta-analytical investigation, Mirzaei and Namazi (2023) explored the connection between social capital and economic growth in Iran over the past two decades. The research assessed 85 Persian-language publications, whose findings were not necessarily aligned. These types of inconsistencies were attributed to differing definitions of social capital between the 2000s and 2010s. As a result, specific criteria were established, leading to the final selection and analysis of 13 studies. The findings indicated a moderate positive relationship between social capital and economic growth. Muringani and Rodriguez (2021) examined the correlation between social capital and economic growth across 190 regions in 21 EU countries from 2002 to 2016. Their findings indicated that social capital plays a significant role in enhancing regional economic growth, especially in areas with low-skilled areas. Additionally, they showed that human capital can alleviate the negative externalities associated with excessive network embeddedness. Concurrently, Makiyan et al. (2021) performed a comparative analysis of countries with high versus low social capital, utilizing key indicators such as good governance, levels of corruption, internet accessibility, and female labor force participation. Their results revealed that in countries with high social capital, good governance (+0.32), internet access (+0.25), and female participation (+0.18) had a positive influence on development, while corruption had a significant negative impact (-0.41). Conversely, in countries with low social capital, only education enrollment (+0.28) had a positive effect, whereas internet access surprisingly showed negative effects (-0.15) and corruption continued to be harmful (-0.39). This illustrates that the economic impact of social capital varies not only by national context but also according to the specific metrics employed. Given the complexity surrounding social capital's impacts Oliver Huidobro et al. (2022) conducted an innovative examination of its correlation with economic growth through a network-based framework. They argued regarding mechanisms of knowledge transfer, factor mobility, and economic integration. Modern economy, where capital and labor move freely, demands a systematic analytical approach. Their research established connections between network centrality and various forms of social capital by using OECD (Organization for economic co-operation and development) multi-regional input-output data and international migration patterns to construct network representations of capital and labor movements across 63 economies over a decade. So, they applied an augmented Cobb-Douglas production function to evaluate social capital's role as drivers of TFP (Total Factor Productivity), with findings indicating that social capital embedded within production networks help output via productivity improvements. In addition to this macroeconomic viewpoint, Arizkha et al. (2023) had a micro-level research on the Bajoeng tourism village in Indonesia. They assessed influences of social capital, comprising trust, social norms, and community participation as good indicators of growth. Their results demonstrated that social capital significantly enhances community engagement, with trust emerging as the most impactful variable. Ari et al. (2024) read relationships between social capital and sustainable rural development in Indonesia, measuring social capital through various indicators, including intercommunity exchange, mutual trust, reciprocal respect, and social networks. So, their findings indicated that social capital plays a vital role in promoting development, especially for communities not directly engaged in tourism. The results of the reviewed studies suggest that social capital includes a wide range of variables, whose effects on economic growth are neither uniform nor consistently aligned. In this study, we define social capital by utilizing household landline telephone and internet subscription to analyze its impact on economic growth across different subsectors.

Empirical studies consistently highlight natural capital as a vital factor influencing economic growth. The investigation conducted by Keshavarz and Farajzadeh (2021) regarding Iran's economic growth utilized five ecological indicators: ecological footprint, biocapacity, ecological deficit, ecological tension, and agricultural land area, revealing substantial variability in their impacts. The production elasticity varied from -0.02 to -0.04 for ecological footprint, and from 0.10 to 0.15 for both biocapacity and agricultural land, whereas the coefficients for physical capital (0.12-0.17) consistently surpassed those of natural capital. Nourahmadi et al. (2022) examined the impact of natural resources on economic growth through a meta-analysis. Some studies indicated no impact, others identified negative consequences (known as the resource curse), while some reported positive effects. The objective of the study was to reconcile these conflicting findings and evaluate the resource curse hypothesis. Through a multilevel meta-analysis of 87 selected studies, it was ultimately revealed that natural resources tend to exert a slight negative effect (-0.087) on economic growth. Furthermore, the research indicated that studies which included variables such as the type of natural resources, degree of economic dependence on resources, the quality of institutions, levels of investment, and trade openness, among others, observed variations in the influence of natural resources on economic growth. In a study, Eshghi et al. (2023) examined the correlation between environmental quality and indicators of a knowledge-based economy within the MENAP. MENAP refers to the group of Middle East and North Africa (MENA) countries, plus Afghanistan and Pakistan. This classification was formally adopted by the International Monetary Fund (IMF) in April 2003. The results of their study indicate statistically significant correlations. Environmental quality exhibited positive correlation with GDP and the number of published scientific articles, while it showed a negative correlation with rates of secondary school enrollment. Rahim et al. (2021) investigated whether natural resource abundance and human capital development drive economic growth in eleven countries from 1990 to 2019. Those countries were Egypt, Indonesia, Iran, Turkey, Mexico, Nigeria, Pakistan, the Philippines, Bangladesh, South Korea, and Vietnam. The results showed that higher natural resources can hinder economic growth, while human capital and natural resources together positively impact growth, suggesting human capital development helps mitigate the resource curse. Azad Akhbari et al. (2022) examined the impact of various capital types including natural, human, physical, and financial capital, alongside innovation and foreign direct investment (FDI) across two groups of countries: developing countries vs. developed/emerging economies. The results revealed distinct growth patterns; in developing countries, a 1% increase in natural, physical, human, financial capital, innovation, and FDI resulted in income growth of 0.063%, 0.113%, 0.181%, 0.052%, 0.089%, and 0.128%, respectively. Regarding developed/emerging economies, the same 1% increases corresponded to income rises of 0.113%, 0.104%, 0.080%, 0.055%, 0.091%, and 0.118%, respectively. Additionally, control variables such as globalization, political stability, and real exchange rates also had statistically significant positive effects on industrial development in both of the country groups. The research conducted by Lee and He (2022) investigates the intricate relationship among natural resources, energy consumption, gross capital formation, and green economic growth within Chinese provinces. The results show a dualistic outcome: natural resources may either hinder growth (termed as "resource curse") or promote it (referred to as "resource blessing"). Market-oriented institutions play a role, as regions with stronger market mechanisms can experience a "blessing" effect. Importantly, twelve provinces transitioned from a "curse" to a "blessing" path during the study period, underscoring the influence of institutional and policy reforms. This research contests conventional linear views by highlighting that the role of natural resources in green growth is influenced by contextual factors, advocating for policies that harness their protective functions (such as carbon absorption and renewability) rather than focusing solely on revenue generation. Recent literature reviews highlight the distinct influences of the three primary forms of capital, human, social, and natural on economic growth, with some studies examining their simultaneous effects. For example, Farajzadeh et al. (2017a) analyzed the determinants of Iran's economic growth using an augmented neoclassical growth model, quantifying natural resources by means of agricultural output and mining/oil/gas production, while employing per capita judicial case filings as an indicator of social capital. Their findings revealed negligible contributions from both social and natural capital, whereas the returns on human capital fluctuated between -0.19 and 0.10. Importantly, such research generally evaluates these effects at the macroeconomic scale, often neglecting sectoral differences. Nevertheless, it is essential to assess the impacts of capital across various economic subsectors, considering the considerable variations in growth patterns among them. For instance, Zoghipour et al. (2023) assessed the influence of natural and human capital in conjunction with physical capital within the agricultural subsector of Iran. Their results indicated that agricultural value-added products experience a long-term increase of 0.44% for each 1% rise in physical capital. The corresponding values were found to be 0.20% for natural capital, 0.75% for human capital, and 0.12% for advancements in technology. In light of the observed decline in capital stock growth, the study recommended technology-driven investments combined with the right enhancements in human capital to maintain productivity levels. Similarly, Bashir and Susetyo (2018) examined the relationship between economic growth and human capital in Indonesia's agricultural sector, affirming a positive impact of human capital on agricultural growth. Rivera et al. (2019) examined the role of social capital in the agricultural subsector across seven countries (Germany, Spain, Italy, Lithuania, Latvia, Denmark, and Israel), focusing on key terms such as trust, cooperation, sense of community, and cultural traditions. The findings revealed that all four dimensions significantly influence agricultural and rural development by shaping social interactions, self-organization, and collaborative efforts for progress. Meanwhile, Addai et al. (2024) explored social capital's impact on agricultural diversification in rural Ghana. They discovered that socioeconomic factors (household size, education, farm size, and remittances) strongly affect these social capital dimensions. So, the study highlighted farmers' reliance on social networks to improve their livelihoods through agricultural diversity. There are some implications derived from the reviewed literature. Addai et al. (2024) targeted farmer groups or regions and limited policy recommendations to specific local contexts. Another issue is that they have neglected the concurrent examination of human and environmental capital, despite their role in agriculture, especially natural capital, which is crucial for sustainability.

The influence of the three types of capital within the industrial subsector has been examined. For instance, Tran and Vo (2020) investigated the effectiveness of human capital in Vietnam's industrial sector. The results indicated that the efficiency of human capital differs among sectors, with the oil, gas, and energy sectors demonstrating the highest level of efficiency, the banking sector did not show the expected level of human capital accumulation. Al-Tabbaa and Ankrah (2016) examined social capital for facilitating technology transfer from universities to the industry in the UK, highlighting how different dimensions of social capital interact and help reduce barriers over time. Their research also revealed that supportive institutions, such as government entities, could substitute for existing relationships to bring together diverse organizations around collaborative objectives, thus allowing them to utilize previously overlooked opportunities. In a study conducted in the U.S., Hmieleski and Baron (2015) linked industrial growth to the intangible resources of managers, specifically human, social, and psychological capital. The results showed a positive correlation between entrepreneurial experience and performance in stable environments. In dynamic environments, academic achievement and robust social connections, defined as networks of family and friends providing business assistance, significantly influenced performance. These factors were treated as indicators of social capital. Psychological capital, comprising cognitive, emotional, and behavioral attributes, also had a significant effect on dynamic performance. This research highlights the importance of aligning managers' intangible capital with the specific characteristics of their industries to foster growth and development.

Jin et al. (2024), in a study of China's industrial subsector, identified the energy footprint as the primary factor driving the increase in the per capita ecological deficit of the Xinjiang industrial zone. The deficit rose from 2.096 to 11.667 between 2005 and 2020. Their findings also suggested the possibility of decoupling economic growth from environmental pressures, offering a cautiously optimistic perspective.

There are also studies that investigate the three forms of capital within the services subsector. For instance, Simões et al. (2019), in a study conducted in Portugal, found that healthcare and educational activities exerted the most substantial effect on services growth among all subsectors. Finance, insurance, real estate, and business services followed, each making positive and sustainable contributions to overall economic productivity.

Using cross-sectional data, Akintimehin et al. (2019) reported that social capital positively influences business performance. Internal social capital had a significant effect on both financial and non-financial performance.

In contrast, external social capital did not demonstrate a statistically significant impact.

Another cross-sectional study was conducted by Agyapong et al. (2017). They analyzed data collected from 500 medium and small businesses (MSBs). Social capital was measured through several factors, including open and honest communication among employees, an interdisciplinary approach to service improvement, the level of information sharing among staff, the degree of trust between employees and management, and the presence of shared vision and organizational goals. The findings indicated that social capital positively affects both business performance and innovation.

An analysis of research related to the industrial and services sectors suggests several key observations. A considerable portion of scholarly attention has focused on the challenges of technology transfer across various industries and activities. This emphasis has highlighted the importance of social capital. Human capital has also attracted substantial interest. In contrast, physical capital has received comparatively less attention in these studies. Moreover, there appears to be a lack of thorough investigations at the subsector level within the manufacturing and services sectors. The reviewed literature shows that studies have examined human, social, and environmental capital across different subsectors. However, to the best of our knowledge, no empirical study has considered all three types of capital simultaneously within the main economic subsectors. This omission reveals a significant gap in the literature.

The current study addresses this gap and contributes to the existing body of knowledge by building upon and extending previous research efforts. In addition, it makes a further contribution by extracting the impact of technological input on output growth across different sectors.

METHODS

Similar to Ishise and Sawada (2009), we applied an augmented Solow model that incorporates social and human capital alongside physical capital. Furthermore, in line with Farajzadeh et al. (2022), we expanded the model to include environmental capital. The production technology, as stated by Farajzadeh et al. (2023), follows the Cobb-Douglas production function. In addition to capital inputs, labor input (L) and the level of labor-augmenting technology (A) are also considered as production factors. The production function utilized is articulated as follows:

$$Y_{jt} = K_{jkt}(t)^{\alpha_j} K_{jht}(t)^{\beta_j} K_{jst}(t)^{\gamma_j} K_{jnt}(t)^{\lambda_j} \left(A_{jt}L_{jt}\right)^{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} \quad \text{Eq. (1)}$$

where, Y_j is the output in sector j. K_k , K_h, K_s , and K_n are physical, human, social, and environmental or natural capitals in sector j, respectively. AL is the effective labor input. $\alpha, \beta, \gamma., \lambda$ denote the respective share parameters of the capital types. j also stands for the economy sectors including agriculture, manufacturing, and services. t indicates the time, which for the sake of simplicity, we will omit from this point forward. Furthermore, we impose the conditions that $\alpha, \beta, \gamma, \lambda \in [0,1)$., $\alpha + \beta + \gamma + \lambda \in [0,1)$. A, $L.$, K, for each sector, are assumed to grow as follows:

$$L(t) = L(0)e^{nt},\ \ A(t) = A(0)e^{gt} \text{ and } K_{t+1} = K_t(1-\delta) + I_t \quad \text{Eq.(2)}$$

where, n and g are the related growth rates which are determined exogenously. Also, I represents investment and δ is capital depreciation.

Now, we establish the effective labor per capita output as $Y/_{AL}$ in order to derive the steady state growth path for production function outlined in Eq. (1) as follows:

$$\mathrm{y}_j = \frac{Y_j}{A_jL_j} = \left(\frac{K_{jk}}{A_jL_j}\right)^{\alpha_j} \left(\frac{K_{jh}}{A_jL_j}\right)^{\beta_j} \left(\frac{K_{js}}{A_jL_j}\right)^{\gamma_j} \left(\frac{K_{jn}}{A_jL_j}\right)^{\lambda_j} \left(A_jL_j/A_jL_j\right) \quad \text{Eq. (3)}$$

$$y_j = {k_{jk}}^{\alpha_j} {k_{jh}}^{\beta_j} {k_{js}}^{\gamma_j} {k_{jn}}^{\lambda_j} \quad \text{Eq. (4)}$$

Concerning the balanced growth path where $\dot{\hat{k}} = 0$, the fundamental equation of Solow in terms of effective labor is formulated as follows:

$$\dot{k}_{ji} = 0 \Rightarrow s_{ji} f(k_{jk}.k_{jh}.k_{js}, k_{jn}) = (n_j + g_j + \delta_{ji})k_{ji} \quad \text{Eq. (5)}$$

where $i = k, h, s, n$ shows the capital types. As mentioned earlier n and g are labor and productivity growth rates, respectively. δ is the capital depreciation rate and s stands for saving rate. Note that the depreciation rate was not considered the same for different types of capital. By substituting $f(k_{jk}.k_{jh}.k_{js}, k_{jn}) = y_j$ in Eq. (5), the fundamental equation will can be presented as follows:

$$s_{ji}y_j = (n_j + g_j + \delta_{ji})k_{ji} \Rightarrow k_{ji} = \frac{s_{ji}y_j}{(n_j+g_j+\delta_{ji})} \quad \text{Eq. (6)}$$

Regarding k_{ji} in Eq. (6), production function of Eq. (4) can be presented as follows:

$$\hat{y}_j^* = \left[\left(\frac{s_{jk}}{n_j+g_j+\delta_{jk}}\right)^{\alpha_j} \left(\frac{s_{jh}}{n_j+g_j+\delta_{jh}}\right)^{\beta_j} \left(\frac{s_{js}}{n_j+g_j+\delta_{js}}\right)^{\gamma_j} \left(\frac{s_{jn}}{n_j+g_j+\delta_{jn}}\right)^{\lambda_j}\right]^{\frac{1}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j}} \quad \text{Eq. (7)}$$

Moreover, the estimation equation will be as follows:

$$ln\left(\frac{Y_j}{A_jL_j}\right)^* = \frac{\alpha_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{jk}) + \frac{\beta_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{jh}) + \frac{\gamma_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{js}) + \frac{\lambda_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{jn}) - \frac{\alpha_j+\beta_j+\gamma_j+\lambda_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(n_j + g_j + \delta_{ji}) \quad \text{Eq. (8)}$$

Alternatively, considering all capital inputs, the corresponding estimation equation can be presented as follows:

$$ln\left(\frac{Y_j}{L_j}\right)^* = a + gt + \frac{\alpha_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{jk}) + \frac{\beta_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{jh}) + \frac{\gamma_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{js}) + \frac{\lambda_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(s_{jn}) - \frac{\alpha_j+\beta_j+\gamma_j+\lambda_j}{1-\alpha_j-\beta_j-\gamma_j-\lambda_j} ln(n_j + g_j + \delta_{ji}) + \varepsilon_j \quad \text{Eq. (9)}$$

To demonstrate the time path of the variables, the Solow residual method was also applied to assess the impact of productivity growth. This method accounts for the decomposition of economic growth that cannot be attributed to increases in various types of capital or labor inputs. Concerning the four categories of capital, the procedure employed is as follows: It is important to mention that, for the sake of brevity and considering the significance of time notation, we have omitted the sector notation (j) while retaining the time notation (t).

$$Y_t = K_{kt}^{\alpha} K_{ht}^{\beta} K_{st}^{\gamma} K_{nt}^{\lambda} (A_t L_t)^{1-\alpha-\beta-\gamma-\lambda} \quad \text{Eq. (10)}$$

$$lnY_t = \alpha ln\, K_{kt} + \beta ln\, K_{ht} + \gamma ln\, K_{st} + \lambda ln\, K_{nt} + (1-\alpha-\beta-\gamma-\lambda) lnA_t + (1-\alpha-\beta-\gamma-\lambda) lnL_t \quad \text{Eq. (11)}$$

Then, differentiate both sides with respect to time t gives us the equation in growth rates (denoted with a dot).

$$\frac{\dot{Y}}{Y} = \alpha \frac{\dot{K_k}}{K_k} + \beta \frac{\dot{K_h}}{K_h} + \gamma \frac{\dot{K_s}}{K_s} + \lambda \frac{\dot{K_n}}{K_n} + (1-\alpha-\beta-\gamma-\lambda)\frac{\dot{A}}{A} + (1-\alpha-\beta-\gamma-\lambda)\frac{\dot{L}}{L} \quad \text{Eq. (12)}$$

To find the growth rate of the Solow residual, we rearrange the equation:

$$\frac{\dot{A}}{A} = \frac{1}{(1-\alpha-\beta-\gamma-\lambda)}\left[\frac{\dot{Y}}{Y} - \left(\alpha \frac{\dot{K_k}}{K_k} + \beta \frac{\dot{K_h}}{K_h} + \gamma \frac{\dot{K_s}}{K_s} + \lambda \frac{\dot{K_n}}{K_n}\right) + (1-\alpha-\beta-\gamma-\lambda)\frac{\dot{L}}{L}\right] \quad \text{Eq. (13)}$$

where, $\frac{\dot{A}}{A}$ represents the residual output growth after accounting for the contributions of all inputs, excluding the impact of productivity growth or technology.

Variables and data

The enrollment rate in primary schools and the literacy rate were utilized as saving rates for human capital (Keshavarz & Farajzadeh, 2021; Farajzadeh et al., 2017a). Regarding that social capital can be defined by the social connections, networks, and associations that establish an informal type of institutions and organizations, the changes in the users of the internet and the connection via mobile phones were utilized as a variable for social capital savings as applied by other empirical works (Malakotikhah and Farajzadeh., 2019; Keshavarz & Farajzadeh, 2021). Furthermore, changes in ecological footprint serve as a proxy for the saving rate of environmental capital (Farajzadeh et al., 2023). The rate of capital depreciation is documented by the Central Bank of Iran (2023). Additional variables include labor and physical capital of the selected economic sectors. The time series data for these variables, covering the period from 1970 to 2023, were sourced from the Central Bank of Iran (2023), the World Bank (2024), and the FAO (2023). The per capita ecological footprint was acquired from the Global Footprint Network (2021).

RESULTS

The statistical properties of the time series data were examined using a unit root test, which confirmed stationarity (α = 0.05). The estimated coefficients of the Solow model did not directly represent the production elasticities with respect to capital inputs. Therefore, the elasticities were calculated separately and are presented in Table 1.

Autocorrelation was detected in the error terms. To address this issue, a lagged dependent variable (production) was included in the model. The inclusion created an endogeneity problem, which necessitated the application of the GMM for estimation (Baltagi, 1995).

The goodness-of-fit statistic (R^2) exceeded 97% across all specifications, indicating strong explanatory power of the included variables for variations in production. Based on the probability value of the Q statistic, autocorrelation was found to be insignificant. Furthermore, the probability value of the J statistic strongly supported the validity of the instrumental variables, confirming that they are reliable substitutes for the endogenous variables. The estimated elasticities for the different categories of capital are reported in Table 1.

For agriculture specifications, the results show a significant difference between the third specification and the other two. Specifically, the elasticity coefficient of physical capital in the third specification is almost nearly twice as high as in the other two, rising from a range of 0.11–0.13 in the first two specifications to over 0.25 in the third. This difference is even more pronounced for the elasticity coefficient of output with respect to human capital. According to the third specification's results, a 1% increase in physical capital is expected to raise output by a quarter of a percent, whereas the corresponding figure for human capital exceeds 0.22%. In contrast, the results for the other two specifications show an impact of less than 0.01%. Overall, physical capital is the most influential factor in the growth of agricultural production, though the notable impact of human capital in the third specification is also significant. This contribution may be attributed to the low level of human capital accumulation, implying that the returns on human capital remain high. The difference in the coefficients of the two human capital variables in the aforementioned specifications is noteworthy. An increase in primary school enrollment is expected to promote greater human capital accumulation in the future, thus ensuring enhanced growth over the long run. In other words, enrollment rates are more closely aligned with the long-term nature of economic growth. So, in specifications that utilize greenhouse gas emissions as a proxy for natural capital, the output elasticity for each type of capital is significantly higher than in those that employ the ecological footprint. This finding is consistent with the fact that greenhouse gas emissions from the agricultural subsector, especially in crop production and livestock activities exceeds those from other subsectors. Specifically, crop production is responsible for 36% of greenhouse gas emissions, while livestock farming also contributes substantially due to methane production. As a result, the critical role of the environment as a form of natural capital becomes increasingly apparent. The extent to which natural resources can mitigate pollution, primarily greenhouse gases, from agricultural production is a key consideration, both for maintaining ecological integrity and for managing pollution tolerance. Tackling this issue is imperative for achieving sustainable development. This level of coefficients' sensitivity to the various types of natural capital variables seems to arise from the interaction between natural capital with other types of capital. As far as the natural and environmental capital in agriculture is considered, its role goes beyond what is observed in other subsectors since they extremely depend on environmental inputs. As confirmed by Zoghipour et al. (2023), natural resources yielded significant returns.

Table 1. Cobb-Douglas production function estimation results

	Savings variables/Elasticities	Implied α	Implied β	Implied γ	Implied λ
Agriculture	Ash_1- $Asnr_1$- Ass_1	0.111	0.042	0.003	0.004
	Ash_2-$Asnr_1$- Ass_1	0.131	0.040	0.002	0.001
	Ash_1-$Asnr_2$- Ass_1	0.259	0.225	0.009	0.001
Manufacturing/Industry	Ish2 - Isnr1 -Iss1	0.216	0.108	0.000	0.001
Services	Ssh2- Ssnr1-Sss1	0.200	0.024	0.002	0.018
Iranian economy	Tsh1- Tsnr3- Tss1	0.172	0.036	0.006	0.029
	Tsh2-Tsnr3- Tss1	0.182	0.011	0.004	0.036

The symbols are defined as follows: A, I, S, and T in capital letter represent Agriculture, Manufacturing, Services, and entire economy, respectively. sh1: primary school enrollment rate, sh2: rural literacy rate, snr1: ecological footprint (Ecological Footprint (EF): The ecological footprint measures the extent of human demand on natural capital; that is, the amount of nature required to support people or the economy.)), snr2: greenhouse gases emissions, ss1: fixed internet subscriptions in the agricultural subsector, snr3: level of pollution emissions with carbon dioxide as a representative (CO_2 Emissions (Kt).

The production elasticity with respect to social capital in the agricultural subsector is positive and statistically significant across all obtained values. Nonetheless, in terms of the absolute value of the coefficient, it exhibits the lowest effectiveness compared to other capitals coefficient, which could be due to the choice of the proxy applied or a general unawareness of the benefits associated with social capital. Particularly concerning social capital, it should be said that the extensive application of social capital in production does not yet appear to be very significant. However, as social capital becomes more integrated into the agricultural activities, greater impacts can be expected in the future.

Based on the data collected, it is evident that, unlike the agricultural subsector, natural capital within the industrial and services subsectors accounts for a more significant part of the ecological footprint. Currently, about three-fourths of the ecological footprint is attributed to the emissions from energy consumption (Mohammadi Nia et al., 2023), where the industrial and services subsectors identified as the primary consumers of energy. In other words, higher ecological footprint in industrial and services activities is coincident with economic growth in these sectors. Conversely, the extensive utilization of natural capital in these activities has diminished its marginal contribution, thereby rendering the absolute value of its coefficient less significant. Comparable studies revealed similar results.

In the industrial and services subsectors, similar to the agricultural sector, physical capital accounts for the highest share in production, with closely comparable values of 0.21 in industry and roughly 0.20 in services. Human capital ranks next in terms of elasticity value, particularly in the industrial subsector, with elasticity of around 0.11 which highlights its potential for further growth. Therefore, focusing on human capital and its enhancement in these subsectors would be highly beneficial. However, according to the study's results, social capital holds the lowest contribution to the output. It appears that strengthening professional networks among workers and managers, as well as fostering connections between industries and firms, could help mitigate the current gap to some extent.

In summarizing the findings across the Iranian economy subsectors, agricultural, industrial, and services subsectors, and a thorough analysis of the three primary types of capital, human, social, and natural, alongside physical capital, it can be concluded that physical capital contributes to economic growth significantly. This may be inferred that the physical accumulation is not high. This is supported by consistently positive and quantitatively high elasticity values associated with this type of capital in Table 1. Physical capital is followed by human capital. As far as assessing the contribution of natural capital, it should be noted that although its quantitative ranking stands after previously mentioned two, its extensive utilization in conjunction with other capital types emphasizes its undervalued yet essential role. As for the limited impact of social capital across all examined subsectors, adopting more appropriate indicators and raising awareness about the benefits of leveraging this capital could help address its current underutilization in Iran's economic subsectors.

Finally, the obtained findings for the Iranian economy as a whole are presented. Consistent with the subsectors, all computed values for the elasticity of physical capital are significantly higher than those of other elasticities, amounting to 0.17-0.18. There are numerous studies highlighting the substantial returns on physical capital within Iran's economy; for instance, the research conducted by Almasi and Gharehbaba (2009) reported a corresponding value as high as 0.335 in Iran's economy over the long term. In the research by Farajzadeh et al. (2017a), the elasticity of physical capital ranged between 0.10 and 0.29. A study conducted by Malakouti Khah and Farajzadeh (2020) revealed that physical capital is the most pivotal variable, with an elasticity between 0.08 and 0.16. Similarly, in research by Keshavarz and Farajzadeh (2021), the elasticity of physical capital was estimated at 0.18. In specifications where the primary school enrollment rate was used as proxy for human capital, the coefficient for physical capital was relatively higher. It appears that enrollment rates, which experienced significant growth during the study period, placed the economy on a higher growth path. While literacy rate is associated with a lower growth path. Meanwhile, the return on physical capital does not exhibit significant sensitivity to the type of social capital variable employed. This observation may arise from the inadequacy of the selected indicator for assessing social capital. Another possible reason could be that the accumulation of this capital in society is not strongly integrated with production process. Similarly, in specifications where the carbon dioxide emission index was employed as a measure of environmental capital, higher returns on physical capital were obtained. This convergence seems to be primarily due to the heavy reliance of production in Iran's economy on energy, indicating that increased production results in greater energy use and higher carbon dioxide emission. It is important to highlight that Iran ranks among the top ten countries globally in terms of CO_2 emissions, exhibiting a higher emission intensity than the global average.

After physical capital, the highest return at the overall economic level belongs to the natural capital. This result has also been suggested by Keshavarz and Farajzadeh (2021). In specifications where carbon dioxide was used as a measure of environmental capital, a higher contribution is observed for natural capital. Similarly, in the study by Azad et al. (2022), which investigated a sample of countries worldwide, the elasticity coefficients of production with respect to natural and physical capital for developing countries were found to be 0.06 and 0.011, respectively. The contribution of human capital is comparable to that of natural capital, whereas the impact of social capital remains relatively lower. Nonetheless, it is important to highlight that the coefficient for this variable has demonstrated statistical significance.

Time path of variables

This section outlines the time path of selected variables, encompassing both total and per capita output, in addition to total and per capita capital accumulation. To illustrate the time path initially, the Solow residual method was employed to calculate the contributions of technology or labor productivity. Based on the estimation results and the variables utilized, the growth share of the production factors applied in selected sectors is presented in Table 2. It is worth noting that, for agricultural sector, based on the specification characteristics, the second specification was applied. As illustrated in Table 2, productivity growth serves as a fundamental factor across all sectors. Physical capital can also be regarded as an important driving factor. However, in the manufacturing and services sectors, labor contributes more significantly than physical capital. The role of human capital in manufacturing can be considered substantial.

Fig. 1, Fig. 2, and Fig. 3 depict the main variables specifically for the agricultural sector. Concerning the various dimensions for assessing different forms of capital, all variables values have been indexed starting at 1. Although the non-agricultural subsectors may seem appealing, the trends within agriculture are equally significant. A robust productivity growth rate exceeding 2.4% has fostered advantageous conditions for increasing output, as illustrated in Fig. 1. Moreover, a slower labor growth has played a role in the consistent rise of per capita output. In contexts of capital accumulation, significant differences become apparent. Environmental capital is experiencing a downward trend, indicating the persistent environmental degradation. Conversely, both physical and human capital are on an upward path, closely aligned and exhibiting an expanding gap in comparison to social capital (Fig. 2). Nevertheless, the time path of social capital is still of considerable interest. The saving rate for physical capital surpasses 5.5%, whereas that for human capital is below 3.2%. Nonetheless, the lower depreciation rate associated with human capital has enabled its accumulation to keep pace with that of physical capital. In contrast, elevated depreciation rates are the primary factor impeding the growth of social capital. The trends in per capita accumulation reveal a similar pattern (Fig. 3).

Table 2. Inputs contribution to output growth (Solow residual method; %)

	Physical capital	Human capital	Social capital	Environmeneta / natural capital	Labor	Productivity	Total output growth
Agriculture	0.66	0.18	0.03	0.00	-0.01	2.41	3.28
Manufacturing	0.67	0.40	0.01	0.00	1.08	0.68	2.84
Services	0.54	0.09	0.04	0.05	1.33	2.43	4.48

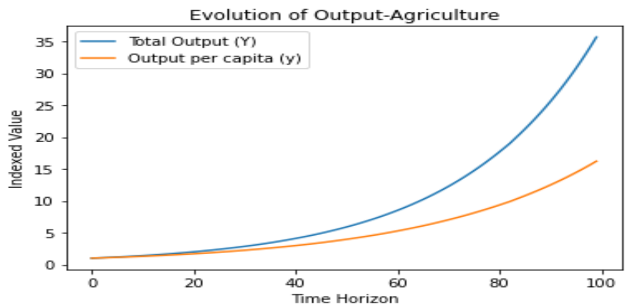

Fig. 1. Time path of output in agriculture sector.

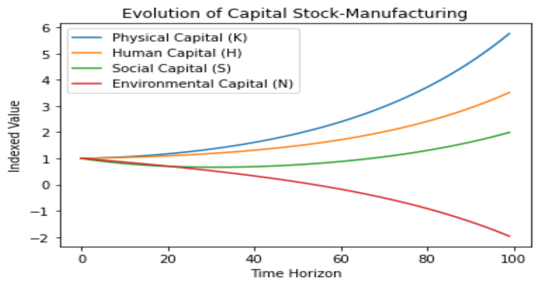

Fig. 2. Time path of total capitals in agriculture sector.

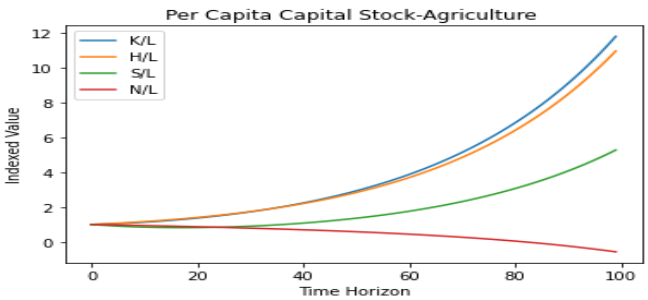

Fig. 3. Time path of per capita capitals in agriculture sector.

As shown in Fig. 4, the total output of manufacturing shows a moderate upward trend. However, per capita output has risen more slowly, due to relatively sharp increase in labor utilization which has widened the gap between the two measures. Since much of Iran's manufacturing is publicly owned, a high level of labor utilization is expected. Fig. 5 illustrates the stock of different types of capital throughout the simulation period in manufacturing subsector. In contrast to the other types of capital, environmental capital exhibits a downward trend, attributed to persistent environmental degradation observed over the last thirty years, as highlighted by Keshavarz and Farajzadeh (2025). Conversely, physical capital demonstrates growth, aligning with the total output depicted in Fig. 4. At the same time, both human and social capital show moderate increases, with human capital consistently surpassing social capital. Regarding the higher depreciation rates faced by social capital, the saving rate for social capital remains inadequate to facilitate its accumulation. The evolution of capital accumulation relative to population or labor growth is of paramount significance, given that per capita output is directly determined by per capita capital. As demonstrated in Fig. 6, even physical capital experiences a decline during the initial decade of the simulation, while both human and social capital exhibit a downward trend that persists for almost half of the total simulation period. This suggests that the manufacturing subsector does not follow a desired growth path. In essence, the industrialization process within the Iranian economy continues to be constrained. The main underlying cause of the low growth path of the variables is the lower productivity growth. The production process of Iran is not regarded as technology-embodied (Gharibnavaz and Waschik, 2015). The time path for services sector variables has been presented in Fig. 7, Fig. 8, and Fig. 9. The significant increase in productivity has boosted the total output to such a degree that a 1.6% rise in labor was insufficient to diminish per capita output. Importantly, the services sector constitutes over 47% of Iran's total output, while the restricted production capabilities in manufacturing and agriculture have resulted in a more rapid growth of the services sector. By over-simulation of time horizons, a significant disparity emerges between physical capital and other forms of capital, as depicted in Fig. 8. The primary factor contributing to this is the saving rates. While physical capital is fueled by a saving rate exceeding 13%, the saving rate for other types is below 1.5%. In the case of social capital, greater depreciation further obstructs its accumulation. Regarding the considerable and expanding gap in overall capital accumulation, the per capita levels exhibit a comparable trend. Notably, environmental capital is also on the rise, although its rate of accumulation remains relatively low. Their indexed values are illustrated in Fig. 10. Values are presented in per capita scale. Due to the significant difference between physical capital of the services sector and that of the other two sectors, this variable was omitted from the initial graph, while Fig. 11 offers a distinct representation of physical capital across all subsectors. The findings reveal that, except for environmental capital, agricultural capitals consistently surpasses that of the other sectors, evoluting above other sectors corresponding values. The services sector holds the second position in capital accumulation in terms of all types of capital, exceeding the corresponding values for manufacturing. But manufacturing capitals show only a slow upward trend that act as remaining relatively close to the horizontal axis. There exists a notable disparity in the accumulation of physical capital among the services sector and the other two sectors. While the index value for services exceeds 35, the corresponding values for agricultural capital is below 15, and for manufacturing, even less than 5 (Fig. 11). The figures of per capita capital, for most of capital forms, generally converge (Fig. 10), as shown in Fig. 12, the index value for services output approaches 25 and that of agriculture surpasses 15. In contrast, the value for manufacturing does not even reach 5.

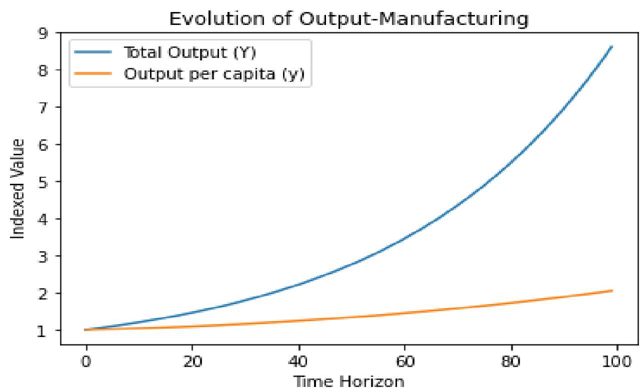

Fig. 4. Time path of output in manufacturing sector.

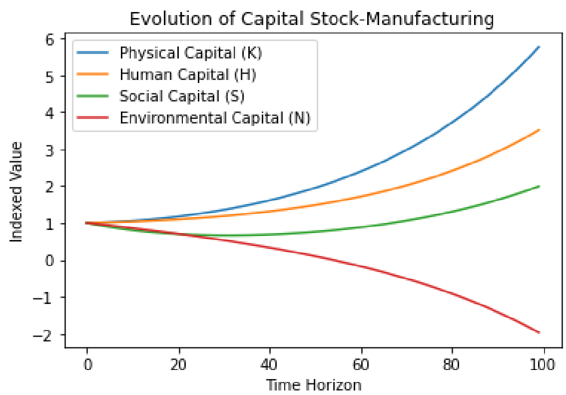

Fig. 5. Time path of total capitals in manufacturing sector.

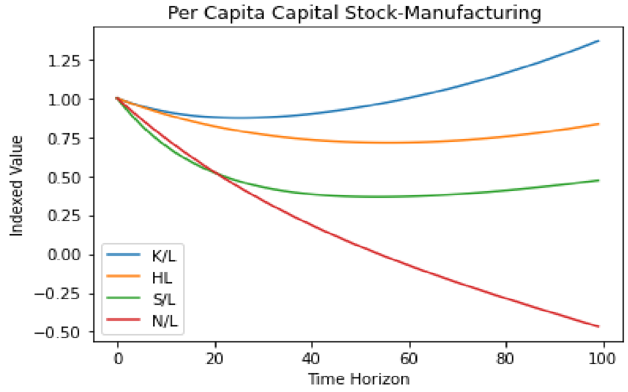

Fig. 6. Time path of per capita capitals in manufacturing sector.

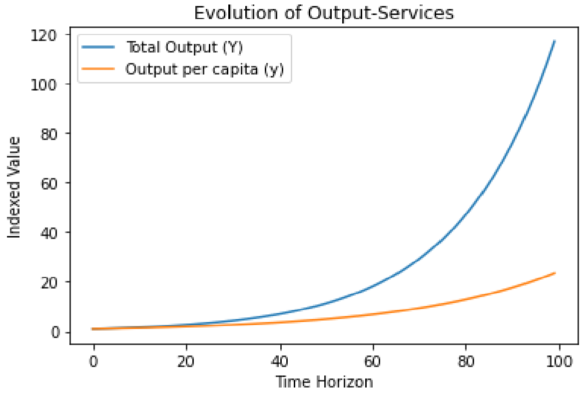

Fig. 7. Time path of output in services sector.

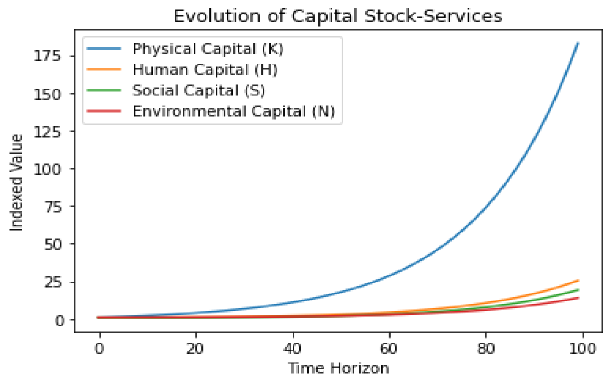

Fig. 8. Time path of total capitals in services sector.

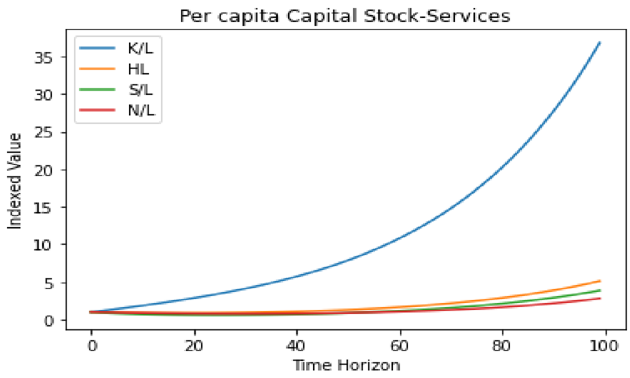

Fig. 9. Time path of per capita capitals in services sector.

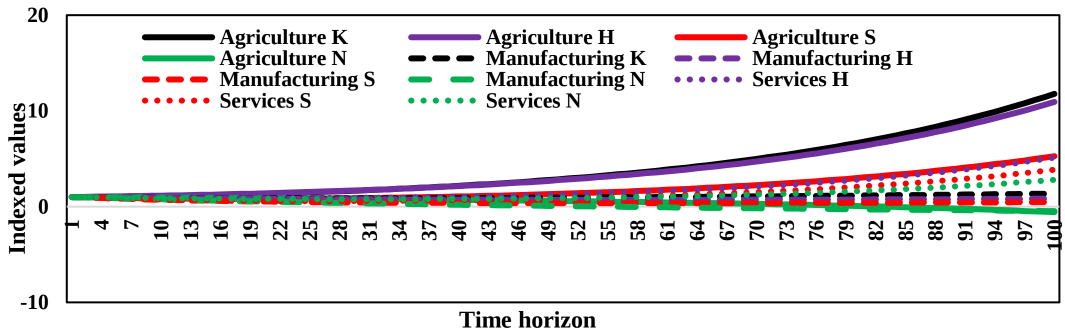

Fig. 10. Time path of per capita capitals in the selected sectors.

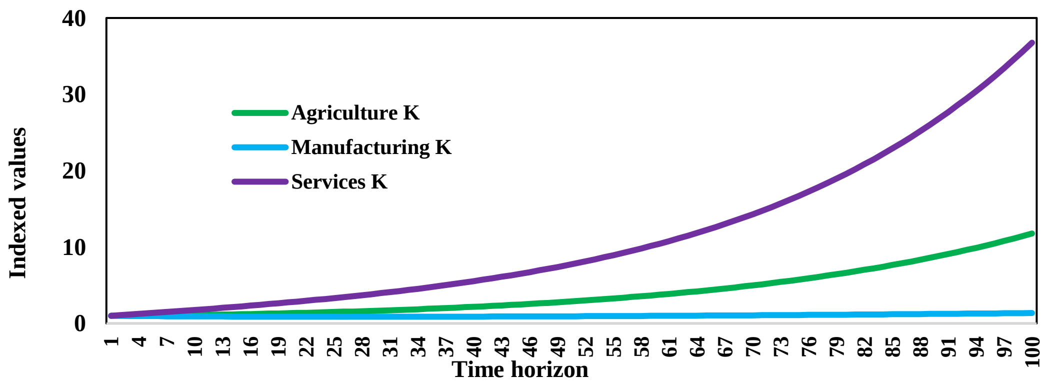

Fig. 11. Time path of per capita capitals in the selected sectors.

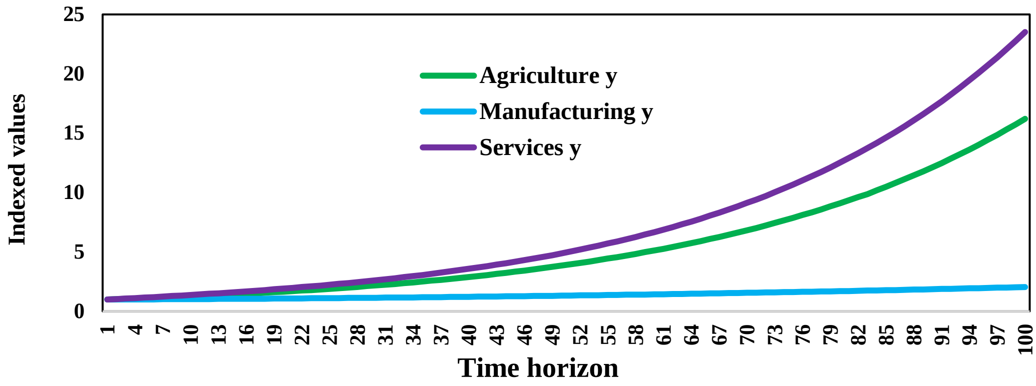

Fig. 12. Time path of per capita output in the selected sectors.

CONCLUSION

Considering the significant differences in the averages and variations of growth rates across the main economic sectors (agriculture, manufacturing, and services), this study showed the growth path of each sector separately. The differences may reflect distinct growth mechanisms that require individual analysis. Manufacturing sectors have been heavily affected by sanctions and oil revenue shocks, thereby recording the lowest growth rates.

The analysis evaluates several forms of capital, including physical, human, social, and environmental (natural) capital. Human capital was the second form of capital, after physical capital, to be incorporated into the production function in the early 1960s, with Schultz pioneering this approach. In contrast, Bourdieu (1986) was the first to emphasize both the tangible and intangible dimensions of social capital. The importance of environmental capital, a more recent addition to growth theory, has been recognized since the early 1970s (Xepapadeas et al., 2007).

This study examines all these forms of capital jointly within the framework of the neoclassical Solow growth model. It contributes to the literature in two main ways. First, it illustrates sectoral growth paths. Second, it evaluates the contributions of different types of capital to sectoral growth.

The findings highlight the limited influence of environmental capital in the agricultural and industrial subsectors, despite their intensive use of natural resources, particularly when environmental capital is proxied by pollution levels. The insignificant coefficient suggests inefficient resource utilization. The inefficiency may be related to the public goods characteristics of environmental assets (Roseta-Palma et al., 2010). Similar results were reported by Farajzadeh et al. (2017a).

In contrast, physical capital emerged as the primary contributor to production, consistent with previous studies (Farajzadeh et al., 2022; Keshavarz & Farajzadeh, 2021). But the estimated coefficient for environmental capital does not necessarily imply low capital intensity, as the choice of measurement indicators requires careful consideration.

Human and social capital, particularly social capital, showed limited effects. This outcome may reflect the lack of comprehensive proxy variables, suggesting the need for more refined measures in future research. The weak effect of social capital may also stem from its public goods nature (Roseta-Palma et al., 2010). Regarding human capital, the current indicators rely primarily on education and therefore lack sufficient comprehensiveness, as also noted in the reviewed literature.

Regarding the production function, which assumes constant returns to scale, most returns are attributed to two primary factors: labor and technology. This is reflected in the fact that the combined elasticity of all types of capital is less than one-third. Within the Solow growth framework, effective labor accounts for more than 70% of total output growth.

Using the Solow residual approach, the results show that in the agriculture and services sectors, productivity or technological change explains the majority of this 70%, while labor growth accounts for the remainder. The time path of the selected variables clearly supports this pattern. In contrast, in the manufacturing sector, labor growth exceeds productivity growth.

In summary, productivity growth plays a crucial role in the agriculture and services sectors, whereas manufacturing relies more heavily on intensive labor utilization. According to the growth classification proposed by Rodriguez and Pena-Boquet (2017), output growth in agriculture and services can be characterized as intensive growth. In manufacturing, however, extensive growth serves as the primary driver of output expansion.

Regarding physical capital accumulation, a widening gap is observed between the services sector and the other sectors, particularly manufacturing. During development processes, it is generally expected that the focus of output growth shifts from commodity-producing sectors to services. Such transitions can be considered desirable. However, it typically occurs at higher levels of capital accumulation and per capita income.

In the present case, this shift may contribute to undesirable output growth patterns and an imbalance in the allocation of physical capital. These distortions may result from interventions in resource allocation. Under normal structural transformation, service activities tend to dominate economic output after a technologically advanced manufacturing base has been established. In Iran, however, the manufacturing production process lacks sufficient technological embodiment, as noted by Farajzadeh et al. (2017b).

The current return on capital is below 20%, which is considerably lower than the expected level for developing economies (Ishise and Sawada, 2009; Romer, 2012). This outcome stems from structural constraints, including limited openness to international markets and the large size of the public sector. These conditions suggest that the Iranian economy has room for structural reform, particularly through a transition toward a more market-oriented system. Such a shift could also support efforts to address climate change.

Farajzadeh et al. (2017b) argued that greater trade liberalization could promote cleaner production processes in Iran while generating welfare gains. The strong contribution of physical capital observed in this study further indicates the need for increased capital formation. At the same time, the limited effect of technology in the manufacturing sector suggests that the production process lacks sufficient technological intensity. This finding is consistent with Gharibnavaz and Waschik (2015) and Farajzadeh et al. (2017b).

Some of these structural weaknesses may be linked to trade barriers, including sanctions. Therefore, deeper integration into the global economy appears advisable. It is also important to note that the technological level in manufacturing seems to be lower than in agriculture and services, despite the expectation that manufacturing should be the more technologically advanced sector.

Finally, as discussed in the literature, the definition and measurement of capital-saving rates, particularly for human and social capital, remain complex and controversial. This limitation should be acknowledged. Future research should therefore explore alternative proxy variables to achieve more robust measurement.

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CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Conceptualization: Zakariya Farajzadeh; Methodology: Leila Asadi Bazardeh and Zakariya Farajzadeh; Software: Leila Asadi Bazardeh; Validation: Leila Asadi Bazardeh and Zakariya Farajzadeh; Formal analysis: Leila Asadi Bazardeh; Investigation: Leila Asadi Bazardeh and Zakariya Farajzadeh; Resources: Leila Asadi Bazardeh; Data curation: Leila Asadi Bazardeh; Writing—original draft preparation: Leila Asadi Bazardeh; Writing—review and editing: Zakariya Farajzadeh and Leila Asadi Bazardeh; Visualization: Leila Asadi Bazardeh and Zakariya Farajzadeh; Supervision: Zakariya Farajzadeh; Project administration: Leila Asadi Bazardeh; Funding acquisition: Not Applicable.

DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest.

ETHICAL STATEMENT

Not Applicable.

DATA AVAILABILITY

The data utilized in the estimation of the simulation can be found in the sources referenced in the Data section. The models presented, along with the results data, are available upon request.

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