The Relationship Between Production Inputs, Factor Substitution, and Economic Growth[a]

Üretim Girdileri, Faktör İkamesi ve Ekonomik Büyüme Arasındaki İlişki

Abdulmecit YILDIRIM[b] iD

ABSTRACT	ÖZET
Factors of production and elasticity of substitution play an essential role in economic growth accounting. Although production functions with constant elasticity of substitution between factors are more commonly utilized in growth accounting, studies based on production functions with variable elasticity of substitution are also conducted. Since production functions with variable elasticity of substitution provide more flexibility in parameters, they are more advantageous than other production functions. Besides, most studies focus on the elasticity of substitution between capital and labor. Studies on the sub-components of production factors are relatively few. In this study, capital stock is analyzed by dividing it into two subcomponents as public capital stock and private capital stock. The empirical results, in general, show that the elasticity of substitution between the public capital stock and the private capital stock is less than unity. In this context, public and private capital stock can be expressed as complementary inputs in the final production of goods and services. As a result, public expenditures on infrastructure can boost economic growth by raising the efficiency of private investments.	Üretim faktörleri ve ikame esnekliği ekonomik büyüme muhasebesinde önemli bir rol oynamaktadır. Büyüme muhasebesinde faktörler arasındaki ikame esnekliğinin sabit olduğu üretim fonksiyonları daha sık kullanılsa da esnekliğinin değişken olduğu üretim fonksiyonları da temel alan çalışmalar mevcuttur. Değişken ikame esnekliğine sahip üretim fonksiyonlarının parametrelerde daha fazla esneklik sağladığı için diğer üretim fonksiyonlarına göre daha avantajlıdır. Bunun yanında, çalışmaların çoğu sermaye ile emek arasındaki ikame esnekliğine odaklanmaktadır. Üretim faktörlerini oluşturan alt bileşenlere ilişkin yapılan çalışmalar görece azdır. Bu çalışmada toplam sermaye, kamu sermaye stoku ve özel kesim sermaye stoku olarak iki alt bileşene ayrılarak incelenmiştir. Ampirik sonuçlar genel olarak kamu sermaye stoku ile özel kesim sermaye stoku arasındaki ikame esnekliğini birden küçük olduğunu göstermektedir. Bu bağlamda, kamu sermaye stoku ile özel kesim sermaye stoku nihai mal ve hizmet üretiminde tamamlayıcı girdiler olarak ifade edilebilir. Dolayısıyla, özellikle alt yapıyı iyileştirmeye dönük kamu yatırımları özel yatırımların verimliliğini artırarak ekonomik büyümeyi olumlu etkileyebilir.
Anahtar Kelimeler	**Keywords**
İkame Esnekliği, Üretim Fonksiyonu, Kamu Sermayesi, Özel Sektör Sermayesi, Ekonomik Büyüme	The elasticity of Substitution, Production Function, Public Capital, Private Capital, Economic Growth

1. Introduction

In recent years, there has been a growing debate on the effects of public capital on economic growth. It is generally considered that resource allocation in the public sector is less effective. This is, in part, due to the fact that the excessive weight of the public sector in the economy may disrupt the efficient distribution of resources, thus impeding economic growth. On the other hand, many developing countries in the 1980s, which were in debt, intended to balance public and private investments with structural adjustment programs (SAPs). This situation requires that the total capital should be divided between public capital and private capital, and these two inputs should be treated as two different production factors.

Although the effect of public spending on private capital accumulation and output has been discussed for a long time, it is hard to say there is a common consensus about the relationship between public spending, private capital, and output. Some studies argue that public capital has a positive influence on private capital accumulation and output (Agenor & Moreno-Dodson, 2006; Aschauer, 1989a, 1989b; Lynde & Richmond, 1992; Nazmi & Ramirez, 1997; Otto & Voss, 1996; Sanchez-Robles, 1998). Some other studies (Holtz-Eakin, 1994; Tatom, 1991) could not find a statistically significant relationship between public spending, private capital, and output. Moreover, there are studies such as Voss (2002) that find the crowding-out effect of public capital on private capital accumulation and output.

The elasticity of substitution between factors of production is explored in this study by distinguishing between public and private capital stocks. Data for 91 countries over the period 1980-2011 is utilized. Countries are classified based on their income levels and the technology-intensive products exported. First and foremost, the link between production variables and growth is investigated in the context of Cobb-Douglas, CES, and VES production functions. The data on the elasticity of substitution produced by Yıldırım (2018) using the VES type production function is then utilized to investigate the link between GDP and elasticity of substitution descriptively.

2. Capital Stock and Economic Growth

According to Aschauer (1989b), public capital affects private capital accumulation from two different channels. First, high public investments may increase public capital accumulation, leading to an equivalent reduction in private capital. Second, public investments generate crowding-in effects on private capital accumulation by increasing the marginal productivity of the private capital stock. Aschauer (1989b) advocates that the second effect will dominate the first, and therefore an increase in public investments will also increase private capital accumulation.

Figure 1 depicts the relationship between real GDP, public and private capital stock. As seen from Figure 1, most countries are clustered towards the lower-left corner of the plot. This indicates that the public and private capital stock are relatively close at the low level of real GDP. The correlation between real GDP and capital stock is stronger for private capital stock. Moreover, at the high level of real GDP, private capital accumulation distinctly diverges from public capital stock.
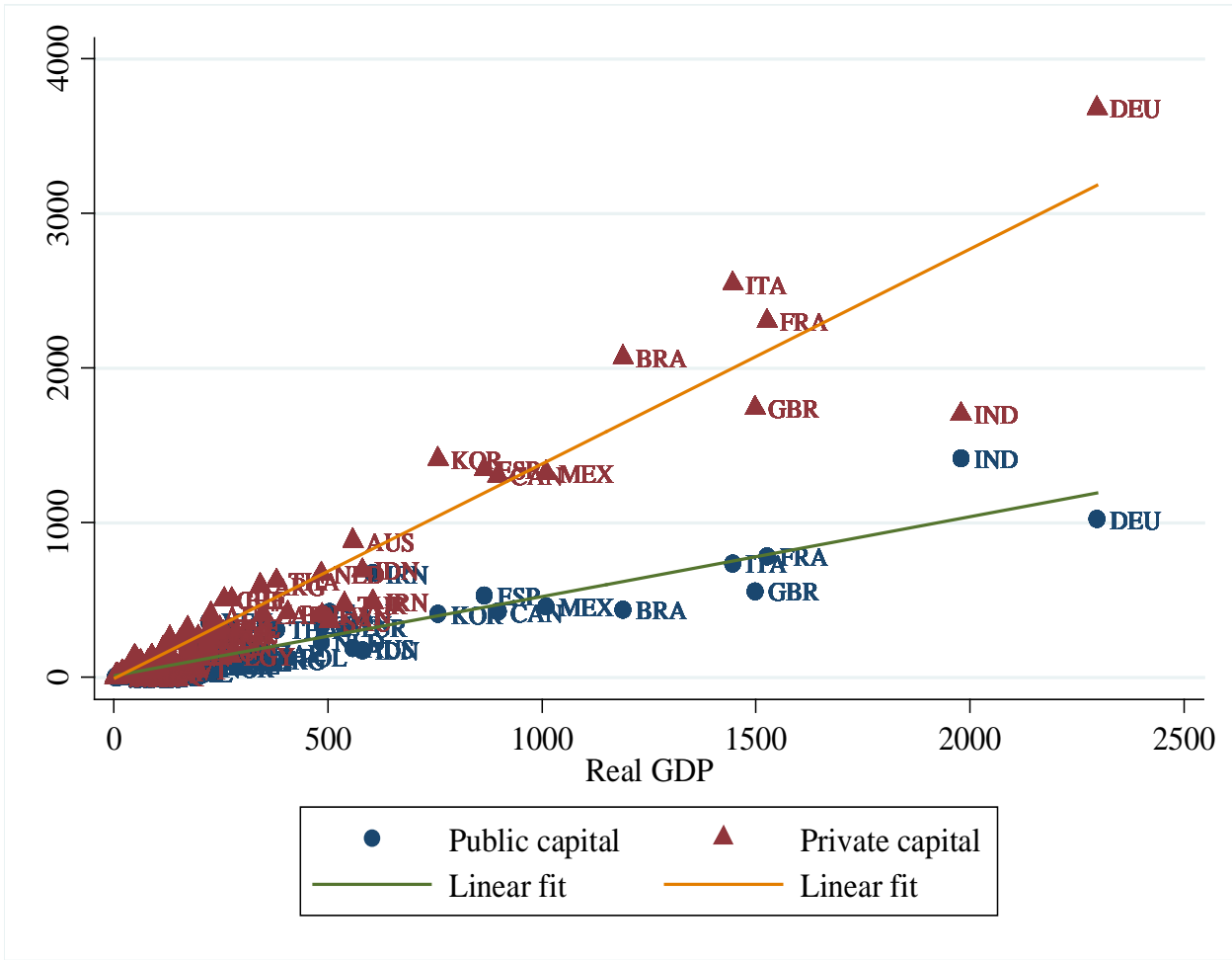
Figure 1. Real GDP and private-public capital stock (billion $)

Public capital, particularly infrastructure investments, can be seen as an essential determinant of long-run growth as it acts as an essential complement to private sector capital (Dessus & Herrera, 2000). Makuyana & Odhiambo (2016) state that public investments in the form of infrastructure (education, airports, highways, roads, power generation, and distribution facilities, etc.) often increase the marginal productivity of private capital. The existence of this basic infrastructure in an economy can reduce the costs of firms operating in the private sector, leading to new private capital accumulation and economic growth. Therefore, the optimal allocation of capital between the public sector and the private sector is fundamental. The degree of elasticity of substitution between public capital and private capital plays an important role in this optimal allocation. For this reason, it is important for policymakers to know whether public capital and private capital are substitutes or complements for the effectiveness of policies. Hence, before specifying economic policies, the degree of elasticity of substitution between factors of production should be determined.

Even though many studies have explored the growth-enhancing role of public and private capital accumulations (see, for example, Atukeren, 2005; Bucci & Bo, 2012), empirical studies suffer from controversial and conflicting results. In other words, the interaction between public and private capital stock depends on the period, sample selected, and technology used for final output

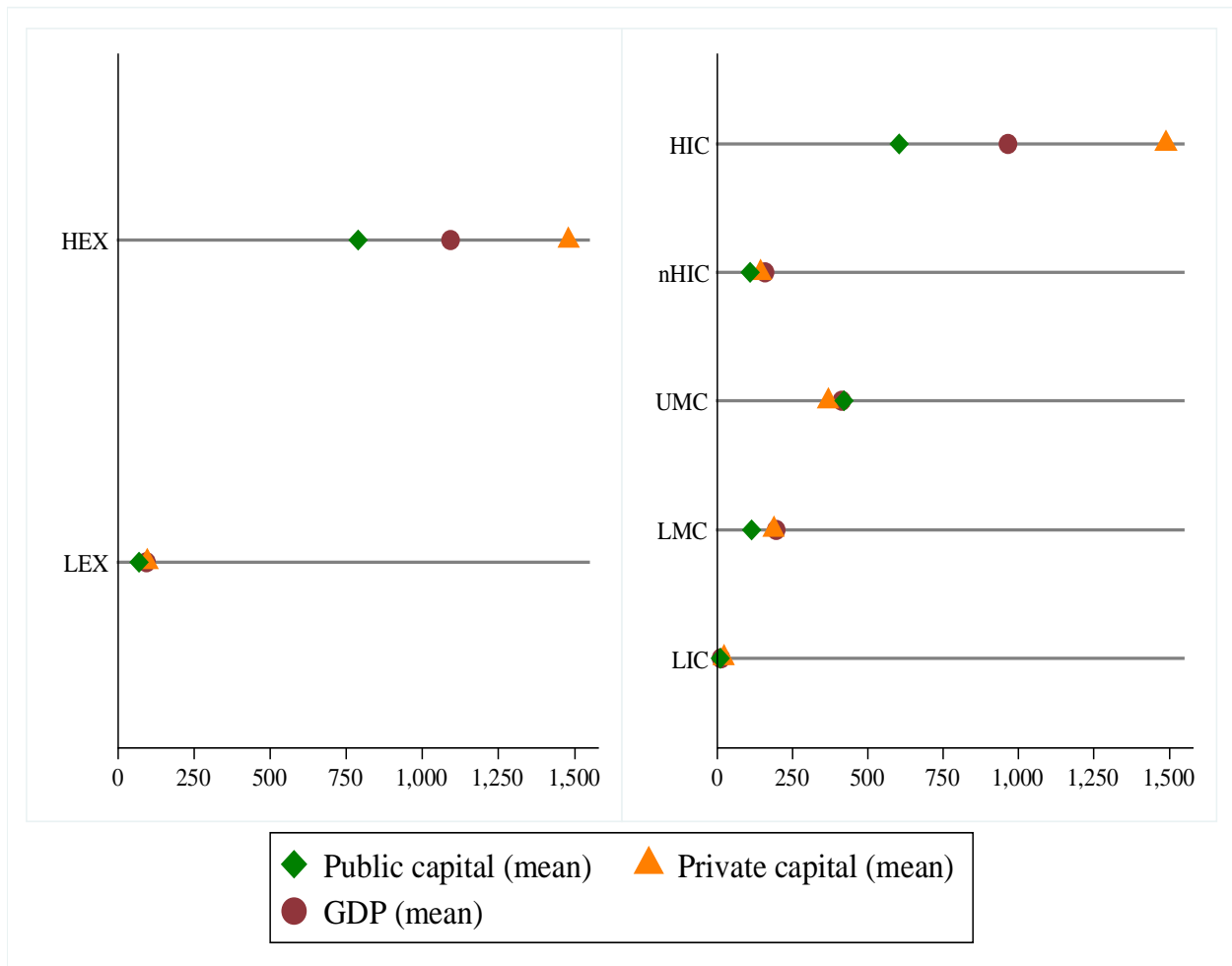production. Therefore, country-specific conditions should be taken into account when determining policies

Figure 2. Private-public capital and real GDP by income groups and export structure (billion $)

Figure 2 illustrates the relationship between real GDP, public and private capital stock for different country classifications. The private capital stock in high technology exporter countries (HEX) is much higher than public capital stock. When we consider country classification by income, private capital stock is greater than public capital stock in high-income countries (see Figure 2, right panel). This indicates that as the country becomes richer, the weight of the private sector increases. However, this is not the case for high-income non-OECD countries, which are heavily dependent on oil revenue.

3. Production Function and Elasticity of Substitution

In growth models, production functions such as constant elasticity of substitution (CES) and variable elasticity of substitution (VES) are used to express the production process in the economy. Arrow et al., 1961) emphasize that it is important to know the elasticity of substitution between the factors of production, indicating that the growth process depends on the value of elasticity of substitution. The concept of elasticity of substitution used in growth models refers to the ease of substitution of inputs used in production. However, most of the studies investigating the dynamics of economic growth are based on the Cobb-Douglas type of production functions (see, for example, Aschauer, 1997; Dessus & Herrera, 2000; Solow, 1956). Such production functions represent a process in which the elasticity of substitution between factors of production is equal to one. Later on, CES type production functions which assumed that the elasticity of

substitution between production factors is a constant value, which is less than or greater than one, has been extensively used in many theoretical or empirical models (see, for example, Arrow et al., 1961; Miyagiwa & Papageorgiou, 2003; Young, 2013).

It is necessary for economies to be able to substitute public capital with other production factors to achieve sustainable growth and development. This is related to the ease of substitution between production factors. The elasticity of substitution between public capital, private capital, and other inputs of production is generally considered to be either one (Cobb-Douglas production function) or constant (CES production function) in the theory of economic growth. However, with the economic liberalization, the growing weight of the private sector in the economy does not make it possible to have a constant elasticity of substitution between public and private capital. Therefore, it is better to express the interaction among public capital, private capital, and other production factors with a production function that allows for non-constant elasticity of substitution.

Standard growth models such as Solow (1956) can explain how different combinations of inputs affect economic growth under the assumption of constant elasticity of substitution (CD or CES). Yet, they are insufficient to describe a change in the elasticity of substitution that increases or decreases economic growth. If we drop the assumption of traditional constant elasticity of substitution (CES), a change in the degree of substitutability between public capital and private capital may affect economic growth.

The VES type production functions assume that, unlike the standard Cobb-Douglas or CES functions, the elasticity of substitution between the factors is not constant. The production functions with the variable elasticity of substitution property were first used by Revankar (1971) and Sato & Hoffman (1968). Following that, a number of researchers contribute to the relevant literature. Karagiannis et al (2005) examined the elasticity of substitution between capital and labor in the framework of VES production function. Lazkano and Pham (2016) developed the model used by Karagiannis et al. (2005) in the context of substitution elasticity between capital and energy.

The VES type production function is more advantageous than other production functions as it provides more flexibility in parameters. The standard Cobb-Douglas production function used in many studies lacks this flexibility since the elasticity of substitution in Cobb-Douglas production function is equal to one. Therefore, the relative shares of production factors are constant. On the other hand, the production function with constant elasticity of substitution (CES) is also frequently used in the growth literature. Although compared with Cobb-Douglas functions, CES functions place relatively few constraints on the parameters, but it is not as flexible as the VES functions.

4. Production Inputs and Elasticity of Substitution

The most fundamental factor determining the direction and degree of the relationship between public investments, private capital accumulation, and output is the elasticity of substitution. Public investment expenditures can facilitate private capital accumulation and thus affect economic growth positively. For example, if the production factors are gross complement, a higher stock of public capital in the form of infrastructure may positively affect the production inputs such as labor, private capital, and energy. As a result, the unit cost of production is reduced.

All of the models that investigate the growth process, even being implicit, take the elasticity of substitution into consideration. This situation indicates that the elasticity of substitution is important in the theory of economic growth. First of all, the elasticity of substitution is one of the

determinants of the level of development. Klump and de La Grandville (2000) state that a higher elasticity of substation leads to not only a higher growth rate of income per capita but also a higher steady-state value of income per capita. Moreover, they conclude that the success of the growth miracles in East Asia countries was not necessarily due to high saving rates and technological progress. The primary reason was the higher elasticity of factor substitution. Second of all, the elasticity of substitution affects the speed of convergence between countries. Klump and Preissle (2000) argue that if capital stock is relatively scarcer than labor input, higher elasticity of substitution may raise the speed of convergence. Third of all, the elasticity of substitution may change the saving behavior of households during the transition period, which in turn affects capital accumulation. Smetters (2003) investigate this fact within the framework of Ramsey-Cass-Koopmans growth model. The results show that if the elasticity of substitution between capital and labor is below unity, the saving rates decrease monotonically. This situation is reversed when the elasticity of substitution is greater than unity. Finally, the elasticity of substitution can influence the income distribution in an economy. Hicks (1932) argues that the elasticity of substitution among production factors is the only determinant of changes in the relative share of production factors. According to Getachew (2009), this argument of Hicks provides a solution to the income distribution problem. In other words, whether the public sector influences the income distribution dynamics depends on the elasticity of substitution between public and private capital.

Figure 3 shows the relationship between the average elasticity of substitution between public and private capital stocks calculated by the VES production function and real GDP. It can be observed that the elasticity of substitution and real GDP have a positive relationship. A higher elasticity of substitution between production inputs leads to a higher level of GDP.
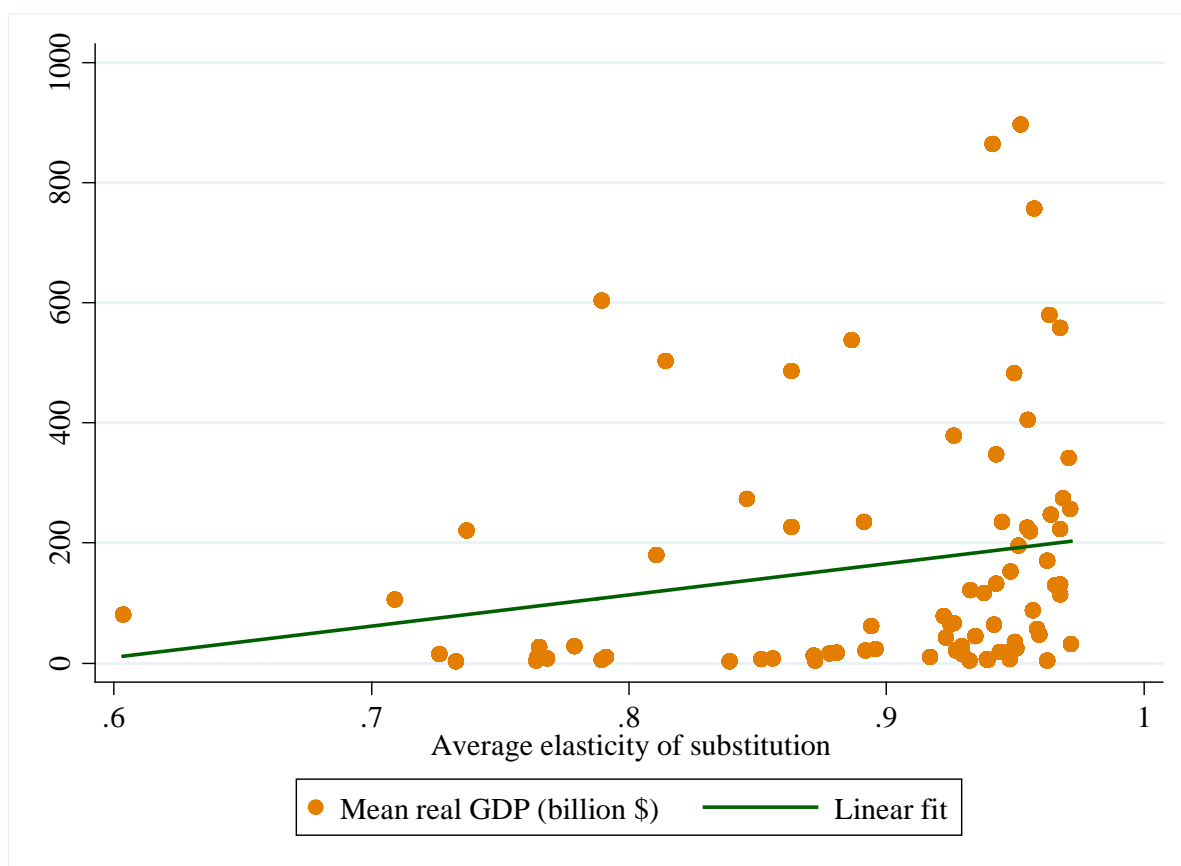
249

Figure 3. The elasticity of substitution and GDP
Source of Data: Yıldırım (2018)

The balanced use of the public and the private component of the total capital stock allows less developed countries to reduce inequality in income distribution (Getachew, 2009). The interaction between these two components of the capital is essential since, regardless of the technology used for good production, the degree of complementarity/substitutability between private and public capital is the primary determinant of optimal growth (Bucci and Bo, 2012).

Empirical studies reveal that the relationship between public capital and private capital varies over time and across countries. In some sectors and countries, the public capital and private capital are complements, while in other sectors and regions, these two factors of production are substitutes. One reason for these conflicting empirical results can be explained by the reduction of the state's weight in the economy and by the private sector filling this vacated field. However, most of the previous studies have focused mainly on the assumption of the existence of a constant elasticity of substitution between production inputs.

While Barro (1990), Aschauer (2000) Glomm and Ravikumar (1997) have shown that there is a non-linear relationship between public capital and economic growth, according to Aschauer (1998), much of the literature is based on the assumption that there is a linear relationship between public capital and economic growth. Within this context, the elasticity of substitution between public capital, private capital, and other inputs may be investigated with the help of the non-linear estimation method under the framework of the VES production function.

5. Factor Substitution and Growth Nexus

The relationship between input and output in the production process is represented by the production functions. Whether a production process is optimal or not is closely related to how much output is obtained from inputs used. The main objective here is to specify a feasible input composition that maximizes the output in final production. The elasticity of substitution plays a significant role in determining the optimal input composition.

In the growth models that make it easier to understand the dynamics of the growth process, capital and labor are used as fundamental inputs. Besides these two primary inputs, other factors (such as public capital, human capital, and energy) that affect the growth process have become the center of interest for many researchers. Various nested CES and VES production functions have been developed to investigate the relationship between inputs and production (Lazkano & Pham, 2016; Zha & Zhou, 2014)

The elasticity of substitution plays a significant role between production inputs and growth. The degree of elasticity of substitution between production factors gives information about whether inputs are substitutes or complements. Therefore, having knowledge about the elasticity of substitution is essential for policymakers. For example, the knowledge about the elasticity of substitution may be crucial for the determination of tax policy in manufacturing industries.

Although capital stock plays a key role in economic growth, it may not be sufficient to explain the growth process alone. The sub-components of the capital stock need to be examined. In this context, examining public and private capital as two distinct inputs of production may shed light on better understanding the growth process. At this point, it is quite natural to think that whether public and private capital are substitutes or complements. The knowledge about the elasticity of substitution among production factors may give an answer to this issue.

Figure 4 depicts the relationship between inputs and total production for various elasticity of substitution levels. If the elasticity of substitution is greater than unity, the inputs can be easily

substituted for each other, whereas if it is less than one, they are complementary. When the inputs are complementary, the scarce input plays an important role in determining the production level. If the inputs are substitutes, abundant and low-cost inputs can be used more extensively in the manufacturing process. As a result, output rises, and prices fall.
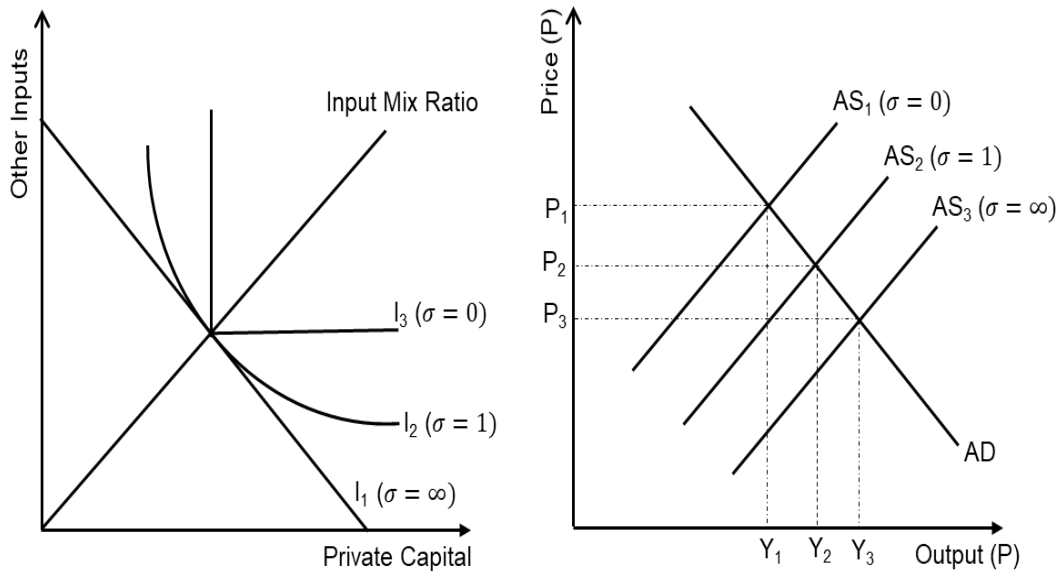

Figure 4: Elasticity of Substitution and the Aggregate Output
Source: Griffin and Steele (1986 p.19)

5. Conclusion

It is important to identify the elasticity of substitution among the factors of production and to take this into consideration in the socio-economic policy to be implemented by policymakers. The elasticity of substitution among the factors directly affects the results and the effects of policies. For instance, in an economy where labor and capital are used as inputs, assuming that capital stock is increasing, the marginal productivity of the capital will decrease faster if the elasticity of substitution between these two inputs is low. Investment incomes will be directly affected by this situation. Therefore, the elasticity of substitution is so important that it cannot be neglected in economic growth accounting.

As Getachew (2009) points out, if the elasticity of public capital to substitute private capital is greater than one, an investment in public capital will increase the relative share of public capital in production and reduce the relative share of private capital. This will have a corrective effect on income distribution if the aim is to improve the living standards of the individuals in the low-income groups. However, if the elasticity of substitution is lower than unity, an increase in public capital will increase the share of private capital, which may have a detrimental effect on income distribution.

It is highlighted in the literature that public investment, particularly infrastructure investment, may boost private investment. Public investment intended to improve infrastructure facilities may improve the efficiency of private capital. This in turn may create private investment opportunities. Hence, a rise in the public capital stock leads to an increase in private capital investments. As a result, via correctly targeted public policies, the favorable contribution of private capital stock to economic growth and its sustainability will be achievable.

In sum, it is important to determine the optimal factor composition in final output production. If it is correctly specified, the elasticity of substitution may help to choose the optimal composition of

inputs. Therefore, the selection of production functions is important. A production function that put fewer restrictions on the parameters may be an important step to investigate the production process. VES type production functions can be a good candidate to analyze the relationship between production inputs and the elasticity of substitution.

References

Agenor, P.-R., & Moreno-Dodson, B. (2006). Public infrastructure and growth: New channels and policy implications (No. 4064; Policy Research Working Paper Series). *The World Bank*. https://ideas.repec.org/p/wbk/wbrwps/4064.html

Arrow, K. J., Chenery, H. B., Minhas, B. S., & Solow, R. M. (1961). Capital-labor substitution and economic efficiency. *The Review of Economics and Statistics*, *43*(3), 225–250. https://doi.org/10.2307/1927286

Aschauer, D. A. (1989a). Is public expenditure productive? *Journal of Monetary Economics*, *23*(2), 177–200. https://doi.org/10.1016/0304-3932(89)90047-0

Aschauer, D. A. (1989b). Does public capital crowd out private capital? *Journal of Monetary Economics*, *24*(2), 171–188. https://doi.org/10.1016/0304-3932(89)90002-0

Aschauer, D. A. (1997). Do states optimize?: Public capital and economic growth (wp_189; Economics Working Paper Archive). *Levy Economics Institute*. https://ideas.repec.org/p/lev/wrkpap/wp_189.html

Aschauer, D. A. (1998). Public capital and economic growth: Issues of quantity, finance, and efficiency (SSRN Scholarly Paper ID 96636). Social Science Research Network. https://doi.org/10.2139/ssrn.96636

Aschauer, D. A. (2000). Do states optimize? Public capital and economic growth. *The Annals of Regional Science*, *34*(3), 343–363.

Atukeren, E. (2005). Interactions between public and private investment: Evidence from developing countries. *Kyklos*, *58*(3), 307–330. https://doi.org/10.1111/j.0023-5962.2005.00290.x

Barro, R. (1990). Government spending in a simple model of endogenous growth. *Journal of Political Economy*, *98*(5), S103-26.

Bucci, A., & Bo, C. D. (2012). On the interaction between public and private capital in economic growth. *Journal of Economics*, *106*(2), 133–152. https://doi.org/10.1007/s00712-011-0239-3

Dessus, S., & Herrera, R. (2000). Public capital and growth revisited: A panel data assessment. *Economic Development and Cultural Change*, *48*(2), 407–418.

Getachew, Y. (2009). The role of public capital on economic development. *The Role of Public Capital on Economic Development*. https://doi.org/10.26481/dis.20091015yg

Glomm, G., & Ravikumar, B. (1997). Productive government expenditures and long-run growth. *Journal of Economic Dynamics and Control*, *21*(1), 183–204.

Griffin, J. M., & Steele, H. B. (1986). *Energy economics and policy—2nd Edition*. New York, Academic Press.

Hicks, J. R. (1963). *The theory of wages*. Palgrave Macmillan UK. https://doi.org/10.1007/978-1-349-00189-7

Holtz-Eakin, D. (1994). Public-sector capital and the productivity puzzle. *The Review of Economics and Statistics*, *76*(1), 12–21.

Karagiannis, G., Palivos, T., & Papageorgiou, C. (2005). Variable elasticity of substitution and economic growth: Theory and evidence. In *New Trends in Macroeconomics* (pp. 21–37). Springer, Berlin, Heidelberg. https://doi.org/10.1007/3-540-28556-3_2

Klump, R., & de La Grandville, O. (2000). Economic growth and the elasticity of substitution: Two theorems and some suggestions. *American Economic Review*, *90*(1), 282–291. https://doi.org/10.1257/aer.90.1.282

Klump, R., & Preissler, H. (2000). CES production functions and economic growth. *Scandinavian Journal of Economics*, *102*(1), 41–56. https://doi.org/10.1111/1467-9442.00183

Lazkano, I., & Pham, L. (2016). Can capital-energy substitution foster economic growth? *Land Economics*, *92*(3), 491–514. https://doi.org/10.3368/le.92.3.491

Lynde, C., & Richmond, J. (1992). The Role of public capital in production. *The Review of Economics and Statistics*, *74*(1), 37–44.

Makuyana, G., & Odhiambo, N. M. (2016). Public and private investment and economic growth: A Review. *Journal of Accounting and Management*, *VI*(2), 25–42.

Miyagiwa, K., & Papageorgiou, C. (2003). Elasticity of substitution and growth: Normalized CES in the Diamond model. *Economic Theory*, *21*(1), 155–165. https://doi.org/10.1007/s00199-002-0268-9

Nazmi, N., & Ramirez, M. D. (1997). Public and private investment and economic growth in Mexico. *Contemporary Economic Policy*, *15*(1), 65–75. https://doi.org/10.1111/j.1465-7287.1997.tb00455.x

Otto, G. D., & Voss, G. M. (1996). Public capital and private production in Australia. *Southern Economic Journal*, *62*(3), 723–738. https://doi.org/10.2307/1060890

Revankar, N. S. (1971). Capital-labor substitution, technological change and economic growth: The U.s. Experience, 1929-1953. *Metroeconomica*, *23*(2), 154–176. https://doi.org/10.1111/j.1467-999X.1971.tb00168.x

Sanchez-Robles, B. (1998). Infrastructure investment and growth: Some empirical evidence. *Contemporary Economic Policy*, *16*(1), 98–108.

Sato, R., & Hoffman, R. F. (1968). Production functions with variable elasticity of factor substitution: Some analysis and testing. *The Review of Economics and Statistics*, *50*(4), 453–460. https://doi.org/10.2307/1926813

Smetters, K. (2003). The (interesting) dynamic properties of the neoclassical growth model with CES production. *Review of Economic Dynamics*, *6*(3), 697–707. https://doi.org/10.1016/S1094-2025(03)00012-7

Solow, R. (1956). A Contribution to the theory of economic growth. *The Quarterly Journal of Economics*, *70*(1), 65–94.

Tatom, J. A. (1991). Public capital and private sector performance. *Federal Reserve Bank of St. Louis Review*. pp. 3-15. https://doi.org/10.20955/r.73.3-15

Voss, G. M. (2002). Public and private investment in the United States and Canada. *Economic Modelling*, *19*(4), 641–664.

Yıldırım, A. (2018). Private-public capital, elasticity of substitution, and economic growth (Ph.D. Thesis) https://tez.yok.gov.tr/UlusalTezMerkezi/tezSorguSonucYeni.jsp.

Young, A. T. (2013). U.S. Elasticities of substitution and factor augmentation at the industry level. *Macroeconomic Dynamics*, *17*(4), 861–897. https://doi.org/10.1017/S1365100511000733

Zha, D., & Zhou, D. (2014). The elasticity of substitution and the way of nesting CES production function with emphasis on energy input. *Applied Energy, 130,* 793-798. https://doi.org/10.1016/J.APENERGY.2014.01.093